



**Proceedings of the Eleventh Meeting  
of the Crops and Soils Wing of the  
Board of Agriculture and Animal  
Husbandry in India**

*Held at Simla  
from the 14th to the 20th June, 195*



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## INTRODUCTORY

The eleventh meeting of the Crops and Soils Wing of the Board Agriculture and Animal Husbandry in India was held at Simla from the 14th to the 20th June, 1956 under the Chairmanship of Shri M. S. Randhawa, I.C.S., Vice-President, I.C.A.R. After the welcome speech by Shri M. S. Randhawa, I.C.S., V. P., I.C.A.R., Shri Ajit Prasad Jain, Minister for Food and Agriculture, Govt. of India inaugurated the session. On the first day the wing constituted itself into nine separate Committees, one for each subject on the agenda, to frame appropriate recommendations for the consideration of the Plenary Session of the wing. The Plenary Session considered the recommendation of the various Committees and passed a number of resolutions. The meeting then terminated on the afternoon of the 20th June, 1956.

**AGENDA OF THE 11TH MEETING OF THE CROPS & SOILS  
WING HELD IN JUNE 1956**

- (1) Use of Atomic energy in Agriculture.
- (2) Role of organic manures and chemical fertilisers in crop production and maintenance of soil fertility.
- (3) Utility of rapid soil tests for evaluating soil productivity and the use of fertilisers.
- (4) A review of methods of reclamation of saline and alkaline soils with special reference to—
  - (a) agronomic practices,
  - (b) soil amendments,
  - (c) afforestation, and
  - (d) crop rotation.
- (5) Value of 'shelter belts' and 'wind breaks'—
  - (a) in soil conservation and
  - (b) in reducing losses in fruit cultivation.
- (6) (a) Water requirements of important fruit crops, and  
(b) Different systems of irrigating fruit crops with a view to economising on the use of irrigation water.
- (7) The rationals of the policy of large scale multiplication of seedlings from open-pollinated, heterozygous seed parents in perennial crops, and the possibility of establishing nucleus plantations with appropriate combinations by way of selected male and female plants away from all possible contamination from foreign pollen for the production of elite seed.
- (8) Plant viruses with special reference to their nature, methods of transmission, the diseases they cause and methods of control.
- (9) Exploitation of Hybrid vigour in improvement of crop plants, fruits and vegetables.



LIST OF THE MEMBERS AND VISITORS WHO ATTENDED THE  
ELEVENTH MEETING OF THE CROPS AND SOILS WING OF THE  
BOARD OF AGRICULTURE AND ANIMAL HUSBANDRY IN  
INDIA HELD AT SIMLA FROM THE 14TH TO THE 20TH JUNE,  
1956

1. Shri B. S. Randhawa, (*Chairman*).
2. Dr. B. N. Uppal.
3. Dr. B. P. Pal.
4. Shri S. K. Mirchandani, (*Secretary*).
5. Shri Boshi Sen
6. Dr. R. S. Vasudeva.
7. Dr. S. P. Raychaudhuri.
8. Dr. E. S. Narayanan.
9. Shri P. P. I. Vaidyanathan.
10. Shri E. A. R. Banerjee.
11. Dr. S. Solomon.
12. Shri B. N. Sinha.
13. Dr. Pushkarnath.
14. Dr. B. L. Sethi.
15. Pt. K. N. Agha.
16. Shri P. J. Gregory.
17. Shri M. Kanthi Raj.
18. Shri K. B. Lal.
19. Shri K. C. Kaith.
20. Shri T. C. Kala.
21. Shri A. M. Thomas.
22. Dr. R. K. Tandon.
23. Shri G. U. Rao.
24. Dr. B. C. Kundu.
25. Dr. B. B. Roy.
26. Mr. H. Ferguson.
27. Dr. A. Mariakulandai.
28. Shri S. K. Swamy.
29. Shri S. Basheshar Singh.
30. Shri Ragottam Reddy.
31. Shri. C. Gopalan.
32. Shri. A. K. Mallik.
33. Shri S. Satwant Singh.
34. Shri D. M. K. Reddy.
35. Shri Bishan Man Singh
36. Shri Ambika Saran Singh.
37. Shri C. K. Ashdir.

38. Shri M. C. Joshi.
39. Shri Sukh Raj Sablok.
40. Shri A. D. Desai.
41. Dr. B. N. Sahu.
42. Dr. S. D. Nijhawan.
43. Shri Balsingh Bajwa.
44. Shri D. V. Krishna Rao.
45. Shri B. P. Tiwari.
46. Shri J. L. Merh.
47. Shri B. Bhimasena Rao.
48. Dr. P. S. Parsai.
49. Shri P. M. Tamboli.

*Visitors.*

1. Prof. David V. Ter-Avanesyan.
2. Mr. E. Chermey Sher.
3. Dr. R. V. Tamhane.
4. Dr. N. P. Datta.
5. Shri A. R. Thapar.
6. Sardar Santokh Singh.
7. Shri R. B. Deshpande.
8. Shri M. J. E. Pritchard.
9. Shri Mokand Lal.

*Officers of the Council.*

1. Shri M. U. S. Jung.
2. Shri P. M. N. Naidu.
3. Shri G. R. Seth.
4. Dr. Sham Singh.
5. Dr. J. A. Daji.
6. Dr. Uttamchand.
7. Dr. A. R. Sen.
8. Shri P. M. Dabadghao.
9. Shri P. L. Malhotra.

**WELCOME SPEECH BY DR. M. S. RANDHAWA, VICE PRESIDENT  
INDIAN COUNCIL OF AGRICULTURAL RESEARCH**

**HON'BLE MINISTER FOR FOOD AND AGRICULTURE, LADIES AND GENTLEMEN,**

As Chairman of the Board of Agriculture and Animal Husbandry in India it is my proud privilege to welcome you to this, the 11th meeting of the Crops and Soils Wing of the Board of Agriculture and Animal Husbandry. This Board was established about 51 years ago, and in 1931, it was divided into two wings—the Crops and Soils Wing dealing with problems of crop plants, and the Animal Husbandry Wing with the problems of animal husbandry. These wings provide a forum to the research workers in the fields of agriculture and animal husbandry to get together to consider research problems of an outstanding nature. An opportunity is provided to the experts of the I.C.A.R. and the Central Research Institutes, as well as the Secretaries of the Commodity Committees, and the Directors of Commodity Research Institutes to get together for pooling information of importance, and exchanging information on techniques. Inter-commodity problems of a scientific nature, which are common to the I. C. A. R. and the Commodity Committees, can also be discussed. It may perhaps be desirable to include problems of an administrative nature also which have an effect on research within the purview of the two Wings. The leadership which the Wings have provided in the field of research, and in the formulation of agricultural policy, is valuable indeed and considerable weight attaches to the recommendations which are made.

The agenda of this meeting includes many important items such as use of atomic energy in agriculture; role of organic manures and chemical fertilizers in crop production and maintenance of soil fertility; utility of rapid soil tests for evaluating soil productivity and the use of fertilizers; review of methods for reclamation of saline and alkaline lands; exploitation of hybrid vigour in improvement of crop plants, fruits and vegetables; value of shelter-belts and wind-breaks in soil conservation and fruit cultivation; water requirements of important fruit crops and methods of irrigation; and a review of work done on virus diseases, their causes and control.

The recent discoveries of atomic scientists have considerable bearing on agriculture. Radio-isotopes have provided agricultural scientists with a handy tool for inducing mutations. It is now possible to get results in a comparatively shorter time as compared with the traditional methods, and this in itself will be of great significance in the field of agricultural research. It is proposed to equip our Central Research Institute, the I. A. R. I., New Delhi, with Cobalt 60 source for inducing mutations. It is also proposed to provide similar facilities in the Central Jute Research Institute and in the proposed Co-ordinated Research Station for Cotton, Oilseeds and Millets. It is hoped that useful crop plants which are high-yielding or disease-resistant may be produced. In the U. S. A., a variety of groundnut which has about 30 per cent. higher yield per acre over the other varieties has been produced by radiation. A variety of barley with a higher yield, and a variety of oats which is resistant to rust have been

produced in the U. S. A. The use of radio-isotopes in fruit crops which are propagated vegetatively holds out great promise, as any change produced in growing points or buds can be vegetatively perpetuated and multiplied.

Fertilizer is the most costly item in the budget of the farmer. At present, in this country, it is not known how much of the fertilizer applied is used by the plant, and how much is in excess of requirements. The use of radio-active isotopes as trace elements has provided a clue to the distribution of elements which the plant absorbs from the soil. It has been shown that a greater uptake of soil phosphorus occurs when small amounts of fertilizers are used, and a lower uptake takes place when larger amounts are used. The use of P32 is also likely to give information regarding the optimum depth for applying fertilizers. In this field, I am glad to note, good work is being carried on in the Radio Tracer Laboratory which has been set up at the Indian Agricultural Research Institute with the co-operation of the T. C. M. The use of radio-isotopes has also provided a clue to the efficiency of insecticides as the rate of their penetration, mode of action and the site of action can be discovered.

With the increased production and use of fertilizers for raising crops, the need for rapid soil tests for evaluating the needs of different soils has been felt. The farmer wants to know what are the major deficiencies in the soil of his fields. The scientists should evolve tests indicating whether a particular soil is very low, high, or very high in nitrogen, phosphorus and potassium, the main requirements of crop plants. He also wants to know whether the soil is alkaline, acidic or neutral. At present, no facilities exist for the farmer to get his soil analysed and to know about his fertilizer requirements. It is proposed to set up 24 soil-testing laboratories, but considering the huge agricultural area of the country, they are quite inadequate. As such, it is necessary that rapid soil tests should be developed and soil-testing kits should be provided to the Village Level Workers under the N. E. S. Scheme, so that they are enabled to advise the farmers of their fertilizer requirements. This is not at all a fantastic proposal in view of the fact that in the U. S. A., a rapid soil-testing service is already provided to the farmers.

It has been estimated that about 30 lakh acres of land are lying waste in the country on account of infestation with salts and alkalies. The State of West Bengal alone has got 21,18,000 acres of saline land. In the Raan of Kutch alone it has been estimated that three lakh acres of saline land can be reclaimed. Introduction of canal irrigation in the States of the Punjab, Uttar Pradesh and Bombay has led to a large scale damage. It has been estimated that 5,000 square miles of land have been rendered unproductive on account of accumulation of soluble salts in the surface soil. All possible methods should be used for reclaiming these areas which will result in an increase of the total agricultural area. This is a problem which should be given special attention in the N.E.S. Development Blocks. Apart from the use of chemical and physical methods, the growing of crop plants which remove salinity and alkalinity from the soil, deserves to be taken up on an extensive scale.

The value of shelter-belts and wind-breaks has been inadequately realized in this country. Experience in the Soviet Union and the U.S.A. where shelter-belts consisting of many rows of trees have been planted over vast areas, has shown the utility of shelter-belts for soil conservation and horticulture. A good deal of irrigation which is given to the fruit plants is wasted on account of rapid evaporation from the soil and increased transpiration from the leaves of the plants. Experience in the U.S.A. has shown that citrus plants in the coastal orchards of California when protected from the wind attain the same size in three years as against that attained by plants in five years when fully exposed to the wind. It was also found that the yield of trees protected from the wind was three times greater than of trees fully exposed to the wind. *Sesbania*, *jantar* and *casuarina* provide effective wind-breaks and their growing on boundaries of orchards should be encouraged on a large scale. This is a work which can be taken up through the agency of the N.E.S. Apart from shelter to the fruit plants resulting in less damage to unripe fruits and to plants, fuel would also be provided to the farmer thus resulting in the saving of animal dung.

There is another problem relating to horticulture which requires close attention of the horticulturists. This relates to the water requirements of important fruit crops of India which are at present unknown and need determination. Research schemes on this problem would be most welcome.

Now we are faced with the challenge of the Second Five Year Plan. An annual additional production of 10 million tons of food-grains, i.e., 15 per cent. more than the present production, and increase in the yields of other crops like oilseeds, cotton, sugarcane, jute, etc., ranging from 25 to 31 per cent. above the present level are aimed at in the Second Five Year Plan. Most of the additional production will be achieved through enhanced irrigation, use of manures and fertilizers, improved seeds, and improved implements. In the field of plant breeding, heterosis or hybrid vigour holds out considerable promise. Considerable progress has been made in the U.S.A. in the use of hybrid maize and sorghums. In the U.S.A. in 1933 while only 0.1 per cent. of the total maize acreage was under hybrid maize, in 1945 it reached 97 per cent. As compared with 1933, in 1948 while the area under maize was less by 21 per cent., the total production was 42 per cent. more than in 1933. It has been reported that in Bombay, two maize hybrids gave 20 per cent. more yield as compared with the local varieties. They have been able to raise hybrid maize seeds from indigenous inbred lines. Promising work is being done at the Indian Agricultural Research Institute, New Delhi, and Jullundhur and Chandigarh in the Punjab. For the present, it is proposed to provide imported hybrid maize seed from the U.S.A. to the farmers in the maize-growing areas during the coming sowing season.

A project for multiplication and distribution of hybrid *bajri* seed is also in operation in Bombay State. It has been estimated that an increased production of one maund per acre will be obtained by the use of hybrid seed. Considering the large area under *bajri*, the total increase which is possible is considerable. Some useful work

has been done in growing hybrid cotton in Gujarat. Hybridization has yielded useful results in tobacco, sugarcane and horticultural crops like tomato, chillies, onions, pumpkins, cucumbers, brinjals and *bhindi*. There is need for utilization of hybrid vigour in fruits, vegetables and crop plants on a much greater scale and this should have the close attention of research workers. In the field of forestry, very little has been done in India to make use of hybrid vigour in raising more vigorous and rapidly growing forest trees. This is a problem which also deserves close attention of the Government.

I have drawn your attention to the salient points which are covered by the items included in the agenda. I do not wish to take any more of your valuable time as these items will be exhaustively discussed in the sub-committees. We are fortunate, Sir, in having you at the helm of the important Ministry of Food & Agriculture at this juncture when the emphasis is again on increased production of agricultural products, particularly foodgrains. You have a unique experience to your credit of successfully dealing with the problem of resettlement of displaced persons. The wisdom and sagacity you have shown in solving the complex problem of rehabilitation of displaced persons is your asset in meeting the challenge of the Second Five Year Plan in the field of agriculture. It deserves to be mentioned that rural rehabilitation operation in North India also brought about a revolution in the field of agriculture and resulted in modernization of agriculture on a large scale. This was mainly due to your generosity in providing loans for sinking of wells and tube-wells and for purchase of tractors. I have no doubt that under your guidance and leadership research workers in the field of agriculture in this country will do their utmost in providing scientific knowledge and techniques to farmers. Considered from this aspect, I feel this meeting of the Crops and Soils Wing would be particularly significant. I have great pleasure, Sir, to request you to inaugurate this meeting.

**INAUGURAL ADDRESS BY SHRI AJIT PRASAD JAIN, MINISTER  
FOR FOOD & AGRICULTURE, GOVT. OF INDIA**

**MR. CHAIRMAN, LADY AND GENTLEMEN,**

It gives me great pleasure to welcome you here today on behalf of the Government of India and on my own behalf, to the Eleventh Meeting of the Crops and Soils Wing of the Board of Agriculture and Animal Husbandry in India. This Board was formed in 1905 and with this session completes 50 years of its useful existence. By bringing together agricultural research workers, administrators, irrigation and agricultural engineers, university professors, principals of agricultural colleges, agricultural experts and farmers, the Board is providing a forum for the interchange of ideas and experiences. This will help in the formulation of a comprehensive agricultural policy, which will benefit the country as a whole.

This Wing has an unrivalled opportunity to serve the masses of India by suggesting the lines on which research and development work in the field of agriculture should be planned. It is necessary that modern methods (your Chairman has already mentioned quite a number of modern methods like the use of radio-isotopes and certain other improved agricultural methods) should be introduced for increasing production and that the masses should be equipped with practical knowledge to make the best use of land by drawing on its productive capacity to the maximum extent. Although some significant good work has been done in our country, yet the N.E.S. blocks on the whole have not been able to play their part. The country judges its real value from the extent to which you are able to benefit the farmer. You are judged now much you have been able to benefit the farmer and to add a few more coins to the pocket of the famshed farmer.

With the introduction of the National Extension Service in about one-fourth of the total number of villages in the country and the decision to cover the entire country during the Second Five Year Plan period, the necessity for intensifying research, which is the basis of all agricultural improvement, is apparent. Most of the States maintain a Department for Agriculture, and one of its functions is to conduct research in agricultural problems. Agricultural research is also conducted at the Central Research Institutes and non-government research organisations privately run. The Indian Council of Agricultural Research and the Commodity Committees give financial assistance for agricultural research in the country. Some of the States, particularly part B and C States have, however, no well equipped laboratories or farms for undertaking research in agriculture. In order to remedy this deficiency, a suitable provision has been made in the Second Five Year Plan for assisting the States to establish new Research Institutes or Farms and to strengthen the existing ones. It is hoped that by the end of the Second Five Year Plan period, adequate facilities for agricultural research will have been created in most of the States. The Indian Council of Agricultural Research has since its inception been planning, co-ordinating and financing schemes of agricultural research throughout the country. With the implementation of some of the recommendations made by the Indo-American

team, the Indian Council of Agricultural Research will be in a position to co-ordinate this work more effectively. It may not be out of place, therefore, to mention here some of the important results of research subsidised by the Council and by the Commodity Committees. It may not be out of place if I attempt to give the broad outline of research done on some Indian crops. Here I may mention that one of the recommendations of the Indo-American Team was that in addition to the financial assistance that the I.C.A.R. gives to the State institutions and to private institutions, we should create a permanent cadre of highly qualified scientists who may be from time to time be detailed to the State Research Institutes or to the private run institutes to carry on research on some specialised problems. I think this recommendation of the Indo-American Team is one of far-reaching nature, and with this additional assistance in the form of highly specialised technical personnel. The work of research in the States and in the private institutes will receive a great impetus.

### Rice

Rice is the most important crop in the country and the Council has given considerable attention to it. Between 1935-1944 several rice breeding schemes were financed in important rice growing States. Of late the Council has been subsidising investigations on specific problems and emphasis has been placed on co-operative projects, e.g., breeding for salt and flood resistance in Assam, Bengal, Andhra, Madhya Pradesh, West Bengal and Hyderabad; breeding for blast resistance in Madras, Andhra and Bombay States etc. A co-ordinated scheme for breeding drought resistant paddy has also been sanctioned.

The Central Rice Research Institute has undertaken the work of crossing *japonica* and *Indica* types and supplying the varieties thus evolved to the States. Other problems under investigation are those connected with the culture of *boro* paddy in West Bengal, and breeding suitable types for the hill areas of Darjeeling, Assam and Kashmir. Some Chinese varieties have been found to do well in Kashmir and Assam.

A word about the Japanese method of paddy cultivation will not be out of place here. The cultural practices which constitute the Japanese method of paddy cultivation are well-known. By following this method, it has been possible to step up paddy production in various areas where it has been adopted. In the last two years a well-planned campaign was organised to popularise the Japanese method of paddy cultivation, and most of the paddy growing States participated in this programme. I hope they will do so more intensively in future.

### Wheat

The research scheme on wheat rust, which was decided to be taken up as a matter of national importance at the Coimbatore meeting in March, 1951, is being actively pursued under the co-ordinated rust research scheme. As a result of the investigations carried on so far it has been possible to evolve a variety of wheat which is resistant to all the three rusts simultaneously and is suitable for cultivation in the hills. Efforts are being made now to evolve a similar variety of wheat which may be suitable for cultivation in the plains.



Besides the Co-ordinated scheme, physiological studies on wheat are in progress at the Delhi University and Cytogenetical studies at Poona at the Maharashtra Association for Cultivation of Science.

A wheat milling and baking laboratory is to be set up at the Indian Agricultural Research Institute.

#### *Millets*

A conference of workers on millets consisting of officials and non-officials was held in Kolhapur in May, 1955. Based on the recommendations of the conference a co-ordinated research programme for the improvement of millets is being planned.

#### *Maize*

The investigation on maize with financial assistance of the Council were started comparatively recently. The first schemes started were at the Indian Agricultural Research Institute and in the Punjab in 1944-45. Since then a number of research schemes in the principal maize-growing areas have been sanctioned. Recently, the work on maize was reviewed by two experts lent by the Rockefeller Foundation. Based on their report the Council has sanctioned a co-ordinated scheme on maize breeding which envisages the establishment of four research centres located at Kangra, Indian Agricultural Research Institute, Kanpur and Hyderabad, with nine sub-centres in the various maize-growing regions. A pilot project for producing hybrid maize seeds on a commercial basis is also under operation in the Punjab.

#### *Pulses*

The Council financed a co-ordinated scheme on pulses in the major States of Madras, Bombay, Uttar Pradesh, Madhya Pradesh, Bihar, Hyderabad, Mysore, Assam and Orissa. A number of improved varieties suitable for various States have been evolved and, in many cases, adopted. Investigations, are, however, still in progress in West Bengal and Madhya Bharat where the work was started late.

#### *Better seed*

I make bold to lay a definite target that the whole of India should be covered with better seed before the conclusion of the Second Five Year Plan. In some States and regions, better seeds have already made headway and the farmer has to some extent become conscious of their benefits. There are other less fortunate areas where work on improved seeds has not so much developed. While I will expect the first type of States and areas to be fully covered with improved seeds during the period of the next three years, the whole of India must have the benefit of improved seeds in the next five years. I would request you to catalogue the improved seeds and their regional suitability, marshal all the resources of the Central and State Government farms, farms run by private institutions and by progressive farmers—and raise sufficient nucleus seed multiply and make it available to all the farmers. Each National Extension Service and Community Development Block should have one or more farms for the multiplication of the seed. There may be some crops which may still be wanting in improved quality of seed and there the responsibility of the research worker

will be to develop the improved variety in the shortest possible time. In short, we have waited too long; we cannot afford to wait any longer and the poorer seed must be uprooted and substituted by a better one.

#### *Pasture land improvement*

The problem of pasture land improvement was examined by a F.A.O. Grass Land Expert, Dr. R. O. Whyte. On his recommendation a co-ordinated scheme for pasture land improvement has been drawn up and approved. The scheme consists of three parts. First, a rapid reconnaissance survey of grasslands both within and outside the reserve forests is to be completed by a Central Team. This survey is to be followed by intensive study in small typical areas within each major grassland region that would be recognised as a result of the reconnaissance survey. The States of the Punjab, PEPSU, Assam and Gujrat and parts of Uttar Pradesh, Bombay State, Saurashtra, Bihar, West Bengal, Andhra and Delhi have already been surveyed. The second part provides for grassland management to be undertaken in Community Project areas, and envisages research on fodder production. And lastly the scheme provides for the selection and breeding of indigenous grasses and legumes of the country.

A special provision has been made for undertaking research on the problem of weed control by hormonal treatment.

#### *Manures and Fertilisers*

The yield of Indian farm is one of the lowest in the world. There is, however, no doubt that it is capable of considerable increase. Government-owned farms have already shown much better results in production. The ordinary farmer has, however, a feeling that the results achieved by these farms are foreign to him. That feeling has to be overcome. The remedy lies in carrying out on the cultivators' field trials of manurial schedules which have been found to be promising on the Government farms, to demonstrate to the cultivators the benefit resulting from the adoption of these practices. Some work has already been done in this direction and the cultivators are now conscious of applying fertilisers to their crops. In the last two years, demonstrations have been conducted for popularising the use of new fertilisers such as urea and ammonium sulphate nitrate. The number of demonstrations carried out on cultivators' fields in the kharif season of 1954 was 60,000, using no less than 16,000 tons of fertilisers. The new fertilisers are becoming popular with the cultivator. As against the current consumption of 6 lac tons of indigenous fertilisers in 1960-61, the use of nitrogenous fertilisers will be stepped up by at least three-fold i.e., to 18.5 lac tons. Government have already planned to set up three new fertiliser factories and we are now examining the possibility of stepping up targets of fertiliser use and the Fertiliser Units to be set up.

#### *Economic use of water*

Another aspect of our agriculture which needs intensive study and research is the economic use of our water resources. Our irrigated area during the First Plan has gone up from 50 million acres

to 68 million acres and under the Second Plan period, there is expected to be an addition of 20 million acres. The increase is quite spectacular, but there is yet scope for more economical use of water. Much of the loss of water on seepage and evaporation can be avoided and a foreign expert has advised us that with the use of Ceyl Alcohol in the form of cakes, we can, at a small cost, reduce the evaporation losses by 50%. Simpler and comparatively cheaper devices for reducing losses through seepage are already in use in some foreign countries. These and use of gate and perforated pipes and sprinkler irrigation for increasing the area under irrigation from the same quantity of water are also under examination by our experts. There is not only need for developing more resources of irrigation but of making the most economical use of the existing ones and those which we may develop.

### *Fruits and vegetables*

The Indian Council of Agricultural Research, in conjunction with the State Governments, has been financing research on fruits to improve their quality and yields. It has recently been decided to set up five regional stations in different parts of the country for dealing with problems relating to the improvement of fruit crops such as mango, citrus, guava, pine-apple, grape and apple. Efforts are also being made to extend the area under fruit cultivation by advancing long-term loans to cultivators for planting new orchards. It is also proposed to assist the growers in increasing the yields of the existing orchards by adequate manuring and the adoption of suitable cultural practices.

Among the vegetable crops, potato has received considerable attention. Several new potato varieties have been evolved and are now being tried out in different parts of the country. Disease-free seed stocks of a well-known commercial variety known as Numbri have been produced and arrangements for their multiplication in the hills are in progress. The hill-grown potatoes are the main source of supply of seed potatoes for the cold season potato crops in the plains.

### *Commercial crops*

Considerable research work has been carried out on some cash crops as well, e.g., sugarcane and cotton to mention two examples of important crops. By suitable breeding methods high-yielding varieties of sugarcane have been evolved at Coimbatore, and these have covered almost the entire area under sugarcane cultivation in the country.

Cotton has also received a great deal of attention. With the partition of the country the production of cotton suffered a set back. As a result, however, of the Grow More Cotton Campaign its production increased from 29 lakh bales to over 42 lakh bales in 1954-55, which was the target fixed for the First Five Year Plan. The development of finer and longer staple cotton has reduced our dependence on imports. Two varieties of cotton, viz., 216 F. and 320 F., evolved in the Punjab need particular mention, as they have helped to increase considerably the area under cotton in that State.

of natural calamities, floods, cyclones and drought, we have been able to maintain the tempo of increased production. The Second Five Year Plan provides an increase of 10 million tons or 15 per cent. of foodgrains and 17.4 per cent. of all agricultural commodities, including cash crops. This Plan also envisages deficit financing of 1,200 crores and has left uncovered a gap of 400 crores in the financial resources. Some expectation about resources such as that of foreign assistance, may not fully come up. In the Plan there is more emphasis on heavy and basic industries and less on the production of consumer goods. The possibility of the 'inflationary gap' may not be altogether ruled out. In an underdeveloped economy, the wage earner and the low salaried people spend a substantial portion—almost 70% of the family budget on food, clothing, etc. We need more of food and cloth to reduce and, if possible eliminate the 'inflationary gap'. My Ministry is actively engaged in examining how and to what extent foodgrains and cash crops can be increased by the re-adjustment and better utilization of allocations already made under the Second Five Year Plan and what other financial allocations and personnel will be needed to step up the production by 30 to 40 per cent. We also want to know at what level the prices of foodgrains should be maintained which may provide an incentive to the grower and may not be too hard on the consumer. I am fully aware that the country is watching our efforts with great interest and you, who have gathered here, will help in working out realistic schemes.

#### *Buffer stock of Foodgrains*

There is a growing apprehension among certain sections of the people about the recent rise in the prices of foodgrains. There is no doubt that the prices of foodgrains have for few months shown an upward trend and during the peak marketing season of rabi crop, they have not shown the normal decline. It would, however, be unrealistic to compare this year's prices with those prevailing last year, which were un-remunerative to the farmer and led the Government to make purchase for maintaining the prices. Part of the rise in prices, to my mind, is due to the speculative activities of the trade to hoard. The farmer is also not freely bringing his produce to the market. These trends are anti-social and Government is determined to combat them. We have, made long-term arrangements for the import of rice from Burma and large quantities of wheat have already been fixed for import from Australia and U.S.A. A long-term arrangement with the U.S.A. for Wheat is under negotiation. These arrangements will enable us to build sufficient buffer stock to arrest undue rise in prices. I can only warn people with 'get-rich-quick' mentality that if they come to grief, as they will, they will have none else except themselves to thank.

#### *Agricultural Co-operative Societies*

The Indian farmer, like other industrialist, needs industrial production finance. He also needs a better marketing organisation and facilities for storage so that he may earn full price for his crop. These facilities have been significantly lacking. The Reserve Bank

had appointed a survey Committee to study the agricultural financing, marketing, processing and warehousing, which has made very valuable recommendations. As a result of the decisions taken on the Survey Committee's Report, it has been decided to set up more than 10,000 large-sized co-operative societies. The programme will be completed during the Second Five Year Plan and will cover about one-third of India. These societies will be a sort of multipurpose societies. They will supply fertilisers, seeds, implements, kerosene oil, etc., to the farmer. Credit will be supplied on the security of the prospective crop. These societies will have store-houses. It will be obligatory upon the peasant, who has taken credit, to sell his produce through the marketing co-operatives. 18,000 such marketing co-operatives will be established by the end of 1960-61.

#### *Warehouses*

The only effective way to reduce the seasonal disparities in agricultural prices is the establishment of a country-wide network of warehouses. During the Second Five Year Plan, there is a provision to establish warehouses all over the country. The State Bank of India and other banks would undertake the financing of agricultural marketing and make advances on the warehouse receipts and against goods in storage. The agriculturist will, thus, be able to get a part of the price of the commodities stored in the warehouse immediately. He will sell when the terms of the trade are in his favour. That, I think, will be very helpful in removing the seasonal disparity in prices and enable the farmer to have the full value of his produce.

We are anxious to ensure that scientific and improved methods of cultivation are evolved and established throughout the country in the shortest time. We are desirous of providing to the farmer credit and marketing facilities which an industrialist normally has. We want the farmer to get full return for his produce. On our ability to achieve these objective depends the future prosperity of India. Millions of peasants look up to you for guidance and if you succeed in helping them to make two ears of corn and two blades of grass to grow where only one grew before, you will have done your duty by the nation. I would like to acknowledge with gratitude the energy and the promptitude which Vice-President and other officers of the Council have brought to bear upon the activities of the Indian Council of Agricultural Research.

Lady & Gentlemen, I thank you once again for the courtesy shown to me in asking me to inaugurate the Conference. I declare the Session open.

## PROCEEDINGS OF THE PLENARY SESSION

The Plenary Session of the Crops and Soils Wing opened at 10 a.m. on the 20th June, 1956, with Shri M. S. Randhawa in the chair to consider the reports of the various Sub-Committees.

The Chairman said that the Crops and Soils Wing provided leadership in the sphere of research to the Indian Council of Agricultural Research and the Central Commodity Committees. He commended the comprehensive agenda drawn up by the Agricultural Commissioner which included a number of items having an important bearing on the development of agriculture in India. He observed that the different items on the agenda had been considered in detail by the members meeting in the form of Committees. He suggested that the Chairman of the respective Committees might read out the recommendations of their Committees (Annexure) one by one. The members could then offer their comments, if any, by way of amendments, which if accepted would be incorporated in the final decisions.

### COMMITTEE No. 1

#### *Use of atomic energy in agriculture*

Shri Boshi Sen explained the recommendations of the Committee on the '*Use of atomic energy in agriculture*'. He said that the intention was that work on radio-active isotopes should be carried out at the Indian Agricultural Research Institute where certain facilities were available.

Shri Krishna Rao (Andhra) : suggested that arrangements should be made for training young men in the use of radio-isotopes in relation to agriculture both in India and outside.

The Chairman supported the suggestion, which was accepted by the Conference.

The following resolutions were accordingly adopted by the Conference :—

"This Conference recommends :

- (i) that in view of the importance of radio-active isotope work in various aspects of agriculture, the I.C.A.R. should set up a Committee to promote and co-ordinate research in this field ;
- (ii) that research work both on the fundamental and applied aspects should be intensified ; and
- (iii) that arrangements should be made for training young men in the use of radio-isotopes in relation to agriculture both in India and abroad."

### COMMITTEE No. 2

#### *Role of organic manures and chemical fertilisers in crop production and maintenance of soil fertility.*

Dr. C. N. Acharya requested Dr. Raychoudhri to take up the subject. Dr. Raychoudhri explained the recommendations of the Committee on the '*Role of organic manures and chemical fertilisers in crop production and maintenance of soil fertility*'.

Shri G. U. Rao suggested that steps should be taken to popularise the use of night soil manures as was being done in countries like Japan. The Chairman observed that care should be taken in this regard lest it might lead to spread of diseases.

The Chairman said that the resolutions on this subject did not seem to be properly worded and should be made more precise. He added that a number of suggestions had been received in this connection. Dr. E.A.R. Banerjee and Shri Bishen Man Singh had suggested the following resolutions :—

- “1. That the Committee, taking due consideration of the research work carried out in the country, feels that both organic manures and chemical fertilisers are necessary for increased crop production and maintenance of soil fertility.
2. That the use of chemical fertilisers is necessary to supplement plant nutrients in the soil in order to maximise production.
3. That the use of organic manures including green manures is necessary to maintain the soil in good physical condition and for proper micro-biological activity which help to maintain soil fertility at a high level and prevent erosion.
4. That in view of certain conflicting data obtained at some places, the Committee further feels that more research work is necessary on the use of organic manures and chemical fertilisers in order to maximise crop production, and this research work should be carried out in a co-ordinated manner throughout the country.”

The Chairman said, these resolutions were better worded and, to make the matter complete, the concluding paragraph of the Committee's recommendation could be added as resolution No. 5.

The Chairman further said that three other suggestions had been received from Shri Satwant Singh and Shri Raghotham Reddy, which were as follows :—

- (i) “As introduction of pasture-mixture of clover and grasses suitable to local soil and climatic conditions in cropping rotation, maintains nitrogen balance of soil, build soil fertility and act as a medium for economically clean up of farm waste and weeds its conversion to wool and meat improves protein level of food crops, provide grazing and hay for live-stock during drought and thus act as a natural instrument of improving farm efficiency and decreasing unit cost of production, the conference recommends that in all manurial trials, those on pasturing may be included for determining its relative efficiency in the economy of general cropping pattern”( From S. Satwant Singh.)
- (ii) “Since it is established that the use of chemical fertilisers considerably increases crop yields, the Crops & Soils Wing of the Board of Agriculture recommends to Government that adequate quantities of chemical fertilisers may be imported and steps including subsidising the price may be taken to

increase their use by the farmers. Since the increased use of fertilisers obviates the need to import food precedence should be given to import and subsidised sale of fertilisers rather than of foodgrains. It further feels that this course would be less expensive and in greater interests of the country than import of foodgrains" (From Shri R. Reddy.) This was supported by G. V. Rao also.

- (iii) "The Crops & Soils Wing of the Board of Agriculture notes with satisfaction that during the Second Five Year Plan period every N.E.S. and Community Project area will be provided with a seed farm of a reasonable size. Since it is necessary to base recommendations to farmers on farm management problems and agronomic practices including the use of organic and chemical fertilisers separately or in suitable combination, on experience gathered in areas near their farms, it recommends to State Governments, Community Project Administration and I.C.A.R. to devise a system by which appropriate studies may be carried on these farms". (From Shri R. Reddy.)

He observed that these suggestions were outside the scope of the item under discussion and might be considered at the next meeting.

On the above basis, the following resolutions were adopted by the Wing :—

1. "This Conference, taking into consideration the research work carried out in the country, feels—
  - (i) that both organic manures and chemical fertilisers are necessary for increased crop production and maintenance of soil fertility;
  - (ii) that the use of chemical fertilisers is necessary to supplement plant nutrients in the soil in order to maximise production; and
  - (iii) that the use of organic manures including green manures is necessary to maintain the soil in good physical condition and for proper micro-biological activity which help to maintain soil fertility at a high level and prevent erosion."
2. "In view of certain conflicting data obtained at some places the Committee further feels that more research work is necessary on the use of organic manures and chemical fertilisers in order to maximise crop production, and this research work should be carried out in a co-ordinated manner throughout the country."
3. "This Conference also recommends that the Indian Council of Agricultural Research should take early steps to compile all the data relating to manurial experiments carried out in the country after 1931 (in continuation of the results summarised in Mr. Vaidyanathan's Report), and publish it in the form of a monograph."



## COMMITTEE NO. 3

*'Utility of rapid soil tests for evaluating soil productivity and the use of fertilisers.'*

Dr. Raychaudhury read out the recommendations made by the Committee on the *'Utility of rapid soil tests for evaluating soil productivity and the use of fertilisers'*.

Referring to recommendation No. 1, the Chairman said, that he was not clear about the use of the word "amendments" occurring in line 3. Dr. Raychaudhury explained that the word "amendments" was generally used in scientific literature for pH determination; the other term that was used to denote this was "soil correctives".

The Chairman suggested that in view of Dr. Raychaudhury's explanation, the resolution No. 1 should be modified to read as follows:—

"This Conference recognises that rapid soil tests are useful in determining the fertility status of soils and for recommending manurial schedules or amendments (soil correctives) to farmers. Sufficient information on the manurial requirements of soils with respect to different crops is available in the country. It is recommended that, with the information thus available, a rapid soil testing service should be organised in as many centres in the country as possible."

As regards recommendation No. 2, the Chairman suggested that the words "extension staff of the" should be added in line 5 of this recommendation before the words "Community Project Areas". In passing he made a reference to the use of soil test kits as were brought by Shri Satwant Singh from Australia.

The following resolutions were then adopted by the Conference:—

1. This Conference recognises that rapid soil tests are useful in determining the fertility status of soils and for recommending manurial schedules or amendments to farmers. Sufficient information on the manurial requirements of soils with respect to different crops is available in the country. It is recommended that, with the information thus available, a rapid soil testing service should be organised in as many centres in the country as possible.

2. This conference recognises that in recent years "Soil Test Kits" have become popular in foreign countries, and are useful in determining, under field conditions, the nutrient deficiencies in the soil and the quantities of nutrients required to be added to make up the deficiency. It recommends that such "Kits" should be made available to the extension staff of the Community Project areas, National Extension Service Blocks, Agricultural Extension Officers and progressive farmers. This Conference also notes that some states have developed "Soil Test Kits", and recommends that information obtained by the use of these "Kits" should be availed of in evolving suitable "Kits" for rapid soil tests for a particular soil region.

3. As the reliability of results obtained by applying rapid soil tests in the field depends upon the accuracy with which the soil samples are taken, this Conference recommends that proper training should be given to extension workers and the progressive farmers in the methods of taking soil samples and the use of these "Kits".

4. This Conference recommends that leaflets describing the advantages of the soil testing service to farmers should be printed in regional languages and widely circulated.

5. This Conference recognises the need for further work to improve the technique of soil testing and for obtaining greater precision in framing manurial schedules by correlating crop responses with soil tests.

#### COMMITTEE No. 4

*A review of reclamation of saline and alkaline soils with special reference to—(a) agronomic practices, (b) soil amendments, (c) afforestation, and (d) crop rotation.*

Shri E. A. R. Banerji suggested that the first sentence of the first Resolution should be modified to say that the existing knowledge related to certain areas of the country and not all the areas of the country. The Chairman said that the words 'certain areas of the country' might be substituted for the words 'in the country' occurring in the second line of this Resolution.

Shri Banerji further suggested that the last sentence of the first Resolution should be deleted. The Chairman enquired whether this sentence was considered unnecessary because of the existence of Resolution No. 5.

Shri Banerji said that the 5th Resolution was unnecessary because it had been stated in the first Resolution that sufficient knowledge for the reclamation of saline and alkaline lands existed in the country.

Dr. Uppal said that the deletion of the 5th Resolution would create a serious omission in the sense that more attention was desired to be given to this type of work to be done by the Soil Conservation Board or some other agency.

Dr. Raychoudhury said that actually the last sentence of the first Resolution referred to the application side, while Resolution 5 referred to the research side of the work. Therefore, both were necessary.

The Chairman said that Shri Banerji's point would be met by changing the last sentence of the 1st Resolution to read "Such an organisation should be properly financed and given the necessary facilities by establishing new laboratories or by strengthening the existing ones, as there is need for further basic research."

Shri Satwant Singh remarked that there were several areas requiring reclamation where adequate provision for the supply of water had to be made.

Dr. Uppal said that all these points were duly considered when this resolution was framed.

The following Resolutions were adopted by the Conference :—

“This Conference is of the opinion that there exists sufficient knowledge in certain areas of the country for the reclamation of saline and alkaline lands as a result of the investigations carried out so far. In view of the fact that there are large tracts of land which have become saline or alkaline in almost every State, a time has come when it is necessary to apply this knowledge for the reclamation of such land. As reclamation of saline and alkaline lands is costly and beyond the means of individual farmers, it is necessary that this problem should be tackled on a national basis. This Conference is, therefore, of the opinion that Government of India should set up an organisation or agency for carrying out reclamation of saline and alkaline soils on an all-India basis or entrust this work to an existing organisation like the Soil Conservation Board. Such an organisation should be properly financed and given the laboratories or by strengthening the existing ones, as there is need for further basic research.”

2. “This Conference is of the opinion that whenever irrigation projects are contemplated, arrangements should be made for the provision of drainage and lining of canals as a measure of prevention, so that the existing cultivable lands do not develop salinity or alkalinity. A soil survey for proper land use and for preparing suitable cropping patterns should also be simultaneously carried out whenever such projects are undertaken.”

3. “This Conference feels that saline and alkaline lands which cannot be economically brought under use for agriculture be utilised for growing pastures and forest trees. The Conference further recommends that subsidy and loans should be given to private land owners who wish to reclaim land by this method.”

4. “This Conference recommends that a popular pamphlet on the methods of reclamation of saline and alkaline lands be published in regional languages.”

5. “This Conference recommends that the plant introduction organisation should take up the work of introduction of all plants known to thrive on saline and alkaline soils. The Conference further suggests that the Indian Council of Agricultural Research should prepare a bulletin giving all available information on salt resistant plants so far known.”

#### COMMITTEE No. 5

*“Value of ‘shelter belts’ and ‘wind breaks’ (a) in soil conservation and (b) in reducing losses in fruit cultivation.”*

Shri Kaith read out the recommendations of the Committee on *“Value of ‘shelter belts’ and ‘wind breaks’ (a) in soil conservation and (b) in reducing losses in fruit cultivation.”*

The recommendations were adopted by the Conference.

## COMMITTEE No. 6

(a) *Water requirements of important fruit crops, and (b) Different systems of irrigating fruit crops with a view to economising on the use of irrigation water.*

Shri Bal Singh Bajwa explained the recommendations of the Committee on (a) *Water requirements of important fruit crops, and (b) Different systems of irrigating fruit crops with a view to economising on the use of irrigation water.* He said that so far no regular experiments on irrigation requirements of fruit trees, the different methods of application of irrigation water and the economics of those methods had been carried out and that the practices that were being followed in different fruit growing regions of the country were not based on experimental data. He emphasized that research on these items should be undertaken as early as possible. To take an instance, Shri Bajwa said that the temperate fruits were generally grown without any artificial irrigation. The result of dependence on rainfall alone was that during the months of April, May and June, before the rains started lot of shedding took place and the quality of fruit was also affected. If adequate irrigation could be provided during this typical period, the quantity and quality of the fruit would certainly improve.

The Chairman asked what were the different horticultural regions of India.

Shri Bal Singh Bajwa said that so far as the northern parts of the country were concerned, there were two main zones—(i) high hill regions with altitudes ranging from 4,000 to 8,000 feet, where temperate fruits like apples, cherries, etc. could be grown, and (ii) low hill regions with altitudes ranging from 1,000 to 4,000 feet, where stone fruits were grown. There was also a distinctive lower region, where different fruits like mango and citrus were predominantly grown. In the central parts of the country sub-tropical fruits were commonly grown, while the tropical zone mostly lay in the south, where mango, papaya, banana, chiku etc. could be grown. Shri Bajwa said that, broadly speaking, the fruit zones could be described as temperate fruit zones, lower hill regions, sub-mountain tracts, plains and tropical zones.

The Chairman said that the position was not very clear and some thought should be given to determining the horticultural regions of the country.

Shri Banerjee said that many regions were to be developed for fruit cultivation in the Second Five Year Plan.

Shri Satwant Singh said that apples have been tried in the South but the yield obtained was very low as compared to the yield obtained in the hills in the north.

Shri Bal Singh Bajwa said that such stray attempts in growing particular fruits in different parts of the country could not form the basis of determining the regions for fruit-cultivation, which should be very well-defined. He agreed with the Chairman that attention was needed for defining the horticultural zones of the country.

The Chairman suggested that a small Sub-Committee should be formed to define the horticultural zones of India, consisting the following :—

1. Dr. B. N. Uppal	}	Chairman
2. Shri Bal Singh Bajwa.		Members
3. Dr. Sham Singh.		
4. Dr. Naik.		
5. Dr. L. B. Singh.		
6. Dr. R. L. Nagpal.		

Shri Basheshar Singh suggested that, in carrying out the recommendations made by the Committee, the information available with the farmers should also be taken into consideration. He added that such information should be passed on to other farms for their information and guidance.

Shri Bal Singh Bajwa said that very little information was available with the farmers and whatever information was available was based on personal experience gained by the farmers concerned which might or might not be correct. This had been kept in view by the Committee while framing their recommendations. To take an example, in northern India irrigation was often done by digging out a small basin round the tree. This might suit in cases where very small amount of irrigation was required, but there were other factors also to be taken into consideration.

The Chairman said that the root system of the fruit plants had also to be studied. Where water table was fairly high, the root system should be enabled to penetrate to the water level. This study would be most useful in an investigation like this. Some work had already been done on a number of fruits but it required to be systematised.

Shri Bal Singh Bajwa said that there could be no two opinions on this point. In addition, other factors affecting growth e.g., soil fertility, etc., had also to be studied.

The Chairman said that the Resolution recommended by the Committee was quite comprehensive.

The Conference adopted the Resolution and approved the Chairman's suggestion regarding the appointment of a sub-Committee for defining the horticultural zones of the country.

#### COMMITTEE No. 7

*On the 'Rationale of the policy of large scale multiplication of seedlings from open-pollinated heterozygous seed parents in perennial crops, and the possibility of establishing nucleus plantations with appropriate combinations by way of selected male and female plants away from all possible contamination from foreign pollen for the production of elite seed'.*

Dr. P. J. Gregory said that this Committee was presided over by Dr. Ramanujam, who had gone away and had asked him to explain recommendations of the Committee.

The Chairman asked whether this was a purely coconut problem or whether it applied to other crops also.

Dr. P. J. Gregory explained that in the Committee it was suggested by Dr. Naik that nucleus plantations in India should be included in the investigations on the lines adopted in Ceylon but it was felt that this may be premature and hence the resolution was kept as it was.

The Chairman suggested that the resolution might be accepted but 'arecanut' should also be included.

The Conference approved the Chairman's suggestion and adopted the following Resolution :—

"This Conference, after considering the problems relating to the production of elite seed in cross-pollinated perennial trees with particular reference to coconut, feels that it is desirable to gather fundamental data on the mechanism of pollination and the distance over which pollen is carried either by wind or insects, before starting nucleus plantations in isolation."

This Conference also feels that additional data on the correlation of seedling characters with yield should be obtained.

This Conference recommends that the data mentioned above should be obtained with reference to arecanut also".

#### COMMITTEE No. 8

*'Plant viruses with special reference to their nature, methods of transmission, the diseases they cause and methods of control',*

Dr. Vasudeva read out the recommendations of the Committee on *'Plant viruses with special reference to their nature, methods of transmission, the diseases they cause and methods of control'*, and said that in view of the vastness of the subject, the Committee had confined its attention to the more pressing problems only.

Shri Bal Singh Bajwa suggested that greater attention should be paid to the malformation of mango and work on this problem should be intensified. He pointed out that this disease was spreading in the north at an alarming rate and if adequate steps to investigate into its causes and to eradicate it were not taken, it would seriously affect the cultivation of mango in the north.

The Chairman desired the suggestion to be put up in the form of a Resolution.

Shri K. B. Lal suggested that vegetable crops might also be included in the first sentence of the first Resolution along with horticultural crops.

Dr. Vasudeva said that horticultural crops included vegetable crops as well and that potato had been mentioned specially because it required particular attention. He added that work was being done on the problem of malformation of mango for the last two years but so far it had not been possible to determine the vector responsible for the disease.

Shri Bal Singh Bajwa proposed that the Resolution might be added as follows:— "In view of the fact that the disease of malformation of mango is spreading at an alarming rate in the mango orchards in northern India and is proving a serious menace to the mango industry, research work on this problem should be intensified. The organisation for this purpose should be strengthened so that control methods may be evolved.

The Chairman suggested that this Resolution be accepted.

The Conference approved the Chairman's suggestion and adopted the following Resolutions:—

1. "This Conference recommends that in view of the fact that there are heavy losses to crops particularly to horticultural crops and potato due to virus diseases, greater attention should be paid to their investigation to cut down losses. In addition, work on 'grassy shoot' disease of sugarcane and 'Foorkey' disease of larger cardamum should be intensified. Systematic work on sandalwood 'spike' which is responsible for heavy losses should also be taken up, particularly with a view to establishing its vector."

2. "This Conference recommends that in addition to breeding for resistance direct methods of control of virus diseases, *i.e.*, Chemotherapy, should receive greater attention than hitherto. Feasibility of introduction of mild strains to protect plantation crops, in particular, should be investigated. These methods, the Conference feels are necessary because of rapid change in strains of viruses".

3. "This Conference recommends that in view of the heavy losses caused by virus diseases, State Governments should supplement the plant pathological laboratories with a small unit of virus workers, with a view to surveying and dealing with the problems from practical angle. Also that a regional station should be set up in the south under the co-ordinated Plant Virus Research Scheme in due course.

4. "The Conference notes with concern that the 'grassy shoot' of sugarcane is assuming alarming proportions and, in all probability, is a new introduction and recommends that more strict quarantine methods should be adopted for regulating import of vegetatively propagated material."

5. "The Conference recommends that in view of the fact that the disease of malformation of mango is spreading at an alarming rate in the mango orchards in northern India and is proving a serious menace to the mango industry, research work on this problem should be intensified. The organisation for this purpose should be strengthened so that control methods may be evolved."

This Conference considers seed certification as one of the most effective methods of controlling virus diseases, particularly in asexually propagated crops, like the potato and strongly recommends development of such methods. Further as the early sown potatoes (being grown at a period of low aphid infestation in the plains) have generally a better seed value. The conference strongly recommends the use of early harvested crops as seed. In this connection, realising that the existing practice of storing late harvested

stocks in cold storage for seed purposes is harmful, the Committee considers that some effective control on seed potato cold storage is necessary".

#### COMMITTEE No. 9

##### *Exploitation of hybrid vigour in improvement of crop plants fruits and vegetables.*

Dr. Pushkar Nath read out the recommendations of the Committee on *Exploitation of hybrid vigour in improvement of crop plants fruits and vegetables.*"

Shri Satwant Singh suggested that the words "preferably at commercial level, duly equipped with technical staff" should be added in Resolution No. 1 at the end, because he visualised that the organisation which this body of scientists was recommending to take care of commercial exploitation of hybrid seed would definitely be a commercial one. He felt that it would not be possible for the Government to provide the wherewithal and the technical personnel required for such an organisation. He said that there should be some regulating supervision by Government officers to see that the organisations were properly equipped and had the necessary technical staff.

Shri Boshi Sen said that production of hybrid maize seed should be decentralised and should be taken up in the Community Project areas for the following reasons :—

(i) In these areas, the services and guidance of trained agricultural staff were available.

(ii) Given the supply of four inbred parent seeds and knowledge of their best combinations, the production of double cross hybrid maize seed was well within the competence of any willing farmer.

(iii) Co-operative enterprise in seed production could be started in these areas without much difficulty.

(iv) If the production of hybrid seeds was scattered all over the maize-producing areas in small units, capital investment and overhead charges would be minimised.

(v) The small dimensions of the units would make them flexible enough to change over to production of still better strains of hybrids whenever they were found.

(vi) In the beginning, hybrid maize seed would not be in any great demand and it would be necessary to educate the cultivator in the desirability of the use of hybrid maize seed. Production of seed in Community Project areas would automatically evoke interest in the farmers of those areas and the question of distribution would present no difficulty, because the people would see for themselves the obvious advantages of using hybrid maize.

(vii) The Agricultural Officer of the Project area would be able to certify the inbreds and single cross and double cross hybrids.

(viii) In the rural areas, isolated plots could be easily obtained which would eliminate expensive bagging operations otherwise required for production of hybrid maize.



(ix) The question of storage of small quantities of seed would not present any serious difficulty.

(x) Finally, a new and growing agricultural industry would be developed through these various seed production centres in the Community Project areas.

Dr. Pushkar Nath said that the problem of establishing a suitable organisation for seed multiplication and distribution was considered by the Committee but it was found necessary to give further thought to this matter as there were various conflicting views. It was for this reason that the Committee had recommended that State organisations should be evolved to suit the conditions prevailing in each State. These organisations might be managed by the State or by commercial interests.

The Chairman said that in the Second Five Year Plan it was proposed to acquire 50-100 acres of land in all the N.E.S. Blocks to be utilised for seed multiplication.

Dr. Solomon narrated his experience in the Community Extension Block at Poona. They had thought that the authorities of the Extension Block and the technical staff there would be able to take up and produce the hybrid seed. Inbreeds were supplied to them and they were given all the technical information regarding details of sowing, etc. The result was very unhappy; whatever seeds were produced by the Extension staff or by the Community Projects staff could not be certified as hybrid seeds and the scheme had to be redrafted entrusting the control of production of the seed and the different procedures involved in the matter to the staff of the State Agricultural Department. Dr. Solomon said that it would take some time before the staff in the Extension Blocks could be educated to handle this work and till then the State Agriculture Departments should be asked to produce the hybrid seed. He thought that it was equally risky to hand over the production of hybrid seed to any commercial organisation in this country at present.

The Chairman agreed with the views of Dr. Solomon.

The Chairman added that Shri Boshi Sen had produced some hybrid onions. He suggested that any material which Shri Boshi Sen had got might be tried at a number of centres first and if it was found good, then the Agriculture Departments should be requested to propagate that material. He asked if any of the officers required the material from Shri Boshi Sen.

The following persons expressed their willingness to get the material from Shri Boshi Sen :—

1. Dr. Solomon from Poona, 2. Dr. Pushkarnath from Simla,
3. Dr. Nijawan from Punjab, 4. Shri E. A. R. Banerji from West Bengal, 5. Dr. Sahu from Orissa, 6. Dr. Desai from Hyderabad,
7. Dr. Parsai and 8. Dr. Tiwari from Madhya Pradesh.

The Conference adopted the Resolutions recommended by the Committee as follows :—

"1. This Conference notes with satisfaction that in some crops like maize, *bajra* and cotton, research work has now resulted in the production of suitable hybrid combinations which can be immediately taken up for commercial cultivation. In order, therefore, to exploit to the full the potentialities of hybrid vigour, this Conference recommends as follows :—

(i) Co-ordinated trials with hybrid maize seed should be urgently undertaken with a view to finding out their suitability for different agro-climatic regions and also to determining their suitability for introduction in the existing cropping patterns in the country. This work could be, with advantage, carried out under the co-ordinated maize scheme sponsored by the Indian Council of Agricultural Research.

(ii) The hybrid of *bajra*, already available, should be tried in different *bajra* growing regions.

(iii) The work relating to cotton should be taken up on the above lines by the Indian Central Cotton Committee.

(iv) As there exists at present no effective organisation for the production and distribution of hybrid seed of crops, particularly maize, where some suitable combinations are already available, this Conference stresses that steps should be taken to evolve and establish such organisations.

2. There are adequate data to show that there are great possibilities for commercial exploitation of hybrid vigour in many vegetables like tomato, brinjal, bhindi, etc., and cash crops like tobacco. This conference, therefore, recommends that co-ordinated pilot schemes should be started to work out the economics of hybrid seed production in these crops and to carry out regional yield trials. When the commercial utility of particular hybrid combinations is established, steps should be taken with the co-operation of the State Departments of Agriculture to multiply and distribute the hybrid seeds. Further multiplication may be arranged through commercial seed organisations.

The work on tobacco should be carried out by the Indian Central Tobacco Committee on the lines indicated above.

3. There are crops like *jowar*, wheat, paddy and several vegetables like onion, and many legumes where there exists evidence of occurrence of hybrid vigour. Economic production of hybrid seeds is, however, not possible at present in these crops. This Conference, therefore, recommends that research work should be carried out to evolve suitable techniques like the induction and use of male sterility, etc. The use of the poly-cross breeding method to improve yield should also be evaluated in legumes.

4. Exploitation of hybrid vigour presents great potentialities in forest tree breeding and floriculture. This Conference, therefore, recommends that work on these should be immediately taken up, to

begin with, at one or two centres where adequate facilities for such a type of work exist. Possibility of utilising hybrid vigour in fruit trees should also be investigated."

On completion of the consideration of subjects on the agenda, Shri A. M. Thomas, M.P., Vice-President, Indian Central Arecanut Committee said that he would like to make a few observations on some matters of importance. He said that under the able guidance of Shri Randhawa and with eminent and energetic persons like Dr. Uppal and Dr. Pal to help them, it should not be difficult for the country to achieve the target of additional production of 40% during the Second Five Year Plan period, as desired by the Prime Minister. He expressed gratification at the interest which prominent persons like Prof. David V. Tor-Avanesyan and Technical Co-operation Mission experts like Dr. Gilbert and Dr. Herbert were taking in the national development of our country. Shri Thomas emphasised the importance of transmitting the results of Council's researches to the farmer. He said that there should be greater contact between the Scientific worker and the farmer so that not only could the latter benefit from the findings of the former but that the results of experience acquired by the latter were also available to the farmer. He commended the useful discussions that had taken place at the meetings of the Wing, but urged that more attention should be given to crops like coconut, arecanut, pepper and other spices.

Shri Satwant Singh associated himself with Shri Thomas in commending the work done by the Indian Council of Agricultural Research in the sphere of fact-finding and research. He suggested that greater attention should be paid to 'developmental research' which was necessary for the useful application of the findings of what might be called "laboratory research" on cultivators field. He agreed that it should not be difficult to achieve the target of 40% increase in production provided more attention was given to the developmental and proceeding sides and to providing necessary credit facilities to the farmers, especially the small farmers.

Shri Satwant Singh emphasised the importance of pure seed in raising production. He suggested that a chain of seed-testing centres for quality control should be set up under the supervision of a government agency. Steps should also be taken to develop storage facilities at various levels. He attached great importance to the organisation of farmers on a non-political basis as no amount of aid from outside bodies was likely to solve the problems of the farmers on a permanent basis unless they stood on their own legs.

Coming to the question of land policy, Shri Satwant Singh said that it should be based on factual data provided by a fact-finding impartial body like the Indian Council of Agricultural Research and not on paper reports of authorities who are not advantageously placed like the Council. He suggested that a fact-finding agency like that existing in all countries, especially in Australia, should be set up as an adjunct of the Indian Council of Agricultural Research. This agency should be free from political influence and its sole purpose should be to see how the various administrative policies reacted on the economy of farm production, the position being scrutinised on the basis of statistical data placed before it.

Shri Raghottam Reddy suggested that the information published in the Indian Farming should also deal with the economics of farming and the various difficulties of the growers. This would add to the usefulness of the journal, he said.

Shri Reddy stressed the importance of studying the relationship between the production of food and other agricultural produce on the one hand and the prices of agricultural commodities on the other. He said that in the interest of agricultural production it was very necessary that steps were taken to set up an organization for stabilizing prices. He also emphasized that a suitable organization should be created to deal with the complicated problem of agricultural credit. He said that this organization should form an integral part of the Department of Agriculture and that the Indian Council of Agricultural Research should have a Section to collect the experiences of various States with regard to agricultural credit and render advice in this matter, as it was necessary in the interest of proper development to correlate and co-ordinate technical advice with the credit facilities. He suggested that the Council, as a body primarily responsible for evolving better techniques of agricultural production in this country, should take cognisance of all those factors—economic, sociological, ideological, etc. that bear upon agricultural production.

Shri Reddy further said that agricultural research in India on crop production was based on experiments conducted in "plots" and not on farms or holdings and that it was usual to devote greater attention to the crops that were in short supply. He suggested that research should be conducted on the basis of the cultivators' farms or holdings and with regard to the whole range of crops on which the economy of a particular region depended rather than with reference to those crops which were in short supply from the point of view of the urban consumer.

While concluding, Shri Reddy suggested that some Sections of the Indian Agricultural Research Institute might be transferred to some place in the South, because even though general research was of benefit to the country as a whole, the applied aspect of it was immediate value to the areas around the place of research.

Shri C. Gopalan drew attention to the fact that a great deal of work had been done on the quantitative aspects of food production and the treatment of soil from that point of view but that practically no work had been done on soil conditions and soil treatment with reference to their effect on the nutritive value of food grown on the soil. He suggested that this point should be kept in view in moulding the agricultural policy in future.

Shri C. Gopalan also referred to the problem of lathyrus which attacked human beings as well as cattle and was closely connected with agriculture. He requested that the Indian Council of Agricultural Research should interest itself in researches concerning this disease.

Shri Santokh Singh suggested that some members of the Animal Husbandry Wing of the Board of Agriculture and Animal Husbandry in India should be invited to attend the meetings of the Crops &

Soils Wing and *vice versa* so that problems like fodder and grazing lands, mixed farming, etc., which were of common interest to both agriculture and animal husbandry received due consideration. He also suggested that Agricultural Economists should also be associated with the meetings of the two Wings so that the economics of the various systems of farming could also receive proper consideration. Shri Santokh Singh also drew attention to the fact that the problem of meeting the fuel requirement of the countryside in general and the villager in particular had not received proper consideration. He suggested that this matter should be taken up by the Agriculture Department which was in the right position to advise which trees should be grown for this purpose and what was the best manner of growing them.

The Chairman then asked Dr. Uppal to reply to the various points raised by the members.

Dr. Uppal thanked the members for the appreciation expressed by them of the work being done by the Indian Council of Agricultural Research and the officers at the helm of its affairs.

Coming to the points raised by the members, Dr. Uppal said that the southern states of the country were adequately represented on the Board of Agriculture and Animal Husbandry and the Indian Council of Agricultural Research and its various organizations. He observed that the absence of the Directors of Agriculture of some of the States was presumably due to their engagement in work relating to G.M.F. States Reorganisation and other affairs confronting them at the time.

In the course of his reply, Dr. Uppal particularly informed the members that the Indian Council of Agricultural Research was trying its utmost to develop the production of cashewnut, pepper and other spices and that steps were being taken by the Government of India to establish seed-testing stations in different States. One seed testing Station had been established at the Indian Agricultural Research Institute already. Regarding the question of fuel, he said that the problem fell within the sphere of the Soil Conservation Board.

The Chairman said that they had very useful discussions on the various items on the agenda. He complimented the Indian Scientists and research workers who were in no way inferior to the scientists and workers in other countries and expressed the hope that they would try to do even better work in future. He said that the discussions had brought to notice certain gaps in our knowledge and activities and suggested that the representatives of the State Governments and other authorities should put up schemes on these subjects for the consideration of the Council.

In conclusion, the Chairman thanked the research workers, representatives of the farmers and other organizations and particularly the foreign scientists who had participated in the deliberations of the meeting. He also commended the able manner in which Dr. Uppal and Dr. Pal had guided the deliberations of the Conference.

Shri G. V. Rao paid tributes to Shri Randhawa's manifold abilities as an active scientist, an exponent of art, a good writer and an able administrator. Shri Rao expressed the hope that under the able guidance of eminent scientists like Shri Randhawa and Dr. Uppal, the I.C.A.R. would discharge its duties towards the farming communities of India in an efficient manner.

The meeting then came to a close with a vote of thanks to the Chair.

## REPORT OF THE COMMITTEE

SUBJECT No. 1

### Use of Atomic energy in Agriculture

*Present:*

1. Shree Boshi Sen (*Chairman*).
2. Dr. B. N. Uppal, Agricultural Commissioner with the Govt. of India.
3. Dr. B. P. Pal, Director, Indian Agricultural Research Institute, New Delhi.
4. Dr. Gilbert R. Muhr, T.C.M.
5. Dr. Herbert Schulbach, T.C.M.
6. Prof. David V. Ter-Avanesyan, Counsellor, U.S.S.R. Embassy in India with one interpreter.
7. Shree E.A.R. Banerjee, Joint Director of Agriculture, West Bengal.
8. Dr. S. Ramanujam, Director of Agricultural Research (Agri.), Bihar.
9. Shree M. Kanti Raj, Director of Agriculture, Manipur, Imphal.
10. Dr. E. S. Narayanan, Head of the Division of Entomology and Principal, Central College of Agriculture, New Delhi.
11. Dr. S. D. Nijhawan, Agricultural Chemist, Punjab.
12. Pt. K. N. Agha, Secretary, Indian Central Jute Committee, Calcutta.
13. Dr. B. N. Sahu, Agronomist, Orissa, Bhubaneswar.
14. Shree C. K. Ashdhir, Assistant Irrigation Adviser to the Govt. of India, Ministry of Food and Agriculture, New Delhi.
15. Shree M. C. Joshi, Agricultural Officer, Ajmer.
16. Shree S. Solomon, Dy. Director of Agriculture (Crop Research), Poona.
17. Dr. P. S. Parsai, Second Horticulturist to Govt. of Madhya Pradesh, Panchmarhi.
18. Shree B. P. Tiwari, Agriculturist to the Govt. of Madhya Pradesh, Nagpur.
19. Dr. R. H. Richaria, Principal, Bihar Agricultural College, Bihar, Sabour.
20. Shree S. K. Swamy, Secretary, State Farmers' Forum, Idaikal (Non-official).
21. Dr. R. S. Vasudeva, Head of the Division of Mycology, I.A.R.I., New Delhi.

22. Dr. A. D. Desai, Agricultural Chemist, Govt. of Hyderabad, Hyderabad-Dn.
23. Dr. N. P. Data, Soil Scientist, I.A.R.I., New Delhi.
24. Dr. R. V. Tamhane, Special Officer, Soil Testing Scheme, I.A.R.I., New Delhi.
25. Mr. H. Ferguson, Director, Indian Tea Association, Assam.
26. Shree A. T. Sanyal, Professor of Agronomy, State College of Agriculture, West Bengal, Calcutta.
27. Shree H. S. Negi, Deputy Registrar, Co-operative Societies, Simla.
28. Shree A. R. Thapar, Horticultural Officer, Himachal Pradesh, Simla.
29. S. Basheshar Singh, Patiala (Non-official).
30. Shree T. C. Kala, Deputy Director of Agriculture, Rajasthan, Jaipur.
31. Shree Bal Singh Bajwa, Fruit Specialist, Punjab, Jullunder City.
32. Shree R. S. Mathur, Plant Pathologist to U.P. Govt., Kanpur.
33. Dr. C. N. Acharya, Indian Agricultural Research Institute, New Delhi.
34. Dr. P. J. Gregory, Secretary, Indian Central Coconut Committee, Ernakulam.
35. Sardar Santokh Singh, Officer on Special Duty, Planning Commission, Govt. of India.
36. Shree D. V. Krishna Rao, Agricultural Chemist, Andhra, Bapatla.
37. Dr. A. Mariakulandai, Govt. Agril. Chemist, Madras, Coimbatore.
38. Dr. A. R. Khan, Agronomist, Indian Agricultural Research Institute, New Delhi.
39. Dr. A. B. Joshi, Geneticist, Indian Agricultural Research Institute.
40. Dr. P. M. Dabadghao, Ecologist, I.C.A.R., New Delhi.
41. S. Satwant Singh, Biswedat, Patiala. (Non-official.)
42. Dr. Sham Singh, Assistant Agricultural Commissioner, I.C.A.R.
43. Dr. J. A. Daji, Assistant Agricultural Commissioner, I.C.A.R.
44. Dr. Uttam Chand, Prof. of Statistics, I.C.A.R.
45. Dr. A. R. Sen, Statistician (Agriculture), I.C.A.R.
46. Dr. M. S. Swaminathan, Cytogeneticist, I.A.R.I., New Delhi.



47. Shree J. L. Merh, Plant Pathologist, Institute of Plant Industry, Indore.
48. Shree B. Bhimsen Rao, Agricultural Chemist, Mysore, Bangalore.
49. Shree P. M. Tamboli, Chief Chemist, Govt. of Madhya Bharat, Indore.
50. Shree D. M. K. Reddy, Buchireddipalem, Nellore, Andhra (Non-official).
51. Shree A. M. Thomas, M.P., \*Vice-President, Indian Central Arecanut Committee.
52. Dr. B. L. Sethi, Secretary, Indian Central Cotton Committee, Bombay.
53. Shree G. Umamaheswar Rao, Indian Central Oilseeds Committee.
54. Dr. G. R. Seth, Dy. Statistical Adviser, I.C.A.R.
55. Shree M. U. S. Jung, Dy. Agricultural Commissioner, I.C.A.R.
56. Dr. Pushkar Nath, Director, Central Potato Research Institute, Patna.
57. Shree Bishen Man Singh, Fatehpur, U.P. (Non-official).
58. Dr. B. C. Kundu, Director, Jute Agricultural Research Institute.
59. Shree S. H. Tulpule, Delhi.
60. Dr. G. S. Moorty, Indian Agricultural Research Institute.
61. Shree G. Khalam, Orissa.
62. Shree V. K. Srinivasan.
63. Shree S. P. Kohli, Wheat Breeding Station, Simla.
64. Shree V. S. Mathur, Agronomy Dn., I.A.R.I.
65. Shree T. R. Mehta, Gwalior.
66. Shree A. K. Mitra, Kanpur.
67. Shree R. B. Ekbote, Delhi.
68. Krishi Pandit Rishabhkumar, Khurai.
69. Shree S. K. Mirchandani, Additional Secretary, I.C.A.R.—(Secretary).
70. Shree P. L. Malhotra, Under Secretary, I.C.A.R.

Papers of the following officers were considered at the meeting:

1. Dr. Boshi Sen, Vivekananda Laboratory, Almorah, U.P.
2. Dr. E. S. Narayanan, I.A.R.I., New Delhi.
3. Dr. N. P. Dutta, I.A.R.I., New Delhi.
4. Shree T. R. Narayanan, Coimbatore.

5. The Department of Agriculture, Andhra, Bapatla.
6. Dr. R. D. Verma, I.A.R.I., New Delhi.
7. Dr. R. S. Vasudeva and Dr. M. R. S. Iyengar, I.A.R.I., New Delhi.
8. Dr. S. M. Sikka and Dr. M. S. Swaminathan, I.A.R.I., New Delhi.
9. Dr. B. C. Kundu, Barrackpore.

The following resolutions were recommended for the consideration of the Plenary Session :

"It is resolved that in view of the importance of radio-active isotope work in various aspects of agriculture, the Indian Council of Agricultural Research should set up a Committee to promote and co-ordinate research in this field.

It is further resolved that research work both on the fundamental and applied aspects should be intensified."

#### SUBJECT No. 2

#### Role of organic manures and chemical fertilisers in crop production and maintenance of soil fertility.

*Present:*

1. Dr. C. N. Acharya—(Chairman).
2. Dr. B. N. Uppal, Agricultural Commissioner.
3. Dr. B. P. Pal, Director, I.A.R.I.
4. Prof. David V. Ter-Avanesyan, Counsellor, U.S.S.R. Embassy in India.
5. Mr. Chernyshev, Interpreter (U.S.S.R.)
6. Dr. Herbert Schulback, T.C.M., New Delhi.
7. Dr. Gilbert R. Muhr, T.C.M.
8. Shri B. L. Sethi Secy., I.C.C.C., Bombay.
9. Shri S. D. Nijhawan, Agricultural Chemist.
10. Dr. B. C. Kundu, Jute Agril. Research Instt., Barrackpur, West Bengal.
11. Dr. P. S. Parsai, 2nd Horticulturist to the Govt. of M.P., Panchmarhi.
12. S. Satwant Singh, Patiala.
13. Dr. G. R. Seth, Dy. Statistical Adviser, I.C.A.R.
14. Dr. E. S. Narayanan, Div. of Entomology, I.A.R.I.
15. Shri T. C. Kala, Dy. Director of Agriculture, Rajasthan.

16. Dr. B. P. Tiwari, Agriculturist to the Govt. of M.P., Nagpur.
17. S. Bashesar Singh, Patiala (Non-official).
18. S. Santokh Singh, Planning Commission.
19. Dr. M. S. Swaminathan, Cytogenetist, I.A.R.I.
20. Shri D. V. Krishna Rao, Agricultural Chemist, Andhra, Bapatla.
21. Dr. A. Mariakulandai, Government Agricultural Chemist, Coimbatore.
22. Shri B. Bhimsen Rao, Government Agricultural Chemist, Mysore.
23. Dr. P. M. Tamboli, Government Chief Chemist, Madhya Bharat.
24. Shri S. K. Swami, State Farmers' Forum, Madras (Non-official).
25. Dr. S. Solomon, Dy. Director of Agriculture (Crop Research), Poona.
26. Dr. A. T. Sanyal, Prof. of Agronomy, State College of Agri., West Bengal.
27. Dr. N. P. Datta, Soil Scientist, I.A.R.I., New Delhi.
28. Mr. H. Ferguson, Director, Indian Tea Association, Tocklai, Assam.
29. Dr. R. V. Tamhane, Special Officer, I.A.R.I., New Delhi.
30. Dr. A. D. Desai, Agricultural Chemist, Government of Hyderabad.
31. Shri Bishan Man Singh, Chairman, State Board of Agri., Fatehpur, U.P. (Non-official).
32. Dr. Uttam Chand, Prof. of Statistics, I.C.A.R.
33. Dr. A. R. Sen, Statistician, I.C.A.R.
34. Shri S. K. Mallik, Meteorologist, Poona.
35. Dr. R. K. Tandon, Director of Sugarcane Research, Shahjehanpur.
36. Shri E. A. R. Banerjee, Jt. Director of Agri., West Bengal, Calcutta.
37. Dr. J. A. Daji, Asstt. Agricultural Commissioner, I.C.A.R.
38. Shri A. R. Khan, Agronomist, I.A.R.I.
39. Shri K. S. K. Rao, Biochemist, Himachal Pradesh, Simla.
40. Dr. R. S. Vasudeva, Hd. of the Div. of Mycology, I.A.R.I.
41. Dr. Pushkarnath, Director, C.P.R.I.
42. Shri C. K. Ashdhir, Asstt. Irrigation Adviser, Min. of F. & A.

43. Dr. B. N. Sahu, Agronomist, Orissa.
44. Shri P. M. Dabadgao, Ecologist, I.C.A.R.
45. Dr. P. M. N. Naidu, Dy. A.H.C., I.C.A.R.
46. Shri D. M. K. Reddy, Buchhisellipalam, Nellore, Andhra (Non-official).
47. Shri M. Kanti Raj, Director of Agri., Manipur.
48. Shri H. S. Negi, Dy. Registrar, Co-operative Societies, Simla.
49. Shri M. C. Joshi, Agriculture Officer, Ajmer.
50. Shri G. Umamaheswar Rao, I.C.A.C.
51. Shri J. L. Merh. Plant Pathologist, I.P.I., Indore.
52. Shri A. R. Thapar, Horticultural Officer, H.P., Simla.
53. Shri Bal Singh Bajwa, Fruit Specialist, Punjab.
54. Dr. Sham Singh, Asstt. A. C., I.C.A.R.
55. Pandit K. N. Agha, Secy., I.C.S.C., Calcutta.
56. Shri M. U. S. Jung, Dy. A. C., I.C.A.R.
57. Shri D. C. Kaith, Director Soil Conservation, Min. of F. & A.
58. Dr. S. Ramanujam, Director of Agril. Research (Agri.), Bihar.
59. Shri Boshi Sen, Vivekananda Laboratory, Almora.
60. Shri S. K. Mirchandani, Addl. Secy., I.C.A.R. (Secretary).
61. Shri P. L. Malhotra, Under Secretary, I.C.A.R.

Papers of the following Officers were considered at the meeting :—

1. Dr. Sukh Dayal Nijhawan, Agricultural Chemist, Ludhiana.
2. Shri H. R. Arakeri, Sugarcane Research Station, Padegaon.
3. Dr. S. P. Ray Chaudhry, Head of the Division of Chemistry, I.A.R.I.
4. The Department of Agriculture, Andhra State, Bapatala.
5. Dr. S. Sen and Dr. A. G. Kavitkar, I.A.R.I.
6. Dr. P. C. Raheja, Hd. of the Div. of Agronomy, I.A.R.I. (on general condition).
7. Dr. P. C. Raheja, Hd. of the Div. of Agronomy, I.A.R.I. (on crop production).
8. Dr. P. C. Raheja and Shri K. S. Yawalkar, I.A.R.I.
9. Shri Ram Surat Singh and Shri R. K. Tandon, Deptt. of Agri., U.P.
10. Shri M. V. Vachhani, Central Rice Research Institute, Cuttack.
11. Dr. V. G. Panse, Statistical Adviser, I.C.A.R., New Delhi.

12. Shri B. M. Pramnik, Main Sugarcane Research Station, Shahjehanpur.
13. Shri A. T. Sanyal, Prof. of Agronomy, College of Agri., West Bengal, Calcutta.
14. Shri B. P. Mathur and Shri A. R. Khan, Div. of Agronomy, I.A.R.I.
15. Shri B. P. Tiwari, Agriculturist to the Govt. of Madhya Pradesh and Shri J. P. Patel, Lecturer in Agronomy, Madhya Pradesh, Nagpur.
16. Shri Bishan Man Singh, Fatehpur, Uttar Pradesh.
17. Shri R. K. Tandon, Main Sugarcane Research Station, Shahjehanpur, U.P.
18. Dr. A. Mariakulandai, Government Agricultural Chemist, Coimbatore.

The following resolutions were recommended for the consideration of the Plenary Session:

"The Committee noted that bulky organic manures and chemical fertilisers increase yields of crops grown under irrigation and under assured rainfall. However, plots treated with bulky organic manures and chemical fertilisers as well as un-manured plots in long-term experiments conducted at Coimbatore and Pusa (Bihar) have, under conditions of moderate rainfall, shown deterioration in the yields of crops, but such deterioration was less marked in the plots which received bulky organic manures. The factors responsible for this deterioration in soil fertility need further investigation.

In the case of heavily irrigated crops like sugarcane, the results of experiments conducted at Padegaon in the Bombay State and at Shahjehanpur in the Uttar Pradesh indicate that the application of chemical fertilisers without bulky organic manures results in the deterioration of the soil and consequent reduction in yield. The Committee felt that similar experiments have not been conducted with irrigated crops other than sugarcane and also crops grown under assured rainfall, and recommended that long-term experiments should be undertaken in different parts of the country under both irrigated and assured rainfall conditions in order to examine the beneficial effects of organic manures on yield, the changes in soil properties due to the continuous application of manures and fertilisers, and the influence of different manurial practices on the quality of the crop grown from the seed obtained from the treated plot of the previous year.

As the application of chemical fertilisers has shown to increase crop yields, the Committee felt that the use of these fertilisers on a large scale for increasing crop production may be adopted as an emergency measure. However, the cultivators should be advised to prepare and apply as much of bulky organic manures as possible, along with fertilisers.

The Committee recommended that the Indian Council of Agricultural Research should take early steps to compile all the data relating to manurial experiments carried out in the country after 1931 (in continuation of the results summarised in Mr. Vaidyanathan's Report), and publish it in the form of a monograph."

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SUBJECT No. 3

**Utility of rapid soil tests for evaluating soil productivity and the use of fertilisers**

**Present:**

1. Dr. S. P. Ray Chaudhury—(Chairman).
2. Dr. B. N. Uppal, Agricultural Commissioner, I.C.A.R.
3. Dr. B. P. Pal, Director, I.A.R.I.
4. Dr. Gilbert R. Muhr, T.C.M.
5. Dr. Herbert Schulbach, T.C.M.
6. Prof. David V. Ter-Avanesyan, Counsellor, U.S.S.R. Embassy in India.
7. Mr. E. Chernyshev, U.S.S.R. Embassy in India.
8. Mr. E. N. Sanders, Extension Adviser to Govt. of H.P. (T.C.M.)
9. Shri M. Kanti Raj, Director of Agri., Manipur.
10. Dr. J. A. Daji, Asstt. Agri. Commissioner, I.C.A.R.
11. Shri Basheshar Singh (Non-official), Patiala.
12. Dr. P. J. Gregory, Secy., Indian Central Coconut Committee, Ernakulam.
13. Shri E. A. R. Banerjee, Jt. Director of Agri., West Bengal.
14. Dr. R. K. Tandon, Dir., Sugarcane Research Station, Shah-jahanpur.
15. Shri P. P. Chandra, Secy., Indian Central Sugarcane Committee, New Delhi.
16. Mr. H. Ferguson, Dir., Indian Tea Association, Assam.
17. Dr. P. M. Tamboli, Chief Chemist to the Govt. of Madhya Bharat.
18. Dr. B. B. Roy, Research Officer, Central Water & Power Research Station, Poona.
19. Dr. N. P. Datta, I.A.R.I.
20. Shri P. M. Dabadghao, Ecologist, I.C.A.R.
21. Shri R. B. Deshpande, Himachal Pradesh, Simla.
22. Shri A. K. Mallik, Meteorologist, Poona.

23. Shri J. L. Marh, Plant Pathologist, Instt. of Plant Industry, Indore.
24. Shri B. Bhimsenarao, Agricultural Chemist, Mysore.
25. Shri S. K. Swami, Secy., Farmers' Forum, Madras.
26. Shri G. Umamaheswar Rao, Indian Central Oilseeds Committee.
27. Dr. D. V. Krishnarao, Agricultural Chemist, Andhra.
28. Dr. A. Mariakulandai, Govt. Agrl. Chemist, Coimbatore.
29. Shri B. P. Tewari, Agriculturist to the Govt. of Madhya Pradesh.
30. Dr. P. S. Parsai, 2nd Horticulturist to Govt. of M.P., Pachmarhi.
31. Shri D. M. K. Reddy (Non-official), Andhra.
32. Dr. P. M. N. Naidu, Dy. Animal Husbandry Commissioner, I.C.A.R.
33. Shri H. S. Negi, Dy. Registrar, Co-operative Societies, Simla.
34. Dr. R. K. Richaria, Principal, Bihar Agri. College, Sabour.
35. Shri B. N. Sinha, Dir., Extension Services, Patna.
36. Shri B. N. Sahu, Agronomist, Orissa.
37. Shri M. C. Joshi, Agricultural Officer, Ajmer.
38. Shri C. K. Ashdhir, Asstt. Irrigation Adviser, Min. of F. & A.
39. Shri T. C. Kala, Dy. Dir. of Agriculture, Rajasthan.
40. Dr. Sham Singh, Asstt. Agri. Commissioner, I.C.A.R.
41. Shri D. C. Kaith, Dir. of Soil Conservation, Min. of F. & A.
42. Dr. E. S. Narayanan, Head of the Division of Entomology. I.A.R.I.
43. Pt. K. N. Agha, Secy., Indian Central Jute Committee, Calcutta.
44. Shri A. M. Thomas, Vice-President, Indian Central Arecanut Committee.
45. Dr. Boshi Sen, Dir., Vivekananda Laboratory, Almora.
46. Dr. B. C. Kundu, Dir., Jute Research Institute Barrackpore.
47. Dr. A. D. Desai, Agri. Chemist, Hyderabad, Deccan.
48. Shri Bal Singh Bajwa, Fruit Specialist, Punjab.
49. Shri R. Reddy (Non-official), Hyderabad.
50. Shri Bishan Man Singh (Non-official), U.P.
51. Shri S. D. Nijhawan, Agri. Chemist, Punjab.

52. Shri Satwant Singh (Non-official), PEPSU.
53. Shri Santokh Singh, Planning Commission, New Delhi.
54. Dr. Uttam Chand, Prof. of Statistics, I.C.A.R.
55. Dr. A. R. Sen, Statistician, I.C.A.R.
56. Dr. G. R. Seth, Dy. Stat. Adviser, I.C.A.R.
57. Shri M. U. S. Jung, Dy. Agricultural Commissioner.
58. Shri B. L. Sethi, Secy., Indian Central Cotton Committee.
59. Shri Ambika Sharan Singh (Non-official), Bihar.
60. Shri S. K. Mirchandani, Addl., Secy., I.C.A.R. (Secretary).
61. Shri P. L. Malhotra, Under Secretary, I.C.A.R.
62. Shri Mokand Lal, Under Secretary, Ministry of F. & A.

Papers of the following officers were considered at the meeting:—

1. Shree S. V. Patil, Sugarcane Research Station, Padegaon.
2. Shree R. V. Tamhane and Shree B. V. Subbiah, Division of Chemistry, I.A.R.I., New Delhi.
3. The Department of Agriculture, Andhra, Bapatla.
4. Dr. P. C. Raheja, Head of the Division of Agronomy, I.A.R.I.
5. Dr. R. R. Agarwal, Agricultural Chemist to Government of U.P., Kanpur.
6. Dr. A. Mariakulandai, Government Agricultural Chemist, Coimbatore.
7. Shree S. K. Swami, Secretary, State Farmers' Forum, Madras.
8. Shree B. P. Mathur and Shree A. R. Khan, I.A.R.I.

1. This Conference recognises that rapid soil tests are useful in determining the fertility status of soils and for recommending manurial schedules or amendments to farmers. Sufficient information on the manurial requirements of soils with respect to different crops is available in the country. It is recommended that, with the information thus available, a rapid soil testing service should be organised in as many centres in the country, as possible.

2. The Conference recognises that in recent years "Soil Test Kits" have become popular in foreign countries, and are useful in determining, under field conditions, the nutrient deficiencies in the soil and the quantities of nutrients required to be added to make up the deficiency. It recommends that such "Kits" should be made available to the Community Project areas, National Extension Service Blocks, Agricultural Extension Officers and progressive farmers. This Conference also notes that some States have developed "Soil Test Kits", and recommends that information obtained by the use of these "Kits" should be availed of in evolving a suitable "Kit" for rapid soil tests for a particular soil region.



3. As the reliability of results obtained by applying rapid soil tests in the field depends upon the accuracy with which the soil samples are taken, it is recommended that proper training should be given to extension workers and progressive farmers in the methods of taking soil samples and the use of these "Kits".

4. The Conference recommends that leaflets describing the advantages of the soil testing service to farmers should be printed in regional languages and widely circulated.

5. The Conference recognises the need for further work to improve the technique of soil testing and for obtaining greater precision in framing manurial schedules by correlating crop responses with soil tests.

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SUBJECT No. 4

**A review of reclamation of saline and alkaline soils with special reference to—**

- (a) agronomic practices,
- (b) soil amendments,
- (c) afforestation and
- (d) crop rotation.

*Present:*

1. Dr. R. V. Tamhane—(Chairman).
2. Dr. B. N. Uppal, Agricultural Commissioner with the Govt. of India.
3. Dr. B. P. Pal, Director, Indian Agricultural Research Institute, New Delhi.
4. Dr. Gilbert R. Muhr, T.C.M.
5. Dr. Herbert Schulbach, T.C.M.
6. Prof. Ter-Avanesyan, Counsellor, U.S.S.R. Embassy in India.
7. Mr. E. Chernyshev, U.S.S.R. Embassy In India.
8. Shree E. A. R. Banerjee, Joint Director of Agriculture, West Bengal.
9. Dr. J. A. Daji, Assistant Agricultural Commissioner with the Govt. of India, I.C.A.R.
10. Dr. R. S. Vasudeva, Head of the Division of Mycology, I.A.R.I.
11. Dr. P. M. Tamboli, Govt. Chief Chemist, Madhya Bharat.
12. Dr. R. K. Tandon, Director, Sugarcane Research Station, Shahjahanpur.
13. Dr. A. D. Desai, Agricultural Chemist, Hyderabad-Dn.
14. Dr. B. B. Roy, Research Officer, Central Water & Power Research Station, Poona.

15. Dr. S. Solomon, Dy. Director of Agriculture (Crop Research), Poona.
16. Mr. H. Ferguson, Director, Indian Tea Association, Assam.
17. Shree J. L. Merh, Plant Pathologist, Institute of Plant Industry, Indore.
18. Shree B. Bhimsena Rao, Govt. Agricultural Chemist, Mysore.
19. Dr. A. Mariakulandai, Govt. Agricultural Chemist, Coimbatore.
20. Shree D. V. Krishna Rao, Agricultural Chemist, Andhra.
21. Shree M. Kanti Raj, Director of Agriculture, Manipur.
22. Shree M. C. Joshi Agricultural Officer, Ajmer.
23. Dr. B. N. Sahu, Agronomist, Orissa, Bhubaneshwar.
24. Dr. R. H. Richharia, Principal, Bihar Agricultural College, Sabour, Bihar.
25. Shree T. C. Kala, Dy. Director of Agriculture, Rajasthan.
26. Shree C. K. Ashdhir, Assistant Irrigation Adviser, Ministry of Food and Agriculture.
27. Dr. E. S. Narayanan, Head of the Division of Entomology, I.A.R.I.
28. Shree Sukh Raj Sabhlok, Director of Agriculture, Himachal Pradesh, Simla.
29. Dr. S. Ramanujam, Department of Agriculture, Bihar.
30. Shree D. C. Kaith, Director, Soil Conservation, Ministry of Food and Agriculture.
31. Dr. B. C. Kundu, Director, Jute Agricultural Research Institute, Barrackpore.
32. Shree S. D. Nijhawan, Agricultural Chemist, Punjab.
33. Shree Boshi Sen, Director, Vivekananda Laboratory, Almora.
34. Shree Santokh Singh, Planning Commission, New Delhi.
35. Dr. A. D. Desai, Agricultural Chemist to the Govt. of Andhra Hyderabad-Dn.
36. Shree Bal Singh Bajwa, Fruit Specialist, Punjab, Jullunder City.
37. Dr. Pushkar Nath, Director, Central Potato Research Institute, Patna.
38. Dr. P. S. Parsai, Second Horticulturist to Govt. of Madhya Pradesh, Pachmarhi.
39. Dr. B. P. Tiwari, Agriculturist to Govt. of Madhya Pradesh.
40. Shree G. Umamaheshwar Rao, Indian Central Arecanut Committee.

41. Dr. A. R. Sen, Statistician, I.C.A.R.
42. Shree P. M. Dabadghao, Ecologist, I.C.A.R.
43. Shree A. R. Mallik, Meteorologist, Poona.
44. Shree R. B. Deshpande, Himachal Pradesh, Simla.
45. Shree P. P. Chandra, Secretary, Indian Central Sugarcane Committee, New Delhi.
46. Dr. N. P. Datta, Soil Scientist, Indian Agricultural Research Institute, New Delhi.
47. S. Satwant Singh, Pepsu (Non-official).
48. Shree A. R. Thapar, Horticultural Officer, Himachal Pradesh, Simla.
49. Shree D. M. K. Reddy, Andhra (Non-official).
50. Dr. M. S. Swaminathan, Cytogeneticist, I.A.R.I.
51. Shree S. K. Swami, Secretary, Farmers' Forum, Madras.
52. Shree Basheshwar Singh, Patiala (Non-official).
53. Dr. Sham Singh, Assistant Agricultural Commissioner, I.C.A.R.
54. Shree M. U. S. Jung, Deputy Agricultural Commissioner with the Govt. of India.
55. Shree B. L. Sethi, Secretary, Indian Central Cotton Committee.
56. Shree S. K. Mirchandani, additional Secretary, I.C.A.R.
57. Shree R. Reddy, Hyderabad-Dn.
58. Dr. S. P. Ray Chaudhury, Head of the Division of Chemistry, I.A.R.I., New Delhi.
59. Dr. Uttam Chand, Professor of Statistics, I.C.A.R.
60. Dr. G. R. Seth, Deputy Statistical Adviser, I.C.A.R.
61. Shree P. L. Malhotra, Under Secretary, I.C.A.R.

Papers of the following officers were considered at the meeting:—

1. Shri E. A. R. Banerjee, Joint Director of Agriculture, West Bengal.
2. Shri K. V. S. Satyanarayanan, I.A.R.I., New Delhi.
3. Shri B. Ramamoorthy, Division of Chemistry, I.A.R.I., New Delhi.
4. Shri Sukh Dayal Nijhawan, Agricultural Chemist, Punjab, Ludhiana.
5. Shri S. K. Patil, Soil Survey Officer, Sugarcane Research Station, Padegaon.

6. Dr. R. C. Hoon, Director, Central Water & Power Commission, New Delhi.
7. The Deptt. of Agriculture, Andhra, Bapatla. (Vide Consolidated note under item 1.)
8. The Central Silviculturist, Forest Research Institute, Dehra Dun.
9. Dr. R. R. Agarwal, Agricultural Chemist to Govt. U.P., Kanpur.
10. Shri M. Bhavanishankar Rao, Paddy Specialist, Coimbatore.
11. & 12. Shri C. Balasubramaniam, Agricultural Meteorologist, Coimbatore (Two papers).
13. Shri D. Daniel Sundararaj, Agril. College & Research Institute, Coimbatore.
14. Dr. A. Mariakulandai, Govt. Agril. College, Coimbatore.
15. Shree M. Kesava Iyengar, Coimbatore.
16. Shree P. A. Venkateswaran, Coimbatore.
17. Shree B. W. X. Ponnaiya, Coimbatore,  
Shree A. Subramaniam, Coimbatore.  
Shree Charles Ratnaswamy, Coimbatore.
18. Shree K. S. Yawalkar, Indian Agricultural Research Institute, New Delhi.

The following resolutions were recommended for the consideration of the Plenary Session :

1. "The Committee is of the opinion that there exists sufficient knowledge in the country for the reclamation of saline and alkaline lands as a result of the investigations carried out so far. In view of the fact that there are large tracts of land which have become saline or alkaline in almost every State, a time has come when it is necessary to apply this knowledge for the reclamation of such land. As reclamation of saline and alkaline lands is costly and beyond the means of an individual farmer, it is necessary that this problem should be tackled on a national basis. For this, the Committee is of the opinion that Government of India should set up an organisation or agency for carrying out reclamation of saline and alkaline soils on an all-India basis or entrust this work to an existing organisation like the Soil Conservation Board. Such an organisation should be properly financed and given the necessary facilities by either establishing new salinity laboratories or by strengthening the existing ones."

2. "The Committee is of the opinion that whenever irrigation projects are contemplated, arrangements should be made for the provision of drainage and lining of canals as a measure of prevention, so that the existing cultivable lands do not develop salinity or alkalinity. A soil survey for proper land use and for preparing suitable cropping patterns should also be simultaneously carried out whenever such projects are undertaken."

3. "The Committee feels that saline and alkaline lands which cannot be economically brought under use for agriculture be utilised for growing pastures and forest trees. The Committee further recommends that subsidy and loans should be given to private land owners who wish to reclaim land by this method."

4. "The Committee recommends that a popular pamphlet on the methods of reclamation of saline and alkaline be published in regional languages."

5. "The Committee feels that as there is need for further basic-research on reclamation of saline and alkaline soils."

6. "The Committee recommends that the plant introduction organisation should take up the work of introduction of all plants known to thrive on saline and alkaline soils. The Committee further suggests that the Indian Council of Agricultural Research should prepare a bulletin giving all available information on salt resistant plants so far known."

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SUBJECT No. 5

Value of 'shelter belts' and 'wind breaks'

- (a) in soil conservation and  
(b) in reducing losses in fruit cultivation.

*Present:*

1. Dr. D. G. Kaith—(Chairman).
2. Dr. B. N. Uppal, Agricultural Commissioner with the Government of India.
3. Dr. B. P. Pal, Director, Indian Agricultural Research Institute, New Delhi.
4. Prof. David V. Ter-Avanesyan, Counsellor, U.S.S.R. Embassy in India.
5. Mr. E. Chernyshev, Interpreter, U.S.S.R. Embassy in India.
6. Dr. E. N. Sanders, Extension Adviser to the Government of Himachal Pradesh.
7. Mr. H. Ferguson, Director, Indian Tea Association, Assam.
8. Dr. B. C. Kundu, Director, Jute Agricultural Research Institute, West Bengal.
9. Dr. P. J. Gregory, Secretary, Indian Central Coconut Committee, Ernakulam.
10. Shri Boshi Sen, Director, Vivekananda Laboratory, Almora.
11. Shri T. C. Kala, Deputy Director of Agriculture, Rajasthan.
12. Shri C. K. Ashdhir, Assistant Irrigation Adviser, Ministry of Food & Agriculture.

13. Dr. P. S. Parsai, Second Horticulturist to Government of Madhya Pradesh, Pachmarhi.
14. Dr. B. N. Sahu, Agronomist, Orissa.
15. Shri M. C. Joshi, Agricultural Officer, Ajmer.
16. Shri B. N. Sinha, Director of Extension Services, Bihar.
17. Shri J. L. Mehr, Institute of Plant Industry, Indore.
18. Dr. S. Solomon, Deputy Director of Agriculture (Crop Research) Poona.
19. Shri G. Umamaheshwar Rao, Indian Central Oilseeds Committee.
20. Dr. B. B. Roy, Central Water & Power Commission, Poona.
21. Dr. P. M. Tamboli, Government State Chemist, Madhya Bharat.
22. Shri P. P. Chandra, Secretary, Indian Central Sugarcane Committee New Delhi.
23. Shri A. K. Malik, Meteorologist, Poona.
24. Shri E. A. R. Banerjee, Joint Director of Agriculture, West Bengal.
25. Shri Bal Singh Bajwa, Fruit Specialist, Punjab.
26. Shri Santokh Singh, Planning Commission, New Delhi.
27. Shri R. Reddy, Hyderabad-Dn.
28. Dr. A. D. Desai, Agricultural Chemist, Hyderabad-Dn.
29. Dr. A. Mariakulandai, Government Agricultural Chemist, Madras, Coimbatore.
30. Shri D. V. Krishna Rao, Agricultural Chemist, Andhra, Bapatla.
31. Shri S. K. Swami, Farmers Forum, Madras.
32. Shri B. L. Sethi, Secretary, Indian Central Cotton Committee.
33. Shri B. Bhimsen Rao, Agricultural Chemist, Mysore, Bangalore.
34. Shri Basheshar Singh, Patiala (Non-official).
35. Shri M. U. S. Jung, Deputy Agricultural Commissioner.
36. Dr. Sham Singh, Assistant Agricultural Commissioner.
37. Shri R. B. Deshpande, Himachal Pradesh, Simla.
38. Shri A. R. Thapar, Horticulturist, Himachal Pradesh, Simla.
39. Dr. Uttam Chand, Professor of Statistics, I.C.A.R.
40. Dr. A. R. Sen, Statistician, I.C.A.R.
41. Dr. G. R. Seth, Deputy Statistical Adviser, I.C.A.R.

42. Shri Bishen Man Singh, Fatehpur, U.P. (Non-official).
43. Sardar Satwant Singh, PEPSU (Non-official).
44. Shri P. M. Dabadghao, Ecologist, I.C.A.R.
45. Shri S. K. Mirchandani, Additional Secretary, I.C.A.R.
46. Shri P. L. Malhotra, Under Secretary, I.C.A.R.
47. Dr. S. D. Nijhawan, Agricultural Chemist, Punjab.

Papers of the following officers were considered at the meeting :—

1. Shri D. C. Kaith, Director, Soil Conservation (Forests), Ministry of Food & Agriculture, New Delhi.  
and  
Shri I. I. Erusmus, Assistant Soil Conservation Officer, Dehra Dun.
2. The Horticulturist to the Government of Bombay, Poona.
3. Agricultural Department, Andhra.
4. The Central Silviculturist, Forest Research Institute, Dehra Dun.
5. Shri C. Balasubramaniam, Agricultural Meteorologist, Coimbatore.
6. The Department of Agriculture, U.P.
7. Shri Daljit Singh, I.C.A.R., New Delhi.
8. Shri Bishan Man Singh, Fatehpur, U.P.

The following resolutions were recommended for the consideration of the Plenary Session :

“The Board recognises the value of growing shelter belts and wind breaks in (a) soil conservation and (b) in reducing losses in fruit cultivation.

Experience at home and abroad shows that wind breaks have beneficial effect on yield of farm and orchard crops in general and in arid zones in particular.

As very little experimental data are available in India on the extent of effectiveness or drawbacks of shelter belts, or the suitable species to be grown for this purpose, it is recommended that research and experiments should be taken up on—

- (i) the suitability of different species of trees, shrubs and grasses, both local and exotic, for growing as shelter belts and wind breaks for soil conservation and protection of orchards in different parts of the country, and
- (ii) the factors such as different types of belts, their intervals, direction, density to determine their effectiveness on the growth and yields of field and fruit crops.

For giving impetus to the growing of trees and shrubs by the farmers and others, the planting material should be easily made available at subsidised rates at the appropriate time. For this purpose it is urged that a sufficient number of nurseries should be established in the country."

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SUBJECT No. 6

- (a) Water requirements of important fruit crops, and  
 (b) Different systems of irrigating fruit crops with a view to economising on the use of irrigation water.

**Present:**

1. Shree Bal Singh Bajwa—(Chairman).
2. Dr. B. N. Uppal, Agricultural Commissioner with the Govt. of India.
3. Dr. B. P. Pal, Director, Indian Agricultural Research Institute.
4. Prof. David V. Ter-Avanesyan, Counsellor, U.S.S.R. Embassy in India.
5. Mr. E. Chernyshev, Interpreter, U.S.S.R. Embassy in India.
6. Shree M. Kanti Raj, Director of Agriculture, Manipur Imphal.
7. Shree C. K. Ashdhir, Assistant Irrigation Adviser, Ministry of Food & Agriculture.
8. Shree D. C. Kaith, Director, Soil Conservation Officer, Ministry of Food and Agriculture.
9. Shree B. P. Tiwari, Agriculturist to the Govt. of Madhya Pradesh.
10. Dr. A. D. Desai, Agricultural Chemist to the Govt. of Hyderabad.
11. Dr. S. Solomon, Deputy Director of Agriculture (Crop Research), Bombay, Poona.
12. Dr. A. T. Sanyal, Prof. of Agronomy, West Bengal.
13. Mr. H. Ferguson, Director, Indian Tea Association, Assam.
14. Shree T. C. Kala, Deputy Director of Agriculture, Jaipur.
15. Sardar Santokh Singh, Planning Commission.
16. Dr. P. M. Tamboli, Govt. State Chemist, Madhya Bharat.
17. Dr. A. K. Mallik, Meteorologist, Poona.
18. Dr. R. K. Tandon, Director, Sugarcane Research Station, Shahjehanpur.
19. Shree B. Bhimsena Rao, Agricultural Chemist, Mysore.



20. Dr. A. Mariakulandai, Govt. Agricultural Chemist, Coimbatore.
21. Dr. P. S. Parsai, Second Horticulturist to Govt. of Madhya Pradesh, Pachmarhi.
22. Dr. B. N. Sahu, Agronomist, Orissa.
23. Shree J. L. Merh, Institute of Plant Industry, Indore.
24. Shree S. D. Nijhawan, Agricultural Chemist, Punjab.
25. Shree A. R. Thapar, Horticultural Officer, Himachal Pradesh, Simla.
26. Shree B. D. Sharma, Research Assistant, Himachal Pradesh, Agricultural Department.
27. Shree R. N. Paul, Agricultural Department, H.P., Simla.
28. Shree D. M. K. Reddy, Andhra (Non-official).
29. Shree K. S. K. Rao, Himachal Pradesh, Simla.
30. Shree R. B. Deshpande, Himachal Pradesh, Simla.
31. Dr. A. R. Khan, Agronomist, Indian Agricultural Research Institute, New Delhi.
32. Dr. N. P. Datta, I.A.R.I., New Delhi.
33. Dr. R. V. Tamhane, Special Officer, Soil Testing Station, I.A.R.I., New Delhi.
34. Sardar Basheshar Singh (Non-official), PEPSU.
35. Shree G. Umamaheshwar Rao, Indian Central Oilseeds Committee.
36. Dr. B. L. Sethi, Secretary, Indian Central Cotton Committee.
37. Dr. P. J. Gregory, Secretary, Indian Central Coconut Committee, Ernakulam.
38. Shree J. R. Reddy (Non-official), Hyderabad.
39. Shree Bishan Man Singh (Non-official), U.P., Fatehpur.
40. Pandit K. N. Agha, Secretary, Indian Central Jute Committee.
41. Dr. Pushkar Nath, Director, Central Potato Research Institute, Simla.
42. Dr. Sham Singh, Assistant Agricultural Commissioner, I.C.A.R.
43. S. Satwant Singh, Biswedat, Patiala (Non-official).
44. Dr. A. R. Sen, Statistician, I.C.A.R.
45. Dr. Uttam Chand, Prof. of Statistics, I.C.A.R.
46. Dr. G. R. Seth, Dy. Statistical Adviser, I.C.A.R.
47. Dr. J. A. Daji, Assistant Agricultural Commissioner, I.C.A.R.

48. Shree M. U. S. Jung, Dy. Agricultural Commissioner, I.C.A.R.
49. Shree P. L. Malhotra, Under Secretary, I.C.A.R.
50. Shree S. K. Mirchandani—(Secretary).

Papers of the following officers were considered at the meeting:—

1. Dr. A. Mariakulandai, Coimbatore.
2. Shree T. R. Narayanan, Plant Physiologist, Coimbatore.
3. Horticulturist to the Govt. of Bombay, Poona.
4. The Department of Agriculture, Andhra, Bapatla.
5. & 6. Dr. L. B. Singh, Horticulturist, Saharanpur (two papers).
7. & 8. Dr. Sham Singh & Shree Daljit Singh, I.C.A.R. (two papers).
9. Shree Bal Singh Bajwa, Fruit Specialist, Punjab [6(a)].
10. Shree Bal Singh Bajwa, Fruit Specialist, Punjab [6(b)].

The following resolution was recommended for the consideration of the Plenary session:

"This Committee recommends that, in view of the importance of determining the irrigation-cum-manurial requirements of important fruit crops like Mango, Citrus, Banana, Guava and Apple and finding out the best methods of application of irrigation water, experiments should be planned and carried out in important fruit growing regions of the country so that definite recommendations could be made to the fruit growers with regard to economical use of available irrigation water. The work should be carried out in important zones growing the above mentioned fruits."

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SUBJECT No. 7

**The rationale of the policy of large scale multiplication of seedlings from open-pollinated heterozygous seed parents in perennial crops, and the possibility of establishing nucleus plantations with appropriate combinations by way of selected male and female plants away from all possible contamination from foreign pollen for the production of elite seed**

**Present:**

1. Dr. S. Ramanujam, Director of Agricultural Research, Bihar —(Chairman).
2. Dr. B. N. Uppal, Agricultural Commissioner, I.C.A.R.
3. Dr. B. P. Pal, Director, I.A.R.I.
4. Prof. David V. Ter-Avansayan, U.S.S.R. Embassy.
5. Shri E. Charnyshev, Interpreter, U.S.S.R. Embassy.

6. Shri M. U. S. Jung, Dy. Agril. Commissioner, I.C.A.R.
7. Dr. J. A. Daji, Asstt. Agril. Commissioner, I.C.A.R.
8. Dr. Sham Singh, Asstt. Agril. Commissioner, I.C.A.R.
9. Dr. G. R. Seth, Dy. Statistical Adviser, I.C.A.R.
10. Dr. Uttam Chand, Prof. of Statistics, I.C.A.R.
11. Shri Boshi Sen, Director, Vivekananda Laboratory, Almora.
12. Dr. B. L. Sethi, Secy., Indian Central Cotton Committee, Bombay.
13. Dr. E. S. Narayanan, Head of Division of Entomology, I.A.R.I.
14. Dr. S. P. Raychaudhry, Head of the Divn. of Chemistry, I.A.R.I.
15. Dr. N. P. Dutta, Soil Scientist, I.A.R.I.
16. Dr. Pushkar Nath, Director, Central Potato Research Institute, Patna.
17. Dr. C. N. Acharya, I.A.R.I.
18. Dr. R. H. Richaria Principal, Bihar Agriculture College Sabour.
19. Shri H. Ferguson, Director, Indian Tea Association, Cinemara, Assam.
20. Dr. B. B. Roy, Central Water and Power Research Station, Poona.
21. Dr. Herbert Schulbach, T.C.M.
22. Dr. R. Muhr Gilbert, T.C.M.
22. (a) Dr. P. J. Gregory, Secretary, Indian Central Coconut Committee.
23. Shri J. L. Merh, I.P.I., Indore.
24. Shri G. Umamahaswar Rao, Indian Central Oilseeds Committee.
25. Shri M. Kanti Raj, Director of Agriculture, Manipur.
26. Shri Sukhraj Sabhlok, Director of Agril., Himachal Pradesh, Simla.
27. Shri A. R. Thapar, Horticultural Officer, Himachal Pradesh, Simla.
28. Shri M. C. Joshi, Agricultural Officer, Ajmer.
29. Shri B. Bhimsen Rao, Agricultural Chemist, Mysore.
30. Shri P. M. Tamboli, Chief Chemist, Madhya Bharat.
31. Shri T. C. Kala, Dy. Director of Agriculture, Rajasthan.
32. Shri Basheshar Singh, PEPSU (Non-official).
33. Shri Satwant Singh, Bisweddar, Nasirpur Farm, Patiala.

34. Dr. A. D. Desai, Agriculture Chemist, Hyderabad.
35. Shri D. V. Krishnarao, Agricultural Chemist, Andhra.
36. Shri D. M. K. Reddy, Andhra (Non-official).
37. Dr. B. M. Sahu, Agronomist, Orissa.
38. Shri S. K. Swamy, Madras (Non-official).
39. Dr. A. Mariakulandai, Coimbatore.
40. Dr. S. Solomon, Dy. Director of Agriculture (C.R.), Bombay State, Poona.
41. Shri Bal Singh Bajwa, Fruit Specialist, Punjab.
42. Dr. Sukh Dayal Nijhawan, Agricultural Chemist, Punjab.
43. Shri B. P. Tiwari, Agriculturist, Madhya Pradesh.
44. Dr. P. S. Parsai, Second Horticulturist, Madhya Pradesh.
45. Shri Ambika Sharn Singh, Bihar (Non-official).
46. Dr. M. S. Swaminathan, Cytogeneticist, I.A.R.I.
47. Shri P. M. Dabadghao, Ecologist, I.C.A.R.
48. Dr. A. Sen, Statistician, I.C.A.R.
49. Shri A. R. Khan, Agronomist, I.A.R.I.
50. Shri K. S. K. Rao (visitor), Himachal Pradesh.
51. Shree P. L. Malhotra, Under Secretary, I.C.A.R.
52. Shri S. K. Mirchandani—(*Secretary*).

Papers of the following Officers were considered at the meeting :—

1. Indian Central Coconut Committee, Ernakulam.
2. Shri S. G. Aiyadurai, Oilseeds Specialist, Coimbatore.
3. Dr. N. Krishnaswamy, Cytogeneticist, Coimbatore.

The following resolution was recommended for the consideration of the Plenary Session :—

“The Committee considered the problems relating to the production of elite seed in cross-pollinated perennial trees with particular reference to coconut and felt that it is desirable to gather fundamental data on the mechanism of pollination and the distance over which pollen is carried either by wind or insects, before starting nucleus plantations in isolation.”

“The Committee also felt that additional data on the correlation of seedling characters with yield should be obtained.”

## SUBJECT No. 8

**Plant viruses with special reference to their nature, methods of transmission, the disease they cause and methods of control***Present:*

1. Dr. R. S. Vasudeva—(Chairman).
2. Dr. B. N. Uppal, Agricultural Commissioner with the Govt. of India.
3. Dr. B. P. Pal, Director, I.A.R.I.
4. Prof. David V. Ter-Avenesyan, Counsellor, U.S.S.R. Embassy in India.
5. Mr. E. Chernyshev, Interpreter, U.S.S.R. Embassy in India.
6. Dr. A. D. Desai, Agricultural Chemist, Hyderabad-Dn.
7. Dr. D. V. Krishna Rao, Agricultural Chemist, Andhra.
8. Dr. A. T. Sanyal, Professor of Agronomy, West Bengal.
9. Shree A. K. Mallik, Meteorologist, Poona.
10. Dr. P. M. Tamboli, Chief Chemist, Govt. of Madhya Pradesh.
11. Dr. R. K. Tandon, Director, Sugarcane Research Station, Shah-jahanpur.
12. Shree E. A. R. Banerjee, Joint Director of Agriculture, West Bengal.
13. Dr. P. S. Parsai, Second Horticulturist to Govt. of Madhya Pradesh.
14. Dr. B. P. Tiwari, Agriculturist to Govt. of Madhya Pradesh.
15. Shree J. L. Merh, Institute of Plant Industry, Indore.
16. Shree B. Bhimsena Rao, Agricultural Chemist, Mysore.
17. Dr. S. Solomon, Deputy Director of Agriculture (Crop Research), Bombay, Poona.
18. Dr. R. H. Richaria, Principal, Bihar Agricultural College, Sabour, Bihar.
19. Shree M. C. Joshi, Agricultural Officer, Ajmer.
20. Dr. B. N. Sahu, Agronomist, Orissa.
21. Dr. S. Ramanujam, Director of Agriculture, Bihar, Patna.
22. Dr. B. C. Kundu, Jute Research Institute, Barrackpore, West Bengal.
23. Shree A. M. Thomas, Vice-President, Indian Central Arecanut Committee.
24. Dr. D. C. Kaith, Director, Soil Conservation, Ministry of Food and Agriculture, New Delhi.

25. Shree C. K. Ashdhir, Assistant Irrigation Adviser, Ministry of Food and Agriculture.
26. Shree T. C. Kalá, Dy. Director of Agriculture, Rajasthan.
27. Shree A. R. Thapar, Horticultural Officer, Himachal Pradesh.
28. Shree S. D. Nijhawan, Agricultural Chemist, Punjab.
29. Shree M. Kanti Raj, Director of Agriculture, Manipur.
30. Shree D. M. K. Reddy (Non-official), Andhra.
31. Shree P. M. N. Naidu, Dy. Animal Husbandry Commissioner with the Govt. of India.
32. Shri Boshi Sen, Vivekananda Laboratory, Almora.
33. Dr. A. Mariakulandai, Govt. Agril. Chemist, Coimbatore.
34. Dr. Sham Singh, Asstt. Agricultural Commissioner, I.C.A.R.
35. Dr. J. A. Daji, Asstt. Agricultural Commissioner, I.C.A.R.
36. Mr. H. Ferguson, Director, Indian Tea Association, Assam.
37. Shree M. S. Swaminathan, I.A.R.I., New Delhi.
38. Dr. N. P. Datta, Soil Scientist, I.A.R.I., New Delhi.
39. Dr. P. M. Dabadghao, Ecologist, I.C.A.R.
40. Dr. Uttam Chand, Prof. of Statistics, I.C.A.R.
41. Dr. A. R. Sen, Statistician, I.C.A.R.
42. Shri G. Umamaheswar Rao, Indian Central Oilseeds Committee.
43. Shree Basheswar Singh (Non-official), PEPSU, Patiala.
44. Dr. B. L. Sethi, Secretary, Indian Central Cotton Committee.
45. Dr. E. S. Narayanan, I.A.R.I.
46. Shree S. K. Swami, Secretary, Farmers' Forum, Madras (Non-official).
47. Dr. P. J. Gregory, Secretary, Indian Central Coconut Committee.
48. Shree Bal Singh Bajwa, Fruit Specialist, Punjab.
49. Shree Bishen Man Singh (Non-official), U.P., Fatehpur.
50. Sardar Satwant Singh, Patiala (Non-official).
51. Shree R. N. Azad, Assistant Virus Pathologist, I.A.R.I.
52. Shree M. U. S. Jung, Deputy Agricultural Commissioner, I.C.A.R.
53. Shree P. L. Malhotra, Under Secretary, I.C.A.R.
54. Shree S. K. Mirchandani—(Secretary).

Papers of the following officers were considered at the meeting :—

1. Shree J. L. Merh, Institute of Plant Industry, Indore.
2. The Department of Agriculture, Andhra.
3. Dr. R. S. Vasudeva, Dr. S. P. Capoor and Dr. T. K. Nariani Indian Agricultural Research Institute.
4. Dr. Pushkar Nath, Director, Central Potato Research Institute.

The following resolutions were recommended for the consideration of the Plenary session :

1. "It was recommended that in view of the fact that there are heavy losses to crops, particularly to horticultural crops and potato due to virus diseases, greater attention should be paid to their investigation to cut down losses. In addition, work on 'grassy shoot' disease of sugarcane and 'Foorkey' disease of larger cardamom should be intensified. Systematic work on sandalwood 'spike' which is responsible for heavy losses should also be taken up, particularly with a view to establish its vector."
2. "It was recommended that, in addition to breeding for resistance direct methods of control of virus diseases, i.e., Chemotherapy, should receive greater attention than hitherto. Feasibility of introduction of mild strains to protect plantation crops, in particular, should be investigated. These methods, the conference felt, are necessary because of rapid change in strains of viruses."
3. "It was recommended that in view of the heavy losses caused by virus diseases, State Governments should supplement the plant pathological laboratories with a small unit of virus workers, with a view to survey and deal with the problems from practical angle. Also that a regional station should be set up in the south under the Co-ordinated Plant Virus Research Scheme in due course."
4. "The Conference noted with concern that the 'grassy shoot' of sugarcane is assuming alarming proportions and, in all probability, is a new introduction and, recommended that more strict quarantine methods should be adopted for regulating import of vegetatively propagated material."
5. "This Conference considers Seed Certification as one of the most effective methods of controlling virus diseases, particularly in asexually propagated crops, like the potato and strongly recommends development of such methods. Further as the early sown potatoes (being grown at a period of low aphid infestation in the plain) have generally a better seed value. The Conference strongly recommends the use of early harvested crops as seed. In this connection realising that the existing practice of storing late harvested stocks in cold storage for seed purposes is harmful. The Committee considers that some effective control on seed potato cold storages is necessary".

## SUBJECT No. 9

**Exploitation of Hybrid vigour in improvement of crop plants, fruits and vegetables****Present :**

1. Dr. Pushkar Nath, Director, C.P.R.I.—(Chairman).
2. Dr. B. N. Uppal, Agricultural Commissioner with the Govt. of India.
3. Dr. B. P. Pal, Director, I.A.R.I., New Delhi.
4. Dr. Gilbert R. Muhr, T.C.M.
5. Dr. Herbert Schulbach, T.C.M.
6. Prof. Ter-Avanesyan, Counsellor, U.S.S.R. Embassy in India.
7. Mr. E. Chernyshev, U.S.S.R. Embassy in India.
8. Shri E. A. R. Banerjee, Jt. Director of Agriculture, West Bengal.
9. Dr. J. A. Daji, Asstt. Agril. Commissioner with the Govt. of India.
10. Dr. R. S. Vasudeva, Head of the Division of Mycology, I.A.R.I.
11. Dr. P. M. Tamboli, Govt. Chief Chemist, Madhya Bharat.
12. Dr. R. K. Tandon, Director, Sugarcane Research Station, Shahjahanpur.
13. Dr. A. D. Desai, Agricultural Chemist, Hyderabad-Dn.
14. Dr. B. B. Roy, Research Officer, Central Water & Power Research Station, Poona.
15. Dr. S. Solomon, Dy. Director of Agri. (Crop Research), Poona.
16. Mr. H. Ferguson, Director, Indian Tea Association, Assam.
17. Shri J. L. Merh, Plant Pathologist, I.P.L., Indore.
18. Shri B. Bhimsena Rao, Govt. Agricultural Chemist, Mysore.
19. Dr. A. Mariakulandai, Govt. Agricultural Chemist, Coimbatore.
20. Shri D. V. Krishna Rao, Agricultural Chemist, Andhra.
21. Shri M. Kanti Raj, Director of Agriculture, Manipur.
22. Shri M. C. Joshi, Agricultural Officer, Ajmer.
23. Dr. B. N. Sahu, Agronomist, Orissa, Bhubaneswar.
24. Dr. R. H. Richharia, Principal, Bihar Agricultural College, Sabour.
25. Shri T. C. Kala, Dy. Director of Agriculture, Rajasthan.
26. Shri C. K. Ashdhir, Asstt. Irrigation Adviser, Ministry of Food & Agriculture.



27. Dr. E. S. Narayanan, Hd. of the Div. of Entomology, I.A.R.I.
28. Shri Sukh Raj Sabhlok, Director of Agriculture, Himachal Pradesh.
29. Dr. S. Ramanujam, Department of Agriculture, Bihar.
30. Shri D. C. Kaith, Director, Soil Conservation, Ministry of Food & Agriculture.
31. Dr. B. C. Kundu, Director, Jute Agril. Research Instt., Barackpore.
32. Shri S. D. Nijhawan, Agricultural Chemist, Punjab.
33. Shri Boshi Sen, Director, Vivekananda Laboratory, Almora.
34. Shri Santokh Singh, Planning Commission, New Delhi.
35. Dr. A. D. Desai, Agricultural Chemist to the Govt. of Hyderabad.
36. Shri Bal Singh Bajwa, Fruit Specialist, Punjab, Jullundur.
37. Dr. R. V. Tamhane, I.A.R.I.
38. Dr. P. S. Parsai, Second Horticulturist to Govt. of Madhya Pradesh, Pachmarhi.
39. Dr. B. P. Tiwari, Agriculturist to Govt. of Madhya Pradesh.
40. Shri G. Umamaheshwar Rao, Indian Central Arecanut Committee.
41. Dr. A. R. Sen, Statistician, I.C.A.R.
42. Shri P. M. Dabadghao, Ecologist, I.C.A.R.
43. Shri A. R. Malik, Meteorologist, Poona.
44. Shri R. B. Deshpande, Himachal Pradesh, Simla.
45. Shri P. P. Chandra, Secy., Indian Central Sugarcane Committee, New Delhi.
46. Dr. N. P. Datta, Soil Scientist, Indian Agricultural Research Institute.
47. Shree Satwant Singh, PEPSU (Non-official).
48. Shri A. R. Thapar, Horticultural Officer, Himachal Pradesh.
49. Shri D. M. K. Reddy, Andhra (Non-official).
50. Dr. M. S. Swaminathan, Cytogeneticist, I.A.R.I.
51. Shri S. K. Swami, Secretary, Farmers' Forum, Madras.
52. Shri Basheshar Singh, Patiala (Non-official).
53. Dr. Sham Singh, Asstt. Agril. Commissioner, I.C.A.R.
54. Shri M. U. S. Jung, Dy. Agril. Commissioner, I.C.A.R.
55. Shri B. L. Sethi, Secy., Indian Central Cotton Committee.
56. Shri S. K. Mirchandani, Addl. Secy., I.C.A.R.

57. Shri R. Reddy, Hyderabad-Dn.
58. Dr. S. P. Ray Chaudhury, Head of the Division of Chemistry, I.A.R.I.
59. Dr. Uttam Chand, Prof. of Statistics, I.C.A.R.
60. Dr. G. R. Seth, Dy. Statistical Adviser, I.C.A.R.
61. Shri P. L. Malhotra, Under Secretary, I.C.A.R.

Papers of the following officers were considered at the meeting:—

1. Indian Central Coconut Committee, Ernakulam.
2. Shri U. Narasinga Rao, Horticulturist and Professor of Horticulture, Coimbatore.
3. Dr. S. Solomon, Dy. Director of Agriculture (Crop Research), Poona.
4. Shri B. W. X. Ponnaiya, Millet and Pulses Specialist, Coimbatore.
5. Dr. N. Krishnaswamy, Cytogeneticist, Coimbatore.
6. The Department of Agriculture, Andhra, Bapatla, (*Vide* consolidated note under item I).
7. Dr. Y. R. Mehta, Horticulturist, in charge, Govt. Vegetable Research Station, Kalianpur, Kanpur.
8. Dr. B. P. Pal and Dr. S. M. Sikka, I.A.R.I., New Delhi.
9. Shri Boshi Sen, Director, Vivekananda Laboratory, Almora, U.P.

The following resolutions were recommended for the consideration of the Plenary Session:—

The Committee reviewed the work in progress in the country concerning the exploitation of hybrid vigour in crop plants, fruits and vegetables, and noted with satisfaction that in some crops like maize, *bajra* and cotton, research work has now resulted in the production of suitable hybrid combinations which could be immediately taken up for commercial cultivation. In order, therefore, to exploit to the full the potentialities of hybrid vigour, the Committee recommends as follows:—

1. Co-ordinated trials, with hybrid maize seed, should be urgently undertaken with a view to finding out their suitability for different agro-climatic regions and also to determine their suitability for introduction in the existing cropping patterns in the country. This work could be, with advantage, carried out under the co-ordinated maize scheme sponsored by the Indian Council of Agricultural Research.

The hybrid of *bajra* already available, should be tried in different *bajra* growing regions.

The work relating to cotton should be taken upon the above lines by the Indian Central Cotton Committee

Further, the Committee stressed that as there exist no effective organisation for the production and distribution of hybrid seed of crops, particularly in maize, where some suitable combinations are already available, steps should be taken to evolve and establish such organisation.

2. There are adequate data to show that there are great possibilities for commercial exploitation of hybrid vigour in many vegetables like tomato, brinjal, bhindi, etc. and cash crops like tobacco. Co-ordinated pilot schemes should be started to work out the economics of hybrid seed production in these crops and to carry out regional yield trials. When the commercial utility of particular hybrid combinations is established, steps should be taken with the co-operation of the State Departments of Agriculture to multiply and distribute the hybrid seeds. Further multiplication may be arranged through commercial seed organisations.

The work on *tobacco* should also be carried out on the lines indicated above by the Indian Central Tobacco Committee.

3. There are crops like *jowar*, wheat, paddy and several vegetables like onion, and many legumes where there exists evidence of occurrence of hybrid vigour. Economic production of hybrid seeds is, however, not possible at present in these crops. Research work should, therefore, be carried out to evolve suitable techniques like the induction and use of male sterility, etc. The use of the poly-cross breeding method to improve yield should also be evaluated in legumes.

4. Exploitation of hybrid vigour presents great potentialities in forest tree breeding and floriculture. Work on these should be immediately taken up, to begin with, at one or two centres where adequate facilities for such a type of work exist. Possibility of utilising hybrid vigour in fruit trees should also be investigated.

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## **APPENDICES**

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PAPERS ON SUBJECT No. 1

*A Note on Atomic Energy and Agriculture*

by

Bosi Sen, Vivekananda Laboratory, Almora, U.P.

The International Conference on the Peaceful Uses of Atomic Energy, recently held in Geneva, has clearly established the Atomic Age. This Conference, attended by some 3,600 scientists (of which I was fortunate enough to be one) of 74 nations showed that there is not a single branch of science or industry which is not going to be benefited, directly or indirectly, by the achievements of the nuclear physicists in this field. One of the most welcome features of the Conference was that after long years of suffocation nuclear physicists for the first time had the opportunity at Geneva for a free exchange of ideas. Warnings like, "If it is classified, do not mention it," were conspicuous by their absence.

I give below a brief summary of the Contribution of Atomic science to Agriculture, and the new vistas it has opened up, based on the papers read at this conference, a month of training at the Oak Ridge School of Nuclear Physics and my visits to different universities and research centres in the U.S.A. and England, where work in this field is being carried on. But first a few facts of general background information in connection with the development of atomic energy may help to clarify the subject.

Atoms in the nineteenth century were regarded as rigid spheres, devoid of internal structure, unique and indivisible. The foundation of atomic science was only laid by the Frenchman Becquerel in 1896, when he discovered the radioactive element uranium. The discovery that an atom of an element could give off radioactive energy was a new and exciting find, which stimulated a brilliant series of further investigations by other atomic scientists. Atoms have now been proved to be dynamic systems, which are not only composed of different particles, but are capable of being transformed into other atoms.

The central core of every atom, the nucleus, consists of protons, having a positive charge, and neutrons, having no charge. Around the nucleus rotates negatively charged particles, electrons, of practically no weight, exactly equal in number to the protons. Therefore, ordinarily atoms are electrically neutral. The weight of an atom is mostly that of its nucleus, and the atomic number is the number of protons or of rotating electrons. When, however, the nucleus of an atom is naturally unstable or made so, we get radioactive atoms which disintegrate into atoms of lower atomic weights. Radioactive atoms give off different kinds of radiations in the form of alpha and beta particles or electromagnetic waves, called gamma rays, similar to X-rays.

Apart from uranium, several other naturally occurring radioactive elements are now known. It has also been found that atoms of most elements exist in multiple forms, that is, though the chemical properties of these atoms are similar, their atomic weights are slightly

different. Atoms of the same elements with differing weights are called isotopes. When an isotope is radioactive, it is called a radioactive isotope, or simply a radioisotope. Over 1,000 different isotopes of some 100 elements have so far been identified. Of these some 276 are stable isotopes, and over 740 are radioisotopes. Some 47 of the radioisotopes occur in nature, but the others are man made.

The rate of disintegration of a radioactive element is fixed and cannot be altered by any means at present known to science. Different radioisotopes of the same element, however, have widely different rates of disintegration. The time it takes for a radioactive element to lose 50% of its activity is called its half-life. For instance, the half-life of thorium <sup>232</sup> is 13,900 million years, while that of thorium <sup>234</sup> is only 24.1 days. Again, the half-life of polonium <sup>214</sup> is 138.3 days, but that of polonium <sup>218</sup> is 0.3 millionth of a second.

By the use of radioisotopes great advances have been brought about in industry, biochemistry, physiology, medicine and agriculture. For agricultural improvement, high-yielding and disease resistant strains of crops are naturally wanted, and precise knowledge has to be obtained of the most effective use of fertilisers, how they are absorbed and translocated within the plant, and the process of synthesis of carbohydrates, proteins, enzymes and vitamins. Radioisotopes offer hitherto unattainable facilities for furthering these two objectives.

Radiation genetics is, of course, no new science. In earlier times, plant breeders depended on spontaneous mutations for their working material, but spontaneous mutations might occur only once in a hundred years. Muller (1927) working with male drosophila and Stadler (1928) working with maize and barley seeds, demonstrated that by means of X-rays it was possible to induce genetic changes in animals and plants. Now-a-days, with the facilities provided by nuclear reactors it is possible to increase mutation rate a thousandfold. Furthermore, ordinary methods of plant breeding are likely to require 7 to 8 years to stabilise a new line, but once a desirable mutant has been observed as a result of radiation treatment, all that is then required is to multiply the desired mutant.

Gamma rays from radioisotopes can be used at a less cost than X-rays. One of the radioisotopes of Cobalt, Co<sup>60</sup> which has a half-life of 5.27 years, gives off very powerful gamma rays, comparable to those given off by a two million volt X-ray machine. As a source of gamma-rays, Co<sup>60</sup> is now extensively used, alike for medical and agricultural purposes. Not only is it inexpensive but it can be easily manipulated in any desired shape and form.

For subjecting seeds, seedlings, plants or trees to gamma radiation, at any phase of their growth and development, a gamma field like the one at the Brookhaven National Laboratory, Upton, N.Y., is a very convenient set-up. In the centre of a ten-acre field a Co<sup>60</sup> rod, which gives off radiation equivalent to that given off by 1800 grams of radium, is raised or lowered by remote control. Plants are placed in concentric circles around the source of radiation, nearer the centre when a greater intensity of radiation is required. Plants are brought in and removed for the required periods at particular stages of growth

and development, or they may be allowed to grow under continuous radiation. When workers are taking records or are adjusting the arrangements, the Co<sup>60</sup> rod is lowered by remote control into a lead-shielded pit to shut off radiations. For fruit trees which can be propagated by grafting, somatic mutations (mutation of the body cells and not of germ cells) can be induced by this means in the vegetative buds. When desired changes are observed in a branch, the branch is then propagated by grafting.

Contrary to the earlier view that only undesirable mutations are produced by radiation, Gustafson of Sweden has been able to produce by radiation mutants of barley which have higher yield and stronger straw. In the U.S.A. mutants of oats resistant to rust and of peanuts resistant to leafspot disease, with high yield, have been obtained by radiation. Suggestive and encouraging results in inducing resistance to specific races of stem and crown rust in wheat have also been obtained. By radiation it is now possible to break the association of characters and produce a new germ plasm. For instance in the case of oats of Victoria parentage, crown rust is closely associated with blight susceptibility, but by radiation this association can be broken and new germ plasm produced. In the case of maize, in some of the inbred lines resistance to *Helmenthospodium turcicum* have recently been produced by radiation. With these beginnings, the future scope of radiation genetics in agriculture offers immense possibilities of advance.

The use of radioisotopes as tracers is another highly important development. As far back as 1923, Hevesy used radioisotopes of lead to study the absorption and translocation in plants. At that time, only the radioisotopes of heavy elements were available. Those of the lighter elements, generally found in living organism, were unknown. In 1934 Curie and Juliot accidentally discovered that lighter elements could be made radioactive by bombarding them with alpha particles. When powerful cyclotrons for researches in nuclear physics were evolved radioisotopes of practically all the elements were produced. Although the possibilities of utilising these radioisotopes for tracer experiments were fully recognised, the availability of the different radioisotopes was still extremely limited and the cost prohibitive for large scale experiments.

With the development of nuclear reactors during World War II, however, the supply of radioactive isotopes became plentiful, at a reasonable cost. The estimated cost of production by cyclotron of a thousandth of a curie of radioactive carbon C<sup>14</sup> one of the most useful radioisotopes for biological studies—would come to about a million dollars. Produced in the nuclear reactor, one millicurie of C<sup>14</sup> is now sold at about 35 dollars. (A curie is the unit of radioactivity produced by disintegration, of  $3.7 \times 10^{10}$  atoms per second, of the rate of disintegration of one gram of radium.)

Photosynthesis, the process by which green plants fix the solar energy and so make life possible on this earth, was only imperfectly understood. With the help of the radioisotopes C<sup>14</sup> Calvin and his associates at the Radiation Laboratory, Berkely, have been successful in unravelling the various processes involved in photosynthesis. This

knowledge opens out possibilities not only of increased crop production, but of making unicellular green plants produce concentrated proteins, fats and sugars. Using  $C^{14}$ , the Soviet scientists report that they have been able to detect the absorption of  $Co$ , from soil and its translocation to the leaves.

The special value in biological investigations attaching to the use of radioisotopes of any important element already existing in a living system is the ease with which it can be made to serve as a tracer. Chemically, radioisotopes and their stable counterparts behave in a similar manner that is, if a radioactive isotope is mixed with its normal counterpart and a plant or an animal is made to ingest this mixture, the various resulting processes and the path of movement within the living organism can be followed with an unusual degree of accuracy. There exists radiation detector which can make audible or visible the disintegration of a single atom. Since the radiation of the isotope will not be modified by any of the physical or chemical changes to which it might be subjected, the path of the radioisotope can thus be traced with remarkable precision. A mixture of a stable element and its radioactive isotope cannot be separated by chemical means, and no matter what chemical transformation the mixture may subsequently undergo, the original proportion of the mixture is supposed to be retained and the presence of the radioisotope anywhere in the organism can be detected.

One of the most useful radioisotopes for agricultural experiments today is phosphorous  $P^{32}$ . By mixing it with the ordinary fertilisers it has been most effectively used to find out the best placement of phosphorous, the most desirable time of application of this fertiliser, how much of the phosphorous applied as fertiliser, compared to the phosphorous already present in the soil, is actually utilised by a crop in the different phases of growth and development. The actual movements of ions in the soil could not have been studied without radioisotopes.

Radioisotopes of the elements used for fertilisers have made it possible to find out the comparative efficiency of applying fertilisers to the soil and of spraying them on to the leaves and stems of plants and trees. Interesting findings in this connection were reported by Tukey and associates of Michigan State University. They have found that the transport and distribution of radio-phosphorous is similar within the plant, whether it is absorbed by the roots or by the leaves. For herbaceous crops, application of phosphorous to the leaves represents the most efficient method of fertiliser placement yet devised. During the critical periods when the demands for nutrients are high and when the availability from the soil is low, foliar spray application can make up the demand. Soviet workers have further found that foliar spray of  $P^{32}$  prevents falling off of the ovaries of cotton plants and, in the case of sugar beet, increases the sugar content of the roots.

By the use of radiocalcium  $Ca^{45}$  it has been demonstrated that calcium is rapidly absorbed by leaves and fruits but, unlike phosphorous, there is no transport from these to other plant parts



By using radiopotassium,  $K^{40}$ , it has been shown that over 70% of the  $K^{40}$  absorbed by sweetpotato roots in 12 hours could be leached out by 4 hours of simulated rainfall in darkness. This leaching by rain may well be responsible for deficient productivity in certain crops.

$Co^{60}$  has been effectively used for inhibiting sprouting of potato without impairing the taste, thus increasing considerably the storage period. Further extensive use of radioisotopes have been for studying agricultural pests, their dispersal and behaviour, their food relations and disease transmission. The mode of action of insecticides can be followed in great detail by the use of radioisotopes.

From these few examples of the many uses of radioisotopes for agriculture, one can realise the immense possibilities which radioisotopes open up.

It has been established that the use of radioisotopes in industry has already saved industry thousands of millions of dollars, an amount probably equal to the total cost of developing nuclear energy. When full use is made of radioisotopes in agriculture we may easily expect a comparable gain.

India is far behind other countries in the use of this new science. Work should be taken up without delay in our agricultural research institutions on the widest possible scale, so that we may not only take advantage of the latest modern means of solving some of our many acute agricultural problems, but we may contribute through our researches to fundamental knowledge.

### *Use of Atomic Energy in Agriculture*

by

E. S. Narayanan, Head of the Division of Entomology, Indian Agricultural Research Institute, New Delhi.

Within recent years advances in our knowledge of nuclear physics have opened an entirely new vista for enduring research work in biological problems. In the fields of applied entomology the new technique developed in the use of stable and unstable isotopes in one way or the other has helped entomologists to understand more clearly the chemical, physical and physiological processes taking place within the insect body. Radioactive isotopes are used as tracers by entomologists in different aspects of entomological research work. Because of their property of emitting radiations radio-active isotopes can be detected and traced in any system of an insect with the help of suitable electronic instruments.

Radio-active isotopes can be used and have been used with excellent results in ecological, physiological toxicological and cytogenetical investigations.

In insect ecology the movements of insects under the soil or in the woody portions can be studied by tagging the insect under study with radio-active materials. In physiological investigations it is possible to investigate the nutritional requirements of various insect pests and to understand more fully the physiological processes associated with hibernation, mass migration etc.

In toxicology it will enable the entomologists to investigate the rate of penetration of different insecticides through insect body wall, their mode of action and the site of action.

It is well known that radiations cause mutations in living organisms. They have a profound effect on the longevity and fecundity of insects. They also cause sterility. So by the judicious use of the new technique it may be possible to increase the reproductive power of parasites and predators that play an effective role in the biological control of insect pests.

Research work on some of these problems have been started in the Entomology Division of the Indian Agricultural Research Institute, New Delhi.

### *Use of radioactive isotopes in agriculture*

by

N. P. Datta, Indian Agricultural Research Institute, New Delhi.

The first uses of radioactive materials in agriculture were made to see whether these substances have any stimulating or fertilizing effect on crops. Many experiments have been made in progressive countries of the world to test this point but the results were conflicting, while some claimed significant increases in crop growth, others reported no beneficial effect. No definite conclusion about any proved increase in plant growth could be formed. In 1949 experiments were conducted at the Indian Agricultural Research Institute on rice and soyabeans to test the reported fertilizing value of a radioactive soil stimulant which contained 0.05 per cent Uranium oxide. No significant increase in crop growth was noticed. More recently also, the U.S. Atomic Energy Commission financed an extensive trial to test this point in which the U.S. Department of Agriculture and 13 other States co-operated. Crops tested included cotton, soyabeans, groundnuts, maize, oats, wheat, barley, alfalfa, clovers, tomatoes, beans, spinach, carrots, potatoes, sugarbeets and tobacco. Experiments were conducted also in different parts of the country on several different soils. These experiments failed to show any beneficial effect on either crop growth or quality and thus proved conclusively that low level radioactive radiations have no stimulating effect on plant growth. Radioactivity periodically offered to farmers as a fertilizer is therefore worthless and farmers cannot expect increased yields from money invested in radioactive materials.

Work is underway at several stations in U.S.A., U.K., U.S.S.R. also on the effects of high level radiations on plants. The effects of radiation depends upon (1) type of radiation (2) rate of exposure and (3) species resistance. It is well known that higher forms of life are more sensitive to radiation damage than the lower forms. The principal work has been done by having a very high energy radiation source placed at the centre of field and growing plants in circles round it at different distances from the source. Since intensity of radiation is inversely proportional to the square of the distance from the source—differences in radiation dose were easy to obtain. Most plants can tolerate a very high level of external radiation continuously without visible damage. Although plants vary in radiation

sensitivity, all plants are affected by sufficiently high exposure. It is important to note also that no stimulation was observed at any intensity. Hypertrophic growth in certain structures was frequently noted in some species, in others, tumor like growth as well as somatic mutations were observed. Studies have shown that not all radiation induced mutations are deleterious—some are, actually desirable changes. The frequency of an otherwise extremely rare event (spontaneous mutation) can be increased by radiation. The main advantage is that such induced plant characters can be inbred and isolated in hybrid within two or three years which is much less than required by a crossing and backcrossing programme. The science of radiation genetics is growing fast and several spectacular results have been achieved. One of these is the development of rust resistant oats by means of neutron irradiation and another the production at North Carolina of a variety of peanuts which has about 30 per cent. higher yield per acre over other varieties.

By far the most important use of radioactivity has been its use as a tracer. Remembering that a radioisotope has the same chemical properties as its non-radioactive brother i.e., it behaves in any chemical or biological process, in exactly the same way as its brother, the non-radioactive isotope, if we mix a small amount of the radioactive isotope with the ordinary isotope, we, so to say, have achieved a sort of labelling of the material. The plant or animal cannot make any distinction between the two components of this material but we can easily follow or trace its movement through the system by its special property of radioactivity. Here therefore is a new tool or technique of amazing versatility and usefulness. The availability during the last 10 or 12 years to the general body of scientists, of radioactive isotopes of many of the common biologically important elements, like carbon, phosphorus, nitrogen, potassium, sulphur, iron etc. from the atom pile, has provided the necessary fillip and today a large number of experiments are underway round the world and a vast amount of knowledge in all branches of agricultural sciences is being gathered. Many of our old ideas are changing for the better while many problems are being solved which it was impossible to solve by the hitherto used methods. The old problem of photosynthesis which is the basis of all life has been attacked to yield completely new knowledge which is in sharp contrast to the previously held views. We now know for sure that the oxygen of photosynthesis comes from water and not from carbon dioxide and the first reaction involved in the photosynthesis is to produce a compound containing a carboxylic group and not an aldehyde. How this initial product is then converted to complex substances is being tackled also. Everyone knows that photosynthesis is strikingly inefficient. If by understanding the process scientists are able to increase the efficiency, the whole problem of food shortage for the growing population of the world would be solved at one stroke. Legumes fix nitrogen from the air while non-legumes do not—this was the age old knowledge but evidence has been presented now to show that non-legumes also can fix nitrogen. It is most important for us to know for efficient use of fertilizers as to how much of a fertilizer nutrient, say phosphorus, applied to a crop is coming from the fertilizer and how much from the soil, how much of the fertilizer applied one season will remain effective for use of subsequent crops, the efficiency of utilization of different fertilizers supplying the same nutrient by various crops

under varying soil conditions, at what stage in the growth cycle of the crop, a nutrient is taken up most and lastly where and how to put the fertilizer in relation to the crop so that maximum utilization might take place—questions which are of vital importance for a better soil crop fertilizer management. Radioisotopes are being successfully used to solve these practical problems. When it is known that many of the soil-fertilizer problems enumerated above were impossible to solve in the usual way, one can understand the usefulness of the new tool. As a tracer radioisotopes are also being used for study of fertility status of soils, exchange reactions in soil, evaluation of liming materials, measurement of growth and activity of plant root systems, and chlorosis of plants. In plant physiological studies work is in progress in ion accumulation and depletion, transport of solutes within the plant, sulphur utilization by plants. In animal nutrition and physiological studies work is in progress on appraisal of the availability of calcium and phosphorus in various animal feeds, supply of sulphur from herbage for milk production, supply of iodine for thyroid function, urea as a supplementary source for nitrogen and mechanism of formation of milk in cows. Cobalt, copper, manganese and molybdenum are essential for the nutrition of animals and animals lose conditions and die if the food contains too little of these elements. The use of radioactive isotopes in the feed as a tracer, is enabling scientists to find out the distribution of these elements in the organs, their role in the synthesis of vitamins and enzymes and is thus leading to a clearer understanding of the problems of feeding to help get healthy stock. On the side of plant protection against insects, pests and diseases radioisotopes are proving of value as markers or tracers again. Insects can be made radioactive by feeding at larval stage or injecting a minute amount of radioactive material into the adult insect or by other suitable means. By detecting and tracking such labelled insects data on their lives and habits are being accumulated to develop new and more deadly methods of wiping out these pests. By spraying crops with insecticides, labelled in the same way as fertilizers, and following the tracer technique, the effectiveness of spraying, amounts of insecticides that remain effective after periods of time, the amounts absorbed by plants and the insects to be killed are being found out. This will help in the formulation of cheapest and most efficient insecticides. Radioactivity is helping to produce mutation in corn smut and many other plant disease fungi with the object of finding out the maximum virulence that nature can put in these pathogens and in developing better fungicides. This is how scientific knowledge is being accrued through the use of radioisotopes which will ultimately help in better soil-fertilizer-crop management and better insect and disease control programmes and thus increase the agricultural production.

### *Use of Atomic Energy in Agriculture*

by

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Within the course of ten years since the production of the first atomic weapon, scientists have made remarkable progress in utilising atomic energy and atomic materials for peaceful purposes, in

medicine, industry and in Agriculture. The United Nations Conference on the peaceful uses of Atomic Energy held at Geneva in August 1955, has left no doubt that atomic power has immense possibilities, not only for wholesale destruction but also for the good of every country in the world. Leading countries of the world, like the United States for instance, have made available radioactive material for research work in less developed countries. The United States Atomic Energy Commission has made nearly 4,000 shipments of isotopes to 660 laboratories and hospitals in 46 countries.

In Agriculture, atomic materials are used mainly to unravel obscure points that have so far defied elucidation in respect of Crop growth and diseases of plants and animals. The recent spurt of Research (mostly in countries other than India) with the aid of radioactive isotopes, on elements needed by plants has advanced our knowledge on a number of aspects in plant physiology, biochemistry and fertilizer Research.

The absorption of nutrient elements by croplants under field conditions has been favourite subject of study by Radio active isotopes. Essentially, the method consists in mixing a small known amount of radioactive nutrient element with the indigenous plant nutrient and from the plants grown in such a medium, the plant parts are analysed for both indigenous and tracer elements, to determine the efficiency of fertilizer uptake. The method gives us an idea as to how much is taken up from the added fertilizer and how much from the nutrients originally present in the soil. Extensive studies have been made by this tracer technique on phosphorus intake, in several countries. Russian workers have found that phosphate fertilizers supplied as foliar sprays were far more effective than if the phosphate was supplied to the soil. Phosphorus absorption varies of course from crop to crop, but British and American Workers have proved that the period of greatest absorption also varies with the crop, so that the tracer technique would be helpful in determining both the quantity of fertilizers to be applied to different crops as well as the best time to supply them.

In Japan, when sulphuric acid was in very short supply just after World War II, the possibilities of using fused magnesium phosphate were explored very neatly and conclusively with the aid of radioactive (P) Phosphorous added to magnesium phosphate. Japanese workers have also established, by this tracer technique that in hens, the calcium taken in the feed goes directly to form the egg-shell, but that the other elements constituting the rest of the egg are spared from the tissues of the hen's body. Tracer technique has been employed with great benefit in the study of Photosynthesis, and also in the development of new agricultural strains and varieties that can resist diseases and produce more of food, fat and fibre in abundance. It can also play an important role in the preservation and storage of fruits, and food products without spoilage. With the progress of research in Atomic energy a time may come when, by improved ways of growing crops, by effectively combating insect pests and plant diseases, correction of nutrient deficiencies, and by the creation of new types of crop plants to yield larger harvests of better quality, the dread of dearth and famine may disappear from the Earth, ensuring abundance for all.

For Indian Crops and Soil Conditions, it must be admitted that hardly any work at all has been done in this direction so far and there is an urgent need to start work at different centres to elucidate, by the aid of tracer techniques and other atomic methods—the various regional problems that exist in plant nutrition, fertilizer research, disease resistance and the correction of nutrient deficiencies.

*Use of Atomic Energy in Agriculture*

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*Use of Radio Active Isotopes as Tracers*

In recent years increasing uses of atomic materials are being made as tools for research in the field of Agriculture. Radio active P is being mixed with fertilisers for determining the best time of application and the actual quantity of Phosphorus needed for the plants. Radio active Nitrogen will play an important role in understanding the mechanism of Nitrogen fixation by leguminous plants. In the production of disease resistant strains of various crops, radiation may prove a handy tool. At present, there is a well equipped laboratory at the Indian Agricultural Research Institute, New Delhi, for the radio active tracer work. As the State Agricultural Research Institutes have no such facilities at present, it would be desirable for the central institute to collaborate with the State Departments and train personnel in any research problem where the special technique of Radio active indicators is likely to be of value.

*Use of P<sup>32</sup> in Agriculture*

by

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INTRODUCTION

The element phosphorus is so basic to the whole question of crop production that in Agriculturally advanced countries probably no other subject in the field of soil fertility has received more attention than the phosphorus problem in its various soil-plant and soil-animal relationship. Some idea of the volume of the work carried out in this field may be obtained from the fact that in U.S.A. alone in the 15 year period 1935-1950, 673 major articles covering this field were published. As a result of intensive research programme carried out by the soil scientists the United States total annual consumption of phosphate fertilizers on the P<sub>2</sub>O<sub>5</sub> equivalent basis rose from only 246,000 tons in 1900, to 2,434,000 tons in 1950. In the U.K. 50% increase in the consumption, in post-war years as compared to pre-war years, has been estimated. In India unfortunately this subject has not so far received as much attention of our soil scientists as it deserves.

The phosphorus nutrition of the crops is a complex and broad problem. Unlike nitrogen and potassium, where most of the applied nutrients can be accounted for by the uptake of crop and losses due to leaching, in the case of phosphorus only a small fraction (5-20%) of the applied phosphorus is utilized by the crop in the year of application; and very little, if any is leached away under normal farming conditions. Most of it is fixed or retained by the soil in narrow region where the fertilizer comes in contact with the soil.

To understand and solve some of these complex problems new methods have been developed. Of these, the radiotracer technique has proved immensely useful and has been widely adopted in some countries, particularly in U.S.A. This short review is presented with the object of drawing the attention and creating interest of our soil scientists in this technique, which places at their disposal, an accurate and interesting method to tackle some of the fundamental problems in Agriculture. Although very recently radioactive isotopes of elements like Carbon, Nitrogen, Cobalt, Calcium have been introduced in Agronomic research but so far attention has mainly been focussed on the use of  $P^{32}$ . In the following brief review, therefore, reference is made only to a few lines of work in which  $P^{32}$  has been employed in Agronomic research.

Field and pot experiments using  $P^{32}$  tagged phosphate fertilizers have mainly been conducted to study:—

- (i) Uptake of applied phosphorus under different soil and climatic conditions by various crops.
- (ii) Evaluation of different methods of placement for different crops.
- (iii) Relative value of different phosphate fertilizer materials as a source of phosphorus for different crops.
- (iv) Estimation of the phosphorus fertility status of the soils.

#### *I. Uptake of applied phosphorus under different soil and climatic Conditions by various crops*

Although utilization of applied phosphorus has been a popular subject of investigation for a long time, the use of  $P^{32}$  tagged phosphate fertilizers has enabled the soil scientist to make direct and more accurate determination of the phosphorus taken up by the plant from different sources. The results of green-house experiments using radioactive superphosphate, by Dean *et al* (1947) and field studies by showed an increase in the uptake of fertilizer as well as soil phosphorus with the increase in the rate of application. Strzemienski (1948); using  $P^{32}$  found that on two phosphorus deficient soils from New Zealand, plants that received phosphorus fertilizer took up three to eight times as much soil phosphorus as did the control. Dion *et al* who likewise used  $P^{32}$  in their studies concluded that a greater uptake of soil phosphorus is likely to occur when small amounts of fertilizer are used but a lower phosphorus uptake from soil when large amounts are used. The present writer conducted experiments in U.K., using  $P^{32}$  with Potato and Oat crops, using 0.25, 0.5 and 1.0 Cwt. P<sub>2</sub>O<sub>5</sub> per acre rates of application and found that amount of P<sub>2</sub>O<sub>5</sub> applied exerted a major influence on the amount of P<sub>2</sub>O<sub>5</sub> absorbed from the fertilizer and the soil. As the application of phosphorus increased the total amount of phosphorus absorbed by the plant also increased. In phosphate deficient soil, usually the amount almost doubled with the initial increase i.e., from 0.25 to 0.5 Cwt. rate but only a 50% further increase resulted with a further doubling (1.0 Cwt.) of the rate of application. It was also found that though the plant tissues showed a higher percentage of P<sub>2</sub>O<sub>5</sub>, it was not always accompanied by corresponding increase

in the yield. Again, though the number of pounds of  $P_2O_5$  absorbed increased the recovery of applied phosphorus decreased with the increase in the rate of application.

## II. Evaluation of different methods of placement

The method of application of fertilizers has recently attracted a good deal of attention as a means of reducing the fixation and improving the positional availability of applied phosphorus. Developments in use of radio phosphorus in field investigations has given great impetus to research on placement methods. Until  $P^{32}$  tagged phosphate fertilizers came into use it was not possible to evaluate clearly the relative or actual amounts of phosphorus obtained by the plants from different placements. Recent studies using radioactive fertilizer by Stanford *et al* (1949) with Oats and Alfalfa and Nelson *et al* (1949) with cotton and corn have clearly shown that crops generally derive a greater amount of phosphorus from localized placement, than from broadcast applications. The studies reported by Hall (1951) using a technique involving injections of small quantities of radio phosphorus at various positions in the soil with respect to the plant, revealed that corn relies heavily on 3" layer of the soil during the first four weeks of growth, but by the end of seven weeks, the 8" and 13" horizons contribute substantially to the growth of the plant, Drake and Stewart (1950) reported a significant positive correlation between 3" and 8" depth drill placement for alfalfa.

From the above it is clear that experiments with radio phosphorus with different crops with multiple band placement versus placement at one depth would be invaluable in determining the best method of applying fertilizers to meet fully the need of the crop throughout the period of growth.

## III. Relative value of different phosphate fertilizer materials as source of phosphorus

Different phosphate fertilizer materials tagged with  $P^{32}$  have been produced and used in U.S.A. Tagged phosphate fertilizers that have produced and tested include ordinary and concentrated superphosphate, superphosphate ammoniated to different levels of nitrogen, tricalcium phosphate, dicalcium phosphate, calcium meta phosphate, ammonium phosphate, and nitric phosphate. These sources have been used under field and green house conditions. Studies reported by Hall (1949), Stanford and Nelson (1949) and Blaser and McAulliffe (1949) consistently showed that as much or more phosphorus is absorbed from applied superphosphate as from any other source tested. Calcium meta phosphate tended to furnish more phosphorus than either di or tricalcium phosphate but in most cases some what less than superphosphate. On neutral and alkaline soils Dion *et al* (1950) found that monoammonium phosphate supplied significantly larger amounts of phosphorus to wheat and barely than did monocalcium phosphate, and that dicalcium phosphate was inferior to either of these sources Olsen *et al* (1950) also found that dicalcium phosphate furnished less amount of phosphorus, to wheat, barley and sugarbeet, calcareous soils than did superphosphate. Their results further showed that alfalfa and potatoes absorbed about equal amounts of phosphorus from calcium metaphosphate and from super-



phosphate. Tricalcium phosphate generally furnished less phosphorus to plants than did the other sources although occasionally it furnished more than dicalcium phosphate.

#### IV. Estimation of phosphorus fertility status of the soils

From time to time various methods have been suggested and employed to measure the fertility status of the soils. Although extraction methods still remain the main procedure by which the fertility status of the soil is determined because of the ease and rapidity by which large number of samples can be handled; yet it has long been realised that the plant itself would possibly provide a better index of the fertility status of the soil than chemical extractants. Therefore various biological methods have been suggested and used for this purpose. As early as 1912 Mitscherlich suggested a pot method for prediction of the fertility status of the soils on the basis of growth. Yield, he established was a function of the available nutrients in the soils. Early attempts to use plant composition as an index of soil nutrient supply proved impracticable (Hall, 1905). More recent investigations have, however, established that analysis of a particular part of a plant at a definite stage of growth can be used to give useful information on the measure of the phosphorus supply of the soil. More recently Fried and Dean (1952) have found that radio-chemical data can be used to calculate the phosphorus supply of the original soils. They have suggested the following mathematical expression for this relationship:—

$$\frac{A=B(1-Y)}{Y}$$

Where A = amount of soil phosphorus supply.

B = amount of fertilizer phosphorus supply.

Y = fraction of the phosphorus in plant derived from fertilizer.

They assume that a plant presented with two sources of phosphorus, namely the soil and the fertilizer will absorb phosphorus from each in direct proportion to the respective supplies. Since B is known and Y can be determined by radio-chemical analysis technique, the value of A can then be calculated from this equation. The value thus obtained represents the available soil phosphorus in terms of fertilizer added and therefore in this respect corresponds to the values obtained by Mitscherlich method, generally termed as "b" value.

The practical advantages of the radio tracer technique are obvious. Firstly as the plant itself is used as indicator the results could be expected to be more reliable than those obtained with the use of chemical methods. Secondly as only a few pots will provide the necessary data, a much larger number of soils could be handled at the same time than is possible with Mitscherlich method. Thirdly this method could be used as a standard to check the accuracy of the results obtained by chemical methods.

However, as yet, the technique is comparatively new, and great deal of work remains to be done before the accuracy of the method for predicting the phosphorus status of the soils is established. Preliminary studies conducted in U.S.A. have, however, shown the technique to be sound. The author conducted green-house studies with Oat crop, with 11 soils of varying fertility status in U.S.A. in 1954, to compare the values obtained by the chemical and radiochemical methods. The values obtained showed close correlation except in calcareous soils.

## BIBLIOGRAPHY

1. Blaser, R. E. *et al* . . . . . 1949 Utilization of phosphorus from various fertilizer materials I. Orchard grass & Ladino clover in New York Soil Sci. 68:145—150.
2. Dean, A.L. *et al* . . . . . 1947 Application of radioactive tracer technique to studies of phosphatic fertilizer utilization by crops. Soil Sci. Soc. Amer. 12: 107—112.
3. Dion, H.G. *et al* . . . . . 1947 Experiments with radiophosphorus on the uptake of phosphorus by wheat. Sci. Agr. 29: 167—162.
4. Dion, H.G. *et al* . . . . . 1950 Tracer studies with phosphate fertilizers Canadian Chem. and Process. Inds., Nov: 1—7.
5. Drake, M., and Stewart, E.H. . . . . 1950 Alfalfa fertility investigations in south Carolina. Soil. Sci. 69: 459.
- 6.\*Fried M., and Dean, L.A. . . . . 1952 A concept concerning the measurement of available soil nutrients. Soil Sci. 73: 263—271.
7. Hall, A.D. . . . . 1905 Analysis of soil by means of plant. J. Agri. Sci. 1: 65—89.
8. Hall, N.S. . . . . 1951 Studies of root distribution of different crops through the use of radiophosphorus & its relation to fertilizer placement. In Agronomy monograph IV, N.Y. Academic Press Inc.
9. Hall, N.S. *et al* . . . . . 1949 Utilization of phosphorus from various fertilizer materials II. Cotton and Corn in North Carolina. Soil Sci. 68: 161—156.
10. Mitscherlich, F.A. . . . . 1912 In article by Dean L.A. *et al* Agronomy monograph Vol. IV: 43—58. N.Y. Academic Press Inc. 1953.
11. Nelson, W.L. *et al* . . . . . 1947 Application of radioactive tracer technique to studies of phosphatic fertilizer utilization by crop II. Field experiments. Soil, Sci. Soc. Amer. 12: 113—118.
12. Olsen S.R. *et al* . . . . . 1949 Utilization of phosphorus from various fertilizer materials IV. Sugarbeet, wheat & barley in Colorado. Soil Sci. 68: 163—169.
13. ————— . . . . . 1949 Utilization of phosphorus as affected by placement II. Cotton and Corn in North Carolina. Soil Sci. 68: 137—144.

14. \_\_\_\_\_ 1950 Utilization of phosphorus by various crops as affected by source of material and placement, Colorado Agri. Expt. Sta. Bul. 42.
15. Stanford, G. *et al* 1948 Utilization of phosphorus from various fertilizer materials III. Oats & Alfalfa in Iowa. Sci. 68:157—161.
16. Strzemienski, K. 1948 Soil phosphorus uptake as influenced by phosphatic fertilizer Nature, 162:932.
17. Verma R.D. 1954 Residual effect of phosphate fertilizers in three Iowa soils as shown by Chemical and Radiochemical studies M.S. Thesis Iowa State College Ames. Iowa.
18. \_\_\_\_\_ 1956 A study of the uptake of phosphorus by the Potato (*S. tuberosum*) Ph. D. Thesis. University of Edinburgh.

### *Use of Atomic Energy in Agriculture*

by

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Recent world events have focussed a great deal of justified attention on the possible application of atomic energy to peaceful pursuits aimed at the betterment of man and his environment. That Agriculture takes a very prominent place among such pursuits is becoming increasingly evident from results of investigations on plants in which radioactive isotopes or nuclear radiations have been used. Radiation methodology offers great promise for the solution of a great many problems in different branches of agricultural research, both of fundamental and practical nature. This may be illustrated by a few typical instances. Use of fertilizers is one of the best means of increasing agricultural production, but any judicious use of fertilizers needs a thorough background of knowledge regarding the available nutrients in various soils the relative response of various crops on such soils to the nutrients applied and the relative amounts of nutrients not utilized by the plants. Such knowledge can be rapidly obtained by the use of radio-tracers.

One of the chief aims of botanical research in agriculture is the breeding of crop varieties which give improved yields, and at the same time possess important agronomic, nutritional and other economic characteristics. That atomic radiations are powerful tools in such work is clearly evidenced by work in other countries, as for example, the researches of Gustafsson and others on mutations in barley and other crop plants. By the application of classical methods established by Hevesey, Schoenheimer, Rittenberg and others to the study of plant physiological and biochemical investigations valuable information has been obtained in recent years. Among these have to be mentioned the brilliant researches of Calvin and others on pathways of photosynthesis in green plants. Modes of uptake and translocation of nutrient elements from soils, foliar absorption of sprayed chemicals and herbicides and their distribution and retention within plants have also been studied by such methods. Another aspect of practical significance is the use of radiations to prevent sprouting in stored seed material, particularly tubers.

The study of insect pests which cause great damage to crop plants pre-supposes basic knowledge regarding the life histories and habits of insects. Many problems in this field, for example, distribution from breeding sites, flight habits, dispersion, food relationship infestation patterns, longevity in the field and disease transmission have been investigated with the aid of radioactive tracers. Similarly, effects of insecticides, their distribution within insect bodies, the tissues which are not affected by them and their retention or otherwise in both insects and plants have been studied using radio-isotopes. A most interesting and novel application of radiation genetics in this field, namely, the checking or destruction of parasitic species by releasing large numbers of irradiated individuals, is afforded by the work of Bushland and Hopkins on the screw-worm fly *Callitroga americana*. The irradiated individuals give rise to dead zygotes on mating with wild ones. The few survivors in turn kill a large proportion of offspring in the next generation by the same process.

The necessarily brief account given above indicates the usefulness of radiobiological methods in some aspects of agricultural research. Similarly, in the solution of plant pathological and mycological problems, which are of immediate interest to us, atomic energy can be put to varied uses. One of the chief problems faced by the plant pathologist and the breeder is the frequent failure of his improved varieties of crop plants due to new and more virulent races of plant pathogens which continue to appear in nature. In such situations even with a proper re-orientation of breeding programmes it takes a long time to obtain a more resistant variety. Within that time the pathogen is practically free to inflict the maximum damage it can to the farmer's economy. It has been suggested that if virulent races of the pathogen can be artificially produced and used under well-controlled environments it should be possible to forestall what would occur in future. As a result, the breeder may get more time to select proper genetic material and get better varieties. Though such work is attendant with certain technical difficulties, it is well worth a trial in organisms like the wheat rusts and the sugarcane red rot fungus which are of great importance in our country. As an additional line of approach to this problem, attempts could be made to induce greater disease resistance in the varieties of crop plants themselves. An instance of great interest here is the recent work of Konzak in U.S.A. in inducing stem rusts and the sugarcane red rot fungus which are of great importance. By such means the plant pathologist can help the breeder in obtaining very desirable genetic material at his own doorstep instead of hunting for such material by extensive surveys elsewhere.

The work of Hollaender and other investigators in the production of strains of molds and other microorganisms giving increased yields of antibiotics and other economically important chemical substances afford examples of other types of advantages which may be gained by induction of mutation by radiations. Commercially valuable changes in colour, growth rate and fruiting time have been similarly induced in mushrooms. Undoubtedly, several mutagenic agents other than radiations can be used in all this work, but available evidence has substantiated that radiations are most satisfactory in this regard. As pointed out by Muller in a recent survey of the

field of radiation genetics these new tools have immense potentialities in what may be termed artificially accelerated and rationally guided evolution. Recent work has shown that fungi, bacteria and other micro-organisms afford the most suitable material for such investigations aimed at obtaining strains of microorganisms capable of producing foods, food accessories and pharmaceuticals. Further, by successive mutations one should be able to adapt already parasitic organisms to new hosts or even to convert free-living ones into parasitic ones so as to make use of them in the biological control of harmful parasites. Bacteria tagged with P., have been used to determine the distribution and retention of air-borne micro-organisms in studies of respiratory infection. By an extension of such procedure and with proper techniques it may be possible for us to examine and substantiate our present concepts of disease transmission of rusts and other diseases in our country.

Other important problems, some of which have already been investigated in other countries, include the study of the metabolic derangements in plants caused by plant diseases. Using radioactive isotopes it has been demonstrated in certain diseases caused by fungi and viruses that the pathogens lead to an accumulation of certain elements needed for plant growth in the diseased tissues. How this selective absorption of plant nutrients interferes with the normal physiological pattern of the host can be rapidly and conveniently studied only by the use of radioactive isotopes. Such substances can also be used for the study of the mechanisms by which plant pathogens induce wilting in plants—whether the symptoms are due to the production of *vivo* toxins or due to the disturbed translocation of nutrients.

Problems such as the action of fungicides and antibiotics, in particular, their effect on permeability or synthetic processes of cells of test organisms can be studied using labelled sugars, amino acids or other nutrient substances. The work of Gale on the mode of action of Penicillin, and of McCallan and associates on the action of sulphur fungicides are examples. Radiotracers also afford great advantages for research on the uptake in plants of chemotherapeutic substances, thus facilitating the search for systemic compounds that have better disease controlling properties than the presently available formulations.

Radioactive tracers have been used with success to obtain a better understanding of the functions of mycorrhiza in plants. Thus, Melin, Herley and other workers have demonstrated active transport of phosphorus from the fungal sheath into host tissues in pine and beach roots. Tracer methodology can also be used with advantage in several types of investigations on factors contributing to mineral deficiency diseases in plants and the role of trace—or major element nutrition of green plants in the causation of disease by pathogenic micro-organisms.

Turning to more fundamental aspects, by the use of radio tracers one can learn more of the metabolic changes in plants induced by viruses, and mechanisms of virus movement and multiplication in

plant hosts. By the same measure, one can investigate basic physiological and biochemical phenomena in micro-organisms like transformations of nucleic acids, their purine and pyrimidine components, proteins, amino acids and a host of other cell constituents. In fact, a good deal of knowledge in this field has already been obtained by the application of tracer methods to microbial metabolism.

An aspect of considerable practical potentiality is the study of the possible therapy of plant diseases, in particular, internally seed-borne diseases due to fungi and virus diseases of fruit trees, which cannot be easily controlled by known chemotherapeutic measures. Among fungi, for example, we have both organisms which tolerate fairly high levels of radiation and those, like *Phycomyces* sp., which are adversely affected by minute dosages. Such differential effects are known in plants also; several thousand roentgens of external radiation are needed to show visible damage in many plants, but only a few hundred roentgens are sufficient to produce far reaching damage in animals. This offers the hope that in some instances at least it may be possible to destroy internally borne pathogens by irradiation without affecting the plant tissues involved. As a part of such programme investigations will first have to be carried out on the differential effects of particular levels of radiations on fungi, viruses and other disease-causing organisms. Such work has other implications, too. It would give further basic information on the effects of radiation and, perhaps, on the mechanisms underlying differential radiosensitivity or resistance which may be applied to other higher organisms including man, as it is known that several physiological and biochemical mechanisms are common to all living beings. Studies on the effects of different types and dosages of radiations on fungi, bacteria and plant products would also give practical information regarding cold sterilization of laboratory media, soils and other complex substrata. This information is also of value in the preservation of foodstuffs, a field in which already considerable progress has been made by the use of atomic radiations.

Research on some of the aspects mentioned has been recently started at the Division of Mycology, Indian Agricultural Research Institute. One of the important objectives of the work is to afford a better basis for obtaining disease-resistant varieties of crops, wheat and sugarcane in particular, by means of radiation-induced mutations. Other aspects include the study of the differential effects of radiations on plant pathogenic microorganisms and the tissues they invade, study of the uptake of certain antibiotics and fungicides, and physiological investigations on fungi and fungus-induced diseases in plants. Application of radiotracer and other radio-biological methods to mycological and plant pathological research in India is still at its beginning and, as in other branches of agricultural research, is mostly confined to the Indian Agricultural Research Institute. Yet, the advances made in other countries during the last few years and the possibilities outlined above show that much can be accomplished in plant sciences by a planned development of the application of atomic energy. The fact that we will very shortly have nuclear reactors in India will undoubtedly accelerate the pace of such development during the next few years.

## *The role of Radiation in Plant Breeding*

by

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### I. INTRODUCTION

Radiation research as applied to crop improvement was one of the logical consequences of the discovery made soon after World War, I, of the genetic effects of radiation in *Drosophila* by Muller and sometime later in maize by Stadler. It was in Sweden that the first indications of the practical value of this new tool were obtained. Nilsson-Ehle and Gustafsson demonstrated by years of patient and persistent work that higher yields, stiffer straw and earlier ripening types could be produced in cereals by inducing mutations with the help of ionising radiations. After World War II, sources of radiation have become more readily available as a result of the advent of atomic energy and it is now possible to undertake large scale mutation research.

### II. TYPES OF RADIATION AVAILABLE

Prior to the use of atomic fission, the radiations used in mutation work were electro-magnetic. Now, several high energy particle radiations are also available. The types of radiations commonly used in mutation research (besides X-rays and Ultra-violet rays) are as follows :

(i)  $\beta$  *Particles*.—These are electron beams emitted by many radioactive isotopes. Among the isotopes commonly used in cytogenetical work are Phosphorus 32, Sulphur 35 and Carbon 14.

(ii) *Neutrons*.—Fast neutrons (particles having a mass of 1 but carrying no charge) are usually obtained either from a cyclotron or by the bombardment of beryllium with particles. Neutrons do not produce ionization directly but knock out protons from the nucleus of the atom they traverse. Slow neutrons produced in an atomic reactor do not eject a proton but are captured by the nuclei through which they pass, thereby producing a new nucleus which is radioactive and will emit  $\beta$  or  $\gamma$  rays. The biological action of neutrons appears to be primarily on the nuclei whereas other radiations besides affecting the nuclei also cause physiological damage to the rest of the cell constituents.

(iii) *X-rays*.—The ready availability from atomic piles of the radioactive isotope-Cobalt-60 has provided a useful source of pure gamma rays of high energy. This source by virtue of its long half life (5.27 years) is very useful for irradiation of plants on a field scale.

### III. INDUCED MUTATIONS OF ECONOMIC VALUE

With the growing availability of radio-active isotopes for agricultural research, attempts to induce mutations in crop plants have been intensified in many countries. A few of the economically useful mutations that have been isolated during this work are listed in table 1. Swedish workers have distributed for commercial cultivation two mutant varieties—one in white mustard, "Primex",

which produces 7% more oil per hectare than the mother strain and one in peas, "Stralart", which has a seed yield of 5% more than the original variety. From these results, it is clear that the scepticism once expressed against the value of mutation experiments in plant breeding can no longer be considered valid.

TABLE 1  
A list of economically useful mutants in crop plants

Crop	Economic mutants produced	Radiation source	Country
Wheat	Early, stiff strawed types.	X-rays, $^{32}\text{P}$	Sweden.
"	Resistant to stem rust ( <i>Puccinia graminis tritici</i> )	X-rays, thermal and fast neutrons.	Sweden, United States.
"	Superior baking quality, wider range in protein content.	X-rays, Neutrons	Canada.
Barley	Erect, high yielding, stiff strawed, early types.	X-rays, $^{32}\text{P}$ , fast neutrons.	Sweden, United States.
"	Increased drought resistance.	X-rays	Sweden.
"	Mildew resistant spring and winter barleys.	X-rays	Sweden Canada.
Oats	Resistant to <i>Puccinia graminis avenae</i> and <i>Helminthosporium sativum</i> .	Thermal neutrons.	United States.
Groundnut	High yielding types, better adapted to mechanical harvesting and resistant to leaf spot.	X-rays	United States.
Maize	Resistant to <i>Helminthosporium tauricum</i> .	Thermal neutrons, Gamma radiation.	United States.
Mustard	Higher oil content	X-rays	Sweden.
Peas	High yielding types	X-rays	Sweden.
Antirrhinum	Tetraploid sectors	Thermal neutrons, Gamma radiation.	United States.
Carnations	Red flower types.	Gamma radiation	United States.

#### IV. MUTATION RESEARCH AT THE INDIAN AGRICULTURAL RESEARCH INSTITUTE

In the course of the plant breeding work in progress at the Division of Botany, Indian Agricultural Research Institute, during the last 51 years, many naturally occurring mutants have been isolated in various crops and their economic use evaluated. Research on the artificial induction of mutations has however been taken up only recently. The mutagenic agents that are presently being used are  $\beta$  rays from  $^{32}\text{P}$  and  $^{35}\text{S}$  X-rays, Ultra-violet rays of various wave lengths and Fast Neutrons. It is expected that a gamma field



radiation unit may also become available in due course, which will facilitate radiation of plants under natural conditions of growth and at different stages of development. The work so far done and the results obtained are summarised in Table 2.

From the data presented in this table and from the fundamental cytological research on the effects of radiations on plant chromosomes carried out at the Division of Botany, the following general comments can be made.

(1) The cytological effects of a given dose of Beta or neutron or X-ray radiation vary from crop to crop. While some crops like wheat are easily affected, crops like paddy are less sensitive to radiation damage. In general, it appears that plants with large chromosomes are more radio-sensitive than plants with small chromosomes. Some plants like linseed appear to be extremely insensitive; Swedish workers have also reported that linseed and mustard are highly resistant to the actions of X-rays and pile neutrons, for reasons as yet unknown. Possibly, the presence of high oil percentage in these seeds has a buffering effect. Standardisation of dosage thresholds for each crop will hence be an important pre-requisite in mutation work.

(2) Polyploid species within a genus tend to be less sensitive than diploid species. This is because a change in one locus or chromosome is effectively suppressed or buffered by the chromosomes in the other genomes of a polyploid. It will be seen from table 2 that the cytological effects of beta radiation decrease from the diploid to the hexaploid wheats. In the case of Neutron treated material however, the results are reversed. Nearly all the 42 chromosomes in bread wheat are affected in a high proportion of cells; the treatment does not produce any adverse effects on cell metabolism or cell division with the result that the cells continue to grow and differentiate normally although the chromosomes have been drastically affected. This observation provides hope that many new mutations can be produced in the bread wheats by neutron radiation, some of which may prove to be of economic value.

(3) Neutron radiation exhibits certain specific properties not found in the other types of radiations. We have thus observed— (a) neutrons primarily inhibit root growth in contrast to beta rays which affect roots as well as shoots; this is probably because the concentrated meristematic zone of a root is particularly sensitive to nuclear damage; (b) in variegated cells occurring in neutron treated cotton plants, the cells in the chlorophyll deficient regions are normal and grow further in spite of a total lack of plastids; and (c) a localised chromosome breakage may be caused with the result that certain types of mutations may be expected to recur.

(4) Mutation research, to be successful from the economic point of view, should be very broad-based and should be planned on the basis of handling large populations. The work of Gustafsson in Sweden on barley and other cereals showed that about 1 in 10 offspring of irradiated seeds carried some definitely recognisable recessive mutation. Among these mutations, something of the order of 1 in 800 were found to be of economic importance. Thus the

plants had to be bred or inbred on a considerable scale and a multiplication of about 8000-fold was necessary before the original numbers were re-established after the incorporation of the mutation in the strain. The wisdom of large populations in a radiation breeding programme is also evident from the outstanding success achieved by Dr. W. C. Gregory of the North Carolina Experiment Station in the breeding of superior varieties of groundnut by the induction of mutations. Dr. Gregory irradiated with X-rays 100 lbs. of seeds and found among the 975000 X<sub>2</sub> plants grown, a few that gave 30% more yield than the parent strain and some that were better adapted to mechanical harvesting and were resistant to a serious leaf spot disease.

## V. CONCLUSIONS

(1) The advent of atomic energy has facilitated the undertaking of large scale mutation research. The potentialities for creating new variation which will be useful either directly or in breeding work appear to be very great, judging from the results achieved in a short period in Sweden and the United States.

(2) Mutation research besides being a highly skilled and specialised job, will also depend for its success on the size of the populations handled, since the rate of mutations even under radiation is only a few percent and relatively few among the induced mutants will have any practical value. It therefore follows that such research can be undertaken with some prospect of achieving economic results only in centres where large scale plant breeding work is under way.

(3) Work at the Botany Division, Indian Agricultural Research Institute has shown (a) different crops respond differently to a unit dose of radiation, large chromosome plants in general being more sensitive than small chromosome ones; oil seed crops appear to be particularly insensitive to radiation. (b) Radiation with <sup>32</sup>P produces very early flowering in the year of treatment. (c) Neutron radiation appears to be particularly suitable for inducing mutations in polyploid plants like the bread wheats, since it acts selectively on the nucleus. Thus, extensive aberrations leading to new recombinations in the genomes can be effected without lethality being a consequence. (d) Standardisation of dosage thresholds for each crop involving observations on seedling lethality and cytological effects will be an important pre-requisite in mutation work.

(4) In planning mutation research in India, it will perhaps be advisable to follow the examples of Sweden and the United States, where centralised sources of radiation have been set up for the benefit of research workers throughout the country. Since mutation work has an intimate relationship with plant breeding, it would be appropriate that such work is entrusted to an Agricultural Institute which possesses the necessary facilities. This procedure, while meeting the needs of the entire country, will in the long run prove to be the most efficient and economical, both as regards the utilisation of expensive equipment and the building up of a specialised and skilled staff.

TABLE NO. 2  
Mutation work in progress at the I.A.R.I.

Crop and variety	Treatment and dose	Immediate effects		Remarks
		Phenotypic	Cytological	
<i>Triticum aestivum</i> —				
E. 871 (a derivative of Timstein).	Seed treatment 0.04 & 0.4 $\mu$ c. per seed of <sup>32</sup> P.	Treated plants flowered in 52 days (control to 80 days).	Some pollen sterility.	Seeds from treated Plants will be grown during rabi '56.
N. P. 809	Soil application and injection during pre-anthesis stage with 12.5, 25 and 50 $\mu$ c. per plant.	Ear smaller with fewer grains.	Translocations and inversions at the higher doses.	Do.
N.P. 809	Soil application and injection during pre-anthesis stage 12.5, 25 and 50 $\mu$ c per plant + 10000 $\gamma$ of X-Rays.	Do.	Do.	Do.
C. 591	Fast neutrons 16v.	A few seedlings abnormal with curled leaves and stunted growth.	Extensive chromosome breakage in root tips.	Will be studied in detail during rabi, 1956.
C. 591	5 $\mu$ c. per seed of <sup>32</sup> P.	Seedlings normal.	A few chromosome breaks.	Do.
<i>Triticum dicoccum</i> (Khapli).	Fast neutrons 16v.	Seedlings healthy.	About 6 chromosome fragments per cell.	Do.
Do.	5 $\mu$ c. per seed of <sup>32</sup> P.	Seedlings poor.	Many fragments per cell.	Do.
<i>Triticum monococcum</i> (Japanese early).	Fast neutrons 16v.	Some seedlings died.	A mean no. of 2.5 breaks per cell. There is evidence for a localised chromosome breakage in one satellited chromosome.	Plants will be studied in detail during rabi '56.
Do.	5 $\mu$ c./seed of 32P.	Lethal	Extensive chromosome breakage.	Do.
Paddy	2.5, 5.4 and 10.9 $\mu$ c. of <sup>32</sup> P/8 lbs of soil in pots.	No effects.	No effects.	More doses have been given.

Crop and variety	Treatment dose	and Immediate effects		Remarks
		Phenotypic	Cytological	
<i>Cotton—</i>				
M. C. U. 1 320 F Gaorani 12 216-F 134-Co2-M Kalyan.	1. Seeds treated with 50 & 500 $\mu$ c./seed of $^{32}\text{P}$  2. Fast neutrons, 16v, with or without pre-soaking in water.  3. 24000 and 48000 r of X-rays.  4. 1 hour ultra-violet + 24000 & 48000 r of X-rays.  5. X-rays + ultra-violet rays + pre-soaking in water.	1. Some variegated seedlings in all treatments.  2. 216F treated with $^{32}\text{P}$ on 31-3-56 started flowering on 9-5-56. Controls have not flowered until 25-5-56.	Not studied.	Plants are growing in pots and in field. Observations are being recorded.
<i>Tobacco Rustica</i> (N.P. 219) <i>Tabacum</i> (Nattu & Amarelo 5) <i>Rustica-Tabacum</i> hybrids.	Seeds and pollen treated with various doses of X-rays, Fast neutrons and $^{32}\text{P}$ either above or in combination.	Chlorophyll mutants in the hybrid populations vigorous plant growth at 20,000 r.	3-4 breaks per cell. Dicentric bridges at anaphase.	Populations are under study.
<i>Linseed</i> N.P. 12	.04 and .4 $\mu$ c. per seed of $^{32}\text{P}$ .	No effect	No effect.	Higher doses will be tried during, 1956.
<i>Sesamum—</i>				
S.T.6 N.P. 6	Fast neutrons 16v.	Not yet studied.		
<i>Vegetables Tomato</i> Sioux Hyb-10	Fast neutrons 16v.	A few variegated seedlings.	No effects on somatic division.	Plants are under study.
<i>Guar</i> Pusa Sadabahar.	$^{32}\text{P}$ at 2.5 and 10 $\mu$ c. per seed.	A few leaf abnormalities.	Do.	Do.
Do.	Fast neutrons 16v.	Do.	Do.	Do.
<i>Cowpea—</i>				
Pusa Barsati Pusa Phalguni	1. $^{32}\text{P}$ at 2.5 and 10 $\mu$ c. per seed.  2. Fast neutrons at 16v.	In some seedlings one Cotyledon suppressed some leaf abnormalities.	No effects on somatic division.	Do.
<i>Ornamental Plants—</i>				
Marigold	24,000 & 36,000 $\mu$			Do.

*Use of Radioactive Isotopes in improvement of crops*

by

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The conventional methods of improvement of crop plants employ the use of suitable breeding materials collected from different parts of the world; selections made from these are purified and fixed and are as such released for cultivation. Often desirable genes like earliness, higher yield and resistance to diseases, pests, wilt or drought available in these are combined with the indigenous types lacking one or more of these characters by means of hybridisation and promising recombinations are fixed and utilised for cultivation. Grafting and clonal selection is also practised in vegetatively propagated crops. These time-tested methods are, no doubt, very popular but the desirable variations required for the improvement of a crop are produced by nature at a fairly slow rate. According to Moseley-Ressovsky (New Systematics 1942) the rate of spontaneous mutation is of the order of  $10^{-5}$  to  $10^{-6}$  and only a small proportion of these are beneficial to the organism. An increase in the rate of mutation would naturally lead to an increase in the number of useful mutations available to the breeder for improvement of the crop or animal. Muller X-rayed male *Drosophila* in 1927 and Stadler in 1928 treated seeds of barley and maize with both X-rays and radium emanations. Both of them found that irradiation increases the rate of mutation to a level far higher than that reached by nature. Fairly early in the field of work on the production of mutations by artificial agencies, it was established that variations produced are fundamentally similar to the spontaneous ones and in some of the crops as high a proportion as 0.1 to 0.2 per cent. of the induced mutations are beneficial. In barley among the X-ray induced mutants even about 10 per cent. are useful (D'Amato and Gustafsson, 1948). Besides X-rays, a wide variety of mutagenic radiations have been discovered in ultra violet and infra-red rays, gamma rays from the radio isotope  $Co^{60}$ , beta rays from  $P^{32}$ ,  $S^{35}$ , and  $S^{33}$  radiations from radioactive Na and Pb, and thermal and fast neutrons. Though Stadler used radium in his irradiation studies in 1928, the high cost of radium almost prohibited its use and it only since midforties that cheaper radioactive isotopes produced by 'cooking' the elements in atomic piles have become more readily available to the biologist. A number of workers have since been evaluating their utility in programmes of crop improvement. Most of the work has been done by the use of a few important isotope like  $Co^{60}$ ,  $P^{32}$ , and  $S^{33}$  and thermal and fast neutrons from nuclear reactors. Sometimes, as in the case of Bikini atom bomb test of 'Test Able' the live materials have been exposed to radioactive radiations direct from bomb explosions.

$Co^{60}$ .—Important crops like Maize (Singleton 1951, Sparrow and Singleton 1953, Singleton and Casper 1955, Dollinger 1954 and several others), *Nicotiana* (Sparrow and Singleton 1953), Barley (Lawrence 1955), fruit crops (several Swedish workers) and materials like *Datura*, *Tradescantia*, etc., suitable for cytogenetical studies have been treated with gamma rays.  $Co^{60}$  as a source of continuous gamma radiations is considered to be the most suitable of the radio-isotopes for biological purposes as its half life of 5.3 years is fairly

long and the emission of gamma rays is relatively steady during the short periods of a week to 6 or 8 weeks for which the materials have to be exposed. The general effects of continuous gamma radiation correspond to those of X-rays and in some crops like fruit trees where X-ray treatment is often difficult, use of field irradiator producing gamma rays has given good results. In the case of maize, Singleton (1954) noticed that genes showing high rate of spontaneous mutation (like gene R) under treatment with gamma rays showed lower rates of mutation than genes showing low mutability in nature. The threshold limit for inducing mutation showed a linear relationship with dosage. In these studies by Sparrow and Singleton (1953), Singleton and Casper (1954), it was observed that the tolerance limit of different species and genera varied very widely. *Tradescantia paludosa* showed marked effects at only 30 $\gamma$  per day but *Gladiolus* showed only minor effects at 2000r per day even after 42 days. It was also felt that natural polyploids like *Gladiolus* were more resistant to the action of gamma rays than diploids. Other effects due to gamma radiation in maize included abnormal patterns of growth, delay or inhibition of flowering, lethality, stunting, abortion of pollen and reduced fertility. Dimond (1951) studied the effects of gamma rays on disease of some plants and found that in the case of tomato plants 30,000 $\gamma$  units of gamma rays delivered at 80r per hour prevented the formation of galls in plants inoculated with *Agrobacterium tumefaciens*; but the cultures of bacteria subjected to even 50,000r at the rate of 80r per day still retained the capacity to produce normal galls in non-irradiated plants. Cytological aberrations resulting from the treatment consist of fragments, bridges, isochromosomes, etc., and Sparrow and Christenson (1953) found that chromosomes of species of different genera showed a wide range of tolerance and plants like *Tradescantia*, *Lilium*, *Vicia*, etc., with long chromosomes are more sensitive than those with small chromosomes. In *Cannabis sativa*, Moutschen and Govaets (1955) found that the two arms of the heterochromosome X react differently to gamma rays and felt that this may ultimately lead to the experimental control of sex in the species.

Among the other uses of gamma rays, it has recently been established by American workers that sprouting and rotting of potatoes during storage can be checked for at least a year by treatment of the tubers before storage. The cost of this treatment has been found to be as low as 0.7 cents per lb.

Gran after studying a number of sources of mutation concluded that "r radiation from a Co<sup>60</sup> source, finally, seems to offer the most adaptable way of treatment. If strong enough, it can be used for easily controlled and measurable short-time and long-time irradiations without applying any disturbing incisions".

Beta rays from P<sup>32</sup>, S<sup>35</sup>, and S<sup>35</sup>-P<sup>32</sup> S<sup>35</sup> were used by Shebaski & Lawrence (1954) & Larter (1955) on barley, Lesly & Lesly (1955) on tomato (P<sup>32</sup> only), Von Rosen (1955) on *Pisum*, Osborne and Elliot (1955) on wheat and P<sup>32</sup> and P<sup>32</sup> by Micheles (1954) on *Epilobium*. The mutations are mostly similar to those produced by X-rays and most of the workers except Von Rosen have felt that these sources are not as effective as X-rays of Co<sup>60</sup>. Some of the variations in barley, autumn wheat, oat sweet lupin and white mustard obtained by the Swedish workers (Annual report on the work of the Swedish

Seed Association, 1953) by the use of these sources and Na<sup>23</sup> and Pb<sup>210</sup> and Lesley and Lesley (1955) on tomato were found to be of practical interest. Some mutations like those producing viability chromosomal translocations, polymorphis of apparently similar genotypes, differences in the strength of straw, etc., in cereals were of interest. In some of these, the mutagenic agents included Co<sup>60</sup> and thermal and fast neutrons.

*Thermal and fast neutrons and direct exposure to emanations from atomic pile.* Among the first to be exposed to radiations from atomic pile are wheat, barley, cotton and oats and in the first attempt the mutations were generally not useful. Later attempts (Ehrenberg, 1955, Ehrenberg and co-workers 1952, Caldecott and co-workers, 1952) have shown that neutrons act chiefly by directly affecting the chromosome material whereas X-rays affect both directly and indirectly. It has recently been established that fast neutrons from atomic detentions are 14 times more effective in causing mutations than X-rays or gamma rays (Yest, Cummings and Blakeslee, 1954) though the types of mutations produced are almost similar in all the three cases.

In the Bikini bomb test, two varieties of each of barley and wheat and one of oats were exposed to bomb rays and some of these were also treated with X-rays (Luther Smith, 1950). The data on frequency of mutations showed 15 fold increase over the controls in the bombed materials and 10 fold in X-rayed material and in wheat the mutation rate was even as high as 0.8 to 1.0 per cent. The work also showed that segmental interchange in 4n wheat (durum) was higher than that in 2n barley and in X-rayed than in bombed material. In both 4n and 6n wheats, the mutation rate was very high in both X-rayed and bombed material. This observation is confirmed by Mac Key (1954) who worked with 6n wheat (Vulgare) and 2n barley. Stadler (unpublished, quoted by Luther Smith 1950) feels that the rate of mutation polyploids is lower due to the duplication of genes. In the case of cotton, it was noticed that the mutation rate greatly increased and, in general the mutant plants were sterile and dwarf, and the majority exhibited leaf variations. Among all the organs, it was found that the leaf and chlorophyll were the most easily affected and the frequency of mature plant mutants was considerably lower than that of the seedling mutants. Caldecott and co-workers (1952) studied the effect of thermal neutrons and X-rays on the dormant seeds of barley and felt that effect on the extra-chromosomal rather than the chromosomal constituents of the cell. Similar conclusions on the effects of thermal and fast neutrons and those of other radiations have been made by work on several materials like *Datura* (Yest Cummings and Blakeslee, 1955), *Nicotiana* (Scarascia, 1955), *Barley* (Lawrence, 1955) and others. In a comparison of the effects of neutrons and gamma rays on the cells of *Nicotiana tabacum* Scarascia felt that the relation between the frequency of aberrations is linear in the case of gamma rays. Singleton (1954), while studying the dosage relationship of gamma rays with the frequency of mutations, however, found linear relation only in the case of the high doses, but the seed set of treated plants showed inverse relation with dose.

Use of neutrons has produced in the case of Mohawk oat (Konzak, 1954) resistance to stem rust race 7a in addition to a large number of other mutations of leaf, chlorophyll and stem. In experiments at

the University of Minnesota, exposure of seeds of Ajax oats and Lee wheat to radiation from atomic pile resulted in production of a strain of wheat resistant to stem rust race 15B and of a strain of oats resistant to stem rust race 8 though in the case of these resistant mutations, no other differences from normal were observed. Neutrons, it has recently been pointed out by Ehrenberg (1955), unlike X-rays have the additional advantage of not being influenced by the moisture content of the seeds.

Little or no work has been done in our country in this important field and the fruitful results obtained in other countries, should induce us to improve our crops by the use of this new tool. Selections of desirable materials made from these stocks can be purified in a period of 3 to 4 years unlike the usual methods of hybridization which take about twice or even more as long. Apart from X-rays which have proved effective in producing desirable mutations in the case of barley, wheat, oat, groundnut, etc., the use of Co<sup>60</sup> at present, offers the most fruitful source of radiations. When neutrons from the nuclear reactor in course of construction at Bombay become available even Co<sup>60</sup> may eventually be replaced.

#### REFERENCES

1. Brown Meta S. 1950. Cotton from Bikini. Chromosome irregularities from plants from seed exposed to gamma radiation. *J. Hered.* 41 : 115—121.
2. Caldecott, R. S., F. F. Frolik and Rosalind Morris. 1952. A comparison of the effects of X-rays and thermal neutrons on dormant seeds of barley *Proc. Nat. Acad. Sci.* 38 : 804—809.
3. D'Amato F. and A. Gustafsson. 1948. Studies on the experimental control of the mutation process. *Hereditas.* 34 : 181—192.
4. Dimond, A. E. 1951. Continuous gamma radiation supresses crown gall formation in tomatoes. *Phytopathology.* 41 : 10—11.
5. Dollinger, E. J. 1955. Analysis of a mutable system in maize. *Genetics.* 40 : 570.
6. Ehrenberg, L. 1955. Factors influencing radiation induced lethality, sterility and mutations in barley. *Hereditas.* 41 : 123—146.
7. Konzak, C. F. 1954. Stem rust resistance in oats induced by nuclear radiation. *Agron. J.* 46 : 538—540.
8. Larter, E. N. 1955. The use of ionising radiations in the possible utilisation of an Agropyron source of bunt resistance. *Diss. Abstr.* 15. Publ. No. 11847. 664-665.
9. Lesley, J. W. and M. M. Lesley. 1955. The effect in R1 R2 and R3 of treating tomato seeds with X-ray and P-32. *Genetics* 40 : 581-582.
10. Lawrence, T. 1955. The production of mutations by the irradiation of Motelam barley. *Canad. J. Bot.* 33 : 515—530.
11. Mac Key, James. 1954. Neutron and X-ray experiments in wheat and a revision of the speltoid problem. *Hereditas.* 40 : 65—180.
12. Michelis, P. 1954. Uber experimentell induzierte vermutliche Plasmonmutationen. *Naturwissenschaften.* 41 : 22.
13. Moutschen, J. and J. Govaerts, 1951. Action of gamma rays on seeds of *Canabis sativa* L. *Nature.* 172. 350-351.
14. Osborne, T. S. and F. C., Elliot. 1955. Chromosome translocations induced in Triticum x Agropyron hybrids by X-rays. Phosphorus 32 and Sulphur 35. *Amer. J. Bot.* 42 : 646—649.



15. Scarascia, G. T. 1955. (Chromosome aberrations induced in *Nicotiana tabacum* L. by thermal neutrons and X-rays) *Tobacco*. 59 : 257-271.
16. Shebeski, L. H., and T. Lawrence. 1954. The production of beneficial mutations in barley by irradiation. *Canad. J. Agric. Sci.* 34 : 1-9.
17. Singleton, W. R. 1951. Effect of continuous gamma radiation on mutation rate in maize. *Genetics*. 36 : 575-576.
18. Singleton, W. R. 1954. The effect of chronic gamma radiation on endosperm mutations in maize. *Genetics*. 39 : 587-603.
19. Singleton, W. R. and A. L. Casper. 1955. Effect of chronic gamma radiation on somatic mutations in maize. *Genetics*, 40 : 595-596.
20. Smith, Luther. 1950. Effects of atom bomb radiations and X-rays on seeds of cereals. *Jour. Hered.* 41 : 125-130.
21. Sparrow, A. H., and E. Christensen. 1953. Tolerance of certain higher plants to chronic exposure of gamma radiation from cobalt 60. *Science*. 118 : 697-698.
22. Sparrow, A. H. and W. R. Singleton. 1953. The use of radio cobalt as a source of gamma rays and some effects of chronic irradiation on growing plants. *Amer. Naturalist*. 87 : 29-48.
23. Timofeef-Ressovsky. 1948. In *New Systematics* edited by J. S. Huxley.
24. Ven Resen, G. 1954. Radiemimetic reactivity arising after treatment employing elements of the periodic system, organic compounds, acids, electric current in an electrolyte, temperature shocks and ionising radiation. *Sock. Handl.* 8 : 157-272.
25. Yost, H. T., Cummings, J and Blakeslee, A. F. 1954. The effects of fast neutron radiation from a nuclear detonation on chromosome aberrations in *Datura*. *Proc. Nat. Acad. Sci. Wash* 40 : 447-451.

## PAPERS ON SUBJECT No. 2

### *Role of Organic Manures and Chemical Fertilizers in crop production and maintenance of Soil Fertility*

by

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The practice of applying manures to the soil for successful crop production is an old one because it has been very well realized that besides climate and water supply, the essential requirements for the crop production are the supply of plant nutrients and proper soil tilth. It was found out that periodic addition of organic manures like Farm Yard Manure to the soil would keep up the plant nutrient status of the soil and also maintain the soil in good physical condition.

But of late inorganic manures generally called chemical fertilizers have been introduced as an alternative types of manures other than organic ones. The advantages claimed for the use of chemical fertilizers are their easy solubility, immediate supply of plant nutrients, smaller bulk and easy availability as compared to the bulky organic manures.

Thus there can be no two opinions as to the desirability of utilising or addition of manures whether they are organic or inorganic, for increasing crop production and output from our land. The only question remains as to which type of manure should be used so that we increase our crop yields and maintain the fertility status of our soils.

This problem has been very thoroughly thrashed out in the Punjab, and the experiments were conducted from 1943—53 at Hansi, Sirsa, Rohtak, Karnal, Ambala, Jullundur and Gurdaspur on different types of soils. The lines of work adopted were as follows :—

1. Comparative effect of different organic manures on yield.
2. Effect of organic manures in combination with chemical fertilizers on yield.
3. Effect of the application of chemical fertilizers alone on yield and quality of crops and soil.

These lines of work were adopted keeping in view the various advantages and disadvantages claimed for both groups of manures. The summary of results obtained and conclusions drawn crop-wise have been outlined below :—

#### *1. Comparative effect of different organic manures on yield*

*Wheat.*—The organic manures prepared by different methods viz. heaped or trenched town and farm compost gave an increase of about two maunds of grain over control but the difference in yields from different types of organic manures was not significant except that compost invariably gave higher increase than Farm Yard Manure.

The application of farm yard manure upto 10 tons per acre did not appreciably increase the yield and was not even economical. The increase in yield by compost at 10 tons per acre is economical.

The practice of green manuring was not found economical when the cost of green manured crop was taken into consideration. As regards the actual increase in yield conflicting results were obtained ranging from an increase of 2.6 maunds to a decrease of 0.3 maunds per acre.

*Maize.*—The farm yard manure at higher doses upto 15 tons per acre did not appreciably increase the yield to be economical. The increase in yield ranged from 3.3 to 5 maunds per acre by the application of 15-16 tons of farm yard manure per acre.

*Cotton.*—The farm yard manure at higher doses upto 15 tons per acre gives increased yield of about 1.8 to 2.3 maunds per acre. However, the increase was not economical.

*Sugarcane.*—Application of farm yard manure at 8-10 tons per acre gives an economical increased yield of 5.6 maunds of gur per acre. The higher dose of 20 tons per acre was not found economical.

*Groundnut, Gram and Barley.*—The application of farm yard manure at the rate of 6-7 tons per acre was found to give an economical increase in yield of about 1.6—2.6 maunds in groundnut, 1.2—2.0 maunds in gram and 2.0—3.2 maunds in barley.

*Fodders.*—The application of 15 tons of farm yard manure to rapes was found to be economical and on an average gave an increase of 136 maunds per acre of green fodder. In the case of Berseem only very high doses viz. 28 tons per acre of farm yard manure were able to effect just a marginal increase. In the case of oats, jowar and maize fodders the application of farm yard manure at 10 tons per acre was not found economical.

## 2. Effect of organic manures in combination with chemical fertilizers

A number of experiments combining different doses of Farm yard manure and compost with various doses of chemical fertilizer viz., ammonium sulphate and ammonium phosphate were tried. It was found out that when organic manures were combined with artificials, they gave higher yields over control and organic manures alone but this combination was not economical. However the mixture of organic and inorganic manures did not out-yield the chemical fertilizers alone.

## 3. Effect of the application of chemical fertilizers alone

*Wheat.*—All the experiments conducted show that 40 lbs. nitrogen per acre is economical dose for wheat. Doses higher than 40 lbs. nitrogen per acre generally depressed the yield. Further more the application of ammonium sulphate or ammonium phosphate has always out-yielded organic manures and other nitrogenous manures like ammonium nitrate, urea, ammonium sulphate-nitrate supplying equivalent amount of nitrogen. With ammonium sulphate the actual increase in yield obtained varied from 4.7 maunds of grain per acre.

Application of phosphatic fertilizers alone in any dose did not give any favourable response.

However when nitrogenous and phosphatic fertilizer supplying nitrogen and phosphorus respectively were combined or mixed in the ratio of 2:1, the response or increase in yield was the maximum varying from 8.1 to 18.1 maunds per acre. But the best results by the application of phosphatic fertilizers are only obtained when these are applied at depth before sowing rather than broadcasting at the time of sowing or earing.

*Maize.*—The best and most economical dose of nitrogen for maize was 40–60 lbs. per acre and the application of nitrogen in the form of ammonium sulphate or ammonium phosphate was found to be better as compared to all other nitrogenous fertilizers. The average increase in yield by this dose varied from 3.8 maunds to 13.6 maunds.

Application of phosphorus alone was not found to give any response.

Mixed fertilizer supplying nitrogen and phosphorus in the ratio of 2:1 was found to be the best and most economical and gave an average increase in yield of .04 maunds per acre. The application of phosphorus was found to be particularly useful in case of mountain and submountains tracts which are deficient in phosphorus. In these soils as high a dose as 100 lbs. of nitrogen and 100 lbs. of phosphorus resulted in an increased economical yield, the increase being 17.3 maunds per acre.

The application of fertilizers at the time of sowing or half at sowing and other half at the time of first hoeing proved the best.

*Cotton.*—The application of higher doses of nitrogen proved better than lower doses and ammonium sulphate always out-yielded urea, ammonium nitrate, ammonium phosphate and organic manures. However the most economical and best dose was found to be 60 lbs. nitrogen. Cotton did not respond to the application of phosphatic fertilizers whether applied alone or in combination with nitrogen. There was not much difference in yields obtained by the application of fertilizers at the time of sowing, thinning or preflowering. However, application in split doses was found to be slightly better.

The average increase in yield obtained by the application of 60 lbs. nitrogen was 4.4 maunds.

*Sugarcane.*—The application of every high doses of nitrogenous fertilizers proved economical and effective. The best dose was 100 lbs. nitrogen. Ammonium sulphate always out-yielded urea, ammonium nitrate, ammonium phosphate and organic manures like farm yard manure, toria cake, groundnut cake and Mohwa cake. Sugarcane also did not respond to the application of phosphatic fertilizers except in some sub-mountainous tracts which are deficient in phosphorus.

The average increase in yield obtained by the application of 100 lbs. nitrogen in ammonium sulphate was 150–200 maunds of cane or 15–20 maunds of sugarcane per acre.

*Rice.*—Appropriate and most economical nitrogen dose for rice was found to be 40–60 lbs. nitrogen per acre. The application of ammonium sulphate always resulted in higher yield as compared

to ammonium nitrate and urea and organic manures. The actual increase in yield averaged about 6—10 maunds of paddy by the application of 60 lbs. nitrogen per acre.

Application of phosphatic fertilizers alone also resulted in some increased yields but when nitrogen and phosphorus were mixed in the ratio of 1:1 or 2:1 i.e. 50 lbs. nitrogen and 50 or 25 lbs. phosphorus, the results were the best and most economical.

*Groundnut.*—Application of either 25 lbs. nitrogen or 25 lbs. of phosphorus has been found equally good for groundnut. When nitrogen and phosphorus were combined it did not prove better than the single application. The increase in yield obtained came to 7—9 maunds of green pods per acre.

*Berseem.*—Berseem was found to respond to phosphatic fertilizers alone the most whereas its demand for nitrogenous fertilizers was found to be less primarily due to its ability to fix nitrogen from the atmosphere. Therefore the application of 100 to 200 lbs. of phosphorus alongwith 50—100 lbs. of nitrogen in the form of ammonium sulphate was found to give the maximum and most economical yields. The increase in fodder by the application of this mixed fertilizer came to about 150—300 maunds of green fodder.

*Oats.*—The application of 30 lbs. nitrogen in the form of ammonium sulphate was found to give the maximum and economical yields. The increase in yield was 50—60 maunds per acre of green fodder.

*Tobacco.*—Nitrogenous fertilizers were found to increase the yield of tobacco. Increase in yield due to phosphatic fertilizers was not significant and their application was not found to be economical. For *desi* tobacco ammonium sulphate at the rate of 50 lbs. nitrogen per acre was found to be best and most economical. For '*kalkattia*' tobacco the most economical dose of ammonium sulphate found was 150 lbs. nitrogen per acre. The application of nitrogenous fertilizers was also found to greatly increase the nicotine content of the tobacco leaves, thus enhancing its quality.

The application of ammonium sulphate in split doses i.e. one-half before sowing and the rest at the time of flowering was found highly advantageous for '*desi*' tobacco while for '*Kalkattia*' variety, three instalments viz. half before sowing, one quarter at flowering and the rest after completion of flowering were found to be better. The increase in yield obtained in '*desi*' and '*kalkattia*' tobacco leaves was 2½ maunds and 9 maunds respectively.

*Bajra.*—Bajra is mostly sown under barani conditions and under these conditions of dry farming an application of 30 lbs. nitrogen in the form of ammonium sulphate before earing has been found to give an increase of 4 maunds per acre in yield and it was also the most economical.

#### 4. Effect of continuous application of organic manures and chemical fertilizers on the yield of crops and soil

There is a strong prejudice prevailing among the people that the constant use of chemical fertilizers would spoil the land and decrease the yields of crops. These prejudices have not been supported by the experimental data so far obtained.

(1) *Effect of continuous application.*—Ammonium sulphate, ammonium phosphate and farm yard manure were applied to wheat crop every year at the rate of 40 lbs. nitrogen per acre at a number of stations representing different soil types and climatic conditions for the last eight years. The yields obtained are given below in table No. 1.

TABLE NO. 1

*Showing yield of wheat grain in maunds per acre from permanent plots getting ammonium sulphate, ammonium phosphate and farm yard manure continuously every year*

		1947- 1948	1948- 1949	1949- 1950	1950- 1951	1951- 1952	1952- 1953	1953- 1954	1954- 1955
<b>HANSI—</b>									
Control . . .		15.10	13.80	9.28	12.42	16.00	21.00	18.47	17.80
40 lbs. Nin F.Y.M.		16.65	18.50	22.45	11.25	17.00	23.00	19.38	20.30
40 lbs. Nin A/S		27.72	19.95	28.05	28.13	22.25	22.8	24.15	23.10
40 lbs. Nin A/P.		18.17	22.10	24.81	28.62	20.30	25.5	22.57	23.60
<b>JULLUNDUR—</b>									
Control . . .		9.76	20.31	29.37	14.44	21.62	19.66	19.98	8.00
40 lbs. Nin F.Y.M.		13.38	29.75	30.00	15.68	22.11	21.34	22.37	9.80
40 lbs. Nin A/S.		19.47	31.86	31.50	26.21	28.00	25.12	Lodged	22.30
40 lbs. Nin A/P.		17.16	29.44	31.25	24.41	29.09	25.12	Lodged	20.80
<b>KARNAL</b>									
Control . . .		13.35	6.25	13.70	6.95	13.10	10.00	} Experiment dis- continued	
40 lbs. Nin F.Y.M.		15.96	4.93	20.20	7.50	18.70	12.50		
40 lbs. Nin A/S.		17.78	10.80	25.30	15.60	14.20	14.50		
40 lbs. Nin A/P.		..	11.25	22.20	14.45	19.20	15.00		
<b>AMBALA</b>									
Control . . .		13.98	5.90	5.90	8.40	11.05	13.81	11.25	6.9
40 lbs. Nin F.Y.M.		13.50	7.40	7.40	7.60	12.80	8.30	10.25	3.77
40 lbs. Nin A/S.		18.50	10.90	10.90	10.80	13.42	12.62	5.50	5.18
40 lbs. Nin A/P.		17.80	14.60	14.60	12.25	21.18	27.31	15.55	10.40

Almost everywhere the application of chemical fertilizers viz. ammonium sulphate and ammonium phosphate have out-yielded farm yard manure although the same amount of nitrogen was supplied in both the types of manures. It is well known that entire nitrogen in farm yard manure is not available in the first year and therefore it can be said that available nitrogen from farm yard manure was much less than that contained in ammonium sulphate. However one expected accumulative effect of farm yard manure on the crop yields but these results did not show that.

*Effect on soil and crop quality.*—The action of continuous application of ammonium sulphate was studied on the soils. It was found out that in the plains of the Punjab, the pH of soils was lowered by 0.1 after a period of eight years. There was a very insignificant difference in exchangeable calcium content during the same period. The water holding capacity of the soil getting farm yard manure was increased by 1 to 2 per cent. Besides this no other effect on the soil was observed. As far as the quality of the crop was concerned, there was rather an increase in protein content of wheat grains from plots supplied with artificial fertilizers as compared to controlled or plots treated with farm yard manures.

Treatment	Protein percentage	Ash percentage
1. Control . . . . .	8.48	1.92
2. 40 lbs. nitrogen per acre in farm yard manure . . . . .	8.98	1.73
3. 40 lbs. per acre in ammonium sulphate of nitrogen . . . . .	10.93	.86
4. 40 lbs. nitrogen per acre in ammonium phosphate . . . . .	10.93	1.85

These facts indicate that (a) there is no deleterious effect of the application of ammonium sulphate or ammonium phosphate on the soil and (b) that farm yard manure does not release nitrogen in adequate quantities to meet the requirements of the crops and there seems to be no accumulative effect.

(ii) *Residual effect.*—The results show that the ammonium sulphate and ammonium phosphate have got residual effect like farm yard manure. There is a belief that chemical fertilizers supply the nutrients immediately and nothing is left for the succeeding crop. On the contrary it has been sufficiently proved in a number of experiments that ammonium sulphate and ammonium phosphate leave behind residual effect as is clear from the following results.

(a) Fertilizers were supplied to Bajra crop and its residual effect was studied on wheat.

TABLE NO. II

Treatment	Yield of wheat grain in mds. p. a.
Control	8.06
50 lbs. in ammonium sulphate of nitrogen	9.74
100 lbs. N in ammonium sulphate	13.80

(b) Fertilizers were applied to berseem and its residual effect was studied on wheat.

TABLE NO. III

Treatment	Yield in mds. per acre wheat grain	Yield of Berseem in mds./per acre
Control	24.52	703.7
100 lbs. N in ammonium sulphate	26.56	787.4
100 lbs. N in ammonium phosphate	27.72	856.9

(c) Fertilizer was applied to maize and its residual effect was studied on wheat.

TABLE NO. IV

Treatment	Yield of maize in maunds per acre	Yield of wheat in maunds per acre
Control	24.95	16.9
100 lbs. N in F. Y. M.	26.05	17.3
100 lbs. N in ammonium sulphate	31.75	19.7
100 lbs. N in ammonium phosphate	31.15	18.7

Thus the experiments so far carried out in the Punjab have shown that there is no deleterious effect of ammonium sulphate on the soil or on the yields of crops.

In summing up the experimental work conducted in the Punjab on the comparative role of organic and inorganic fertilizers it can safely be concluded that as far as the nutrient supply is concerned, the chemical fertilizers are definitely superior, economical cheap and give more yield per acre as compared to organic manures.



Besides this, fertilizers do not have any deleterious or ill effect on the soil or yield of crops and rather they leave a residual effect which increase the yield of the succeeding crops.

In the Punjab the fertilizer requirements of various crops have been worked out on the basis of detailed experimental work running over a period of about 20 years. The fertilizer schedule for Punjab as recommended by the State Department of Agriculture is as below :—

Crop	Rate of application per acre		Expected increase in mds. per acre	Net gain per acre	Remarks
	Amm. Sul.	Super-Phosphate			
	Mds.	Mds.			
Wheat	1½-2½	(1½-2)	3-8	20-80	A/S & S/P drilled at sowing.
Cotton (American)	2½-3½	..	4-5	80-100	Before flowering. Or half at thinning & half at flowering.
Paddy	1½-2	(1½-2)	4-6	32-48	Two weeks after transplant-ation or drilled at sowing under barau.
Sugar cane	5-6	..	150-200 cane	145-270	Mid June or with first shower.
Potatoes	6	..	50-60	150-200	First earthing up.
Groundnut	1½	..	7-10	75-100	Two weeks after sowing.
Bajra	2	..	5	30-40	At flowering.
Maize	3½-4½	(1½-2)	8-10	50-70	A/S & S/P drilled at sowing
Tea	2½-3½	..	840 lbs.	270	End of February or beginning of March.

*Future Lines of Works.*—It has been attributed that organic manures besides supplying nitrogen, also supply phosphorous, potash and micronutrients. Its addition is also said to improve the physical condition of the soil. As it releases nutrients slowly its effect lasts for longer time as compared to chemical fertilizers and, therefore, it is said to have got a residual effect.

But the work carried out in the Punjab does not support these views. Farm yard manure so far has been considered a nitrogenous manure and, therefore, its application is made on the basis of total nitrogen content. Therefore, such low doses of farm yard manure are not expected to improve the physical condition of the soil. If it is intended to improve the physical condition of the soil, heavier doses shall have to be recommended. The content of organic matter in the soil is conditioned by the climatic conditions and soil texture

and, therefore, it is not possible to increase organic matter beyond certain limits. The constant application of farm yard manure for the last 8 years to plots laid out under different climatic conditions of the Punjab neither could increase the organic matter content of the soil nor it could build up the soil fertility as indicated by soil analysis and crop yields. Therefore, it seems that unnecessarily much value is being put on farm yard manure which it does not deserve. Therefore, to assess the true value of organic manures, the work on the following lines is suggested:—

- (i) Investigations to find out the availability of nitrogen in farm yard manure, compost and other organic manures should be made.
- (ii) Methods should be evolved to increase the availability of nitrogen and other nutrients in the farm yard manure and other organic manures.
- (iii) The application of farm yard manure, compost and other organic manures should be made on the basis of available nitrogen content in these products and not on the basis of total nitrogen content as hitherto done.
- (iv) Investigations should also be made to find out how far the application of farm yard manure and compost can improve the physical condition of different soils developed under different climatic conditions.
- (v) Work should also be conducted to find out whether the increased growth due to the application of artificial fertilizers in the balanced proportions can increase the organic matter content of the different layers of soil and improve its physical condition especially of sub-soil. Work carried out in the Punjab so far shows that it is more essential to improve the structure of sub-soil rather than top soils.

*Role of manures and fertilisers in maintaining soil fertility in Deccan*

by

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Soil productivity is dependent on innumerable factors. Organic matter is considered to play an important role in maintaining soil productivity although it is present in very small quantities in cultivated soils especially in tropics. Its importance is very well realised by the experienced farmers in India. It is just not sufficient if attempts are made only to maintain organic matter content of soil. But it is also necessary to supply all the needed plant nutrients in the form of fertilisers. In Western countries yields of many crops have been increased considerably by the judicious use of fertilisers.

In recent years, however, two schools of thought have developed, one advocates organic farming and the other is of the opinion that without inorganics it is impossible to achieve high yields. It is probably not very practicable to adopt only organic farming although it may be very good because of numerous obvious advantages. At the same time it would not be probably possible to grow crops entirely on inorganics only under fields conditions since it would be necessary

to maintain physical and biological condition of soil by maintaining organic matter at a certain level. It is however not known what is the minimum quantity required to achieve this objective and what role it plays in maintaining the productivity. The exact role of organic matter is not very well understood although it is well known that it helps in improving physical and biological condition of soil and it supplies most of the nutrients required for plant growth. It has been very difficult to assess the role of organic manures exactly. Cooke and Garner (4) after reviewing the work done in England have stated as follows :—

“Organic manures have been used as the cure all of cropping troubles since the dawn of history but it remains difficult to measure and interpret their effects on crop growth. The value of organic manures to farmers must be measured by field experiments on crops. By testing fertilisers at the same time it is possible to estimate how much importance should be given by the organic matter. Increase in crops given by organic matter over and above the increase caused by the added nutrients, may be ascribed to all those effects of organic matter for which improved soil aggregation may be largely responsible.”

In India few attempts have been made to assess the long range effects of organic matter on crop production, but there are very few experiments where the objective has been to study the long range effects of fertilisers on soil as well as on crop production. Some such experiments are in progress at the Sugarcane Research Station, Padegaon. The results obtained so far are briefly summarised in this note.

(1) *Soil changes under continuous irrigation and different manurial practices*

The experiment consists of 3 irrigational treatments (72, 95 and 120 acre inches) and eleven manurial treatments with one irrigational dose (95 acre inches) and a check without irrigation or manure. The manure treatments consist of farm yard manure, sann green manuring safflower cake, sulphate of ammonia, calcium cyanamide, nitrate of soda, superphosphate, bone meal, basic slag, sulphate of potash and muriate of potash. Soil samples upto 2' depth (at an interval of 6") were collected in 1952 and analysed for different fertility constituents. The experiment is laid out in simple randomised block design with duplicate plots. No crop has been grown in these plots and they were kept clean by weeding from time to time.

The results indicate the following:—

1. Dry control has hardly shown any variation in the different constituents from original samples taken in the beginning.
2. *Soil reaction.*—Irrigation has not shown any marked effect on lowering of pH especially with lower doses, although with 120 acre inches per year, trend is towards the reduction of the same. As expected application of ammonium sulphate has reduced the pH and that of sodium nitrate has resulted in increase. Effect of other treatments is of little practical importance.

3. *Calcium carbonate and exchangeable calcium.*—There is increase in irrigation and with the application of F.Y.M. exchangeable calcium is steady and there has been reduction with green manuring, sulphate of ammonia and with safflower cake. Fertilisers like sulphate of ammonia, sulphate of potash and muriate of potash have shown reduction in exchangeable calcium.

4. *Nitrogen.*—There is no noticeable difference between the dry control and continuous irrigation as far as this constituent is concerned. All other treatments have shown increase in total nitrogen content, the highest being with ammonium sulphate, followed by sodium nitrate and calcium cyanamide. Contrary to the belief the loss has been least in ammonium sulphate and it is higher in F.Y.M. Safflower cake also is poor in this respect showing that artificials are better in this respect than the others. Even in the plots receiving only phosphate (particularly) and potassic fertilisers, nitrogen status is better than control.

5. *Phosphates.*—Phosphate status has been naturally high in the phosphate treatments. It has been also high in the plots receiving bulky manures and safflower cake. Out of all phosphatic fertilisers superphosphate has been the best. There has been very little movement of phosphates to lower zones alongwith irrigation water.

6. *Potash.*—Application of potassic fertilisers has resulted in the increase of this nutrient in surface as well as in lower layers showing that there has been some movement of this fertiliser. From potash status point of view F.Y.M. has been next to potassic fertilizers.

7. *Humus and Organic Carbon.*—There is no significant difference in humus content in dry control and irrigation treatments. Application of F.Y.M. and sann have helped in building up of humus content, F.Y.M. being the best in this respect. Safflower cake and green manuring (sann) are better than other fertilisers, where humus is depleted, depletion of organic carbon being maximum in ammonium sulphate treated plots.

8. *Micro-organisms.*—In general total population of micro-organisms has been higher in the plots treated with organic manures than those treated with inorganic fertilisers with the exception of superphosphate, which also has shown higher counts. Plots receiving potassium sulphate and calcium cyanamide also showed fair counts.

It is interesting to note that 95 acre inches treatment has been proved beneficial for microbial activity in January whereas 120 acre inches dose has given better results in April.

## (2) *Soil changes under different systems of continuous cropping and fallowing*

This series has been laid out in light, medium and chopan soils of the farm and it is also in progress since 1932. It consists of 5 types of fallows (dry, cultivated and irrigated, uncultivated, and irrigated, cultivated and unirrigated, cultivated, manured and irrigated) 3 types of continuous cane plantings (Plant cane, Adsali,

Ratoon) with and without manuring and Manjri standard method of cane growing where sann-cane-jowar rotation is followed. Each treatment has a single plot on each type of soil. Soil samples were collected in 1952 and analysed in similar manner as in the previous experiment.

From yield point of view, there has been reduction in the case of continuous cane or ratoon, either manured or unmanured while in the Manjri Standard Method there is reduction in yield only in case of chopan soil. Effect of these treatments on the chemical properties of soil is given below:—

1. *Soil reaction.*—No significant change is produced in light and medium soils but in chopan soils slight reduction is observed in the manured plots. On the contrary in the fallow treatments there is slight increase in the pH as compared to cropped treatments.

2. *Free lime and exchangeable calcium.*—In chopan soils there is slight reduction in free lime reserve in manured and continuously cropped plots but there is no marked difference in exchangeable calcium in any of these plots. In light and medium soils however there is significant difference either in free lime or in exchangeable calcium in any of the treatments.

3. *Humus and organic carbon.*—Manuring maintains the humus status and accordingly organic carbon at high level in fallow as well as cropped plots. In general, cultivation and irrigation has depleted the humus content of the soil in all types of soils. In fallow plots however the humus status is maintained.

4. *Total nitrogen.*—In general, cultivation or irrigation has brought down nitrogen status in fallows but manuring has built up the nitrogen status even in cropped series; in all the three types of soils.

5. *Available P.O. and K.O.*—Available P.O. and K.O are much higher in light soils as compared to other two. Cultivation and irrigation has increased the available P.O. and has maintained the availability of K.O in chopan soils. Similarly in cropped and manured plots P.O. status has gone up but in fallow the effect is not so marked. In medium soils there is definite improvement in available P.O. and K.O due to manuring. In light soils in cropped and manured plots the status of available P.O. and K.O is low as compared to unmanured plots which can be attributed to high yield differences between the two treatments in shallow soils.

6. *Micro-organisms.*—The population of bacteria and actinomycetes was comparatively higher in light and medium types of soils than in chopan soil. In general there has been increase in the population of soil micro-organisms in the manured plots as compared to unmanured plots.

(3) *Soil changes under compost and green manuring in different soil types (Lysimeter studies)*

This series was started in 1938. The object of this experiment to study the relative value of compost and green manuring in maintaining fertility in different soil types and to study the productive

capacity of the six important soils of Deccan (A, B, C, D, F and G), one set is under Cotton-cane rotation, the other under sann-cane rotation. Cotton-cane series received 20 cart loads of compost per acre and it is applied to cane crop. Each set consists of two lysimeters of each soil type. One of these in both the series is treated with 100 lbs. P<sub>2</sub>O<sub>5</sub> since last 6 cycles of cane crop. Cane crop receives 300 lbs. of nitrogen per acre. Soil samples were collected during 1952 and 1953 and they were analysed as in other two experiments.

In general there has been very good response to phosphate application in sann-cane series, which does not receive any compost in the rotation in all soil types especially in heavier types. In compost treated plots the response to phosphate treatment has been good in recent years although it is much less as compared to sann-cane series. Soil studies show that phosphate application has resulted in increase in availability of phosphate in all soil types. The cotton-cane series which has received 20,000 lbs. of compost per acre as basal dose to cane has shown higher values of nitrogen, available P<sub>2</sub>O<sub>5</sub> and organic carbon in all soil types as compared to sann-cane series thus showing that compost is more beneficial in improving the soil fertility than green manuring. There has not been any definite trend as regards other chemical constituents.

*(4) (a) Effect of compost verses no compost series with varying ratios of Sulphate of ammonia and cake on Sugarcane (January plant cane.)*

This experiment was started in 1939 and it had originally 12 treatments replicated 4 times. The top dressing treatments were no top dressing, sulphate of ammonia alone, cake alone, different ratios like 1:1, 1:2 and 2:1 of sulphate of ammonia to cake. One set of these treatments received either no compost or 20,000 lbs. of compost as basal dressing. After its completion of 4 cycles (each of three years because 3 years rotation of groundnut cane-jowar is followed) each of the plots receiving no compost was split into two and one of them is receiving compost equivalents of N.P.K. in the form of inorganics (ammonium sulphate, superphosphate and potassium sulphate). It has completed one cycle recently. With the completion of 4 cycles in 1952 soil samples upto 2' depth were collected at 6" intervals and studied for chemical, physical and microbiological properties. After modification biochemical studies also were taken up to study the nutrient indices in different plots. The method adopted was the one that is advocated by Clements (3).

The results obtained in earlier years indicated the importance of compost and groundnut cake in the manuring of sugarcane. Depressing effect of sulphate of ammonia alone was very clearly brought out. Results of the same experiment after modification indicate that higher yields in compost plots and in the plots treated with higher proportions of groundnut cake are mainly due to better supply of phosphates and to a certain extent potash. Therefore the modified treatments which include artificials to supply N, P and K in equivalent quantities to those present in compost have started giving high yields again over those plots which have been receiving only ammonium sulphate. The results indicate that it is possible

to replace groundnut cake with ammonium sulphate by supplying P and probably K also as artificials. However the humus content has gone down in no compost series. Similarly the population of micro-organisms is lower in no compost series. It is interesting to watch the long range effect of these modified treatments.

**(4) (b) Effect of varying ratios of Sulphate of Ammonia and Groundnut cake with varying dosages of compost (20, 40 and 60,000 lbs. per acre) on sugarcane (Adsali)**

This experiment is the outcome of 4.a. It consists of 15 treatments with 3 levels of compost and 5 ratios of sulphate of ammonia to cake. Total quantity of nitrogen given has been 450 lbs. per acre. The results of last 4 seasons are available and they indicate that there is no advantage in increasing the basal dose beyond 40,000 lbs. per acre for adsali crop. The treatment with 40,000 lbs. and cake alone has out-yielded all treatments. With 20,000 lbs. of compost, the yields have gone down considerably with higher proportions of sulphate of ammonia. With higher rates of basals (40 and 60,000 lbs.) however the depressing effect is not so marked as yet probably because of correcting effect of large quantity of basals.

**(5) N.P.K. requirements of sugarcane grown with and without basal dose of 20,000 lbs. of compost**

This experiment is on October planted cane and has completed 3 seasons. It has 32 treatments as follows:—

Compost—0 and 20,000 lbs.

Forms of nitrogen

Sulphate of ammonia alone.

Sulphate of ammonia and cake in 1 : 2 ratio.

P<sub>2</sub>O<sub>5</sub>

0 and 100 lbs. P<sub>2</sub>O<sub>5</sub> as super-phosphate applied in furrows half way down the ridge, or at the bottom of ridges.

K<sub>2</sub>O

0 and 100 lbs. of potassium sulphate.

The results obtained confirm the finding that the depressing effect of sulphate of ammonia alone is reduced considerably provided P and K are supplied in the form of inorganics. In this experiment also the harmful effect of sulphate of ammonia alone in the absence of compost or P and K has been very conspicuous. Beneficial effect of P<sub>2</sub>O<sub>5</sub> especially by placement method has been brought out very clearly. In the absence of compost and cake potash also has shown some beneficial effect.

### CONCLUSIONS

(1) Farm yard manure helps in building up humus content of soil and the status of other plant nutrients like N, P and K as compared to control although better status of these nutrients is maintained by adding respective fertilisers. Cultivation and irrigation deplete soil humus and manuring of crops build up the status of plant nutrients.

(2) Compost application is superior to sann green manuring in improving fertility of all soil types studied. Crop response to phosphates is better under sann green manuring as compared to compost treatment.

(3) Bulky manures help in maintaining better microbiological status than others. Super-phosphate also is better in this respect and therefore helps in maintaining nitrogen status of soil to a certain extent.

(4) Sulphate of ammonia is advisable as a nitrogenous fertiliser for alkaline soils of Deccan since it helps in reducing pH of the soil. Loss of nitrogen is also very little as compared to other fertilisers tried. But it depletes soil humus.

(5) The yields of sugarcane go on dropping as years go by if no compost is applied, even, if the crop is top dressed to supply 300 lbs. N per acre and regular 3 year rotation is followed. When the top dressing treatments are compared amongst themselves the depressing effect is less when the top dressing material consists of only cake or high proportion of cake as against high proportion of ammonium sulphate or only ammonium sulphate.

(6) The drop in yields appears to be due to deficiency of phosphate. There is no indication to show that the deficiency of K was a limiting factor in any of the treatments.

(7) It appears that it is possible to maintain the yields at high level by applying mineral equivalents of compost in inorganic form especially phosphorus as super-phosphate.

(8) It is observed that compost treated plots show better status in regard to physical and biological properties of soil. It is therefore necessary to watch the long range effect of substituting compost with artificials on crop yields.

#### *Future Plan*

These experiments have shown some indication as regards the role of F.Y.M., compost, cakes and other fertilisers in maintaining soil fertility under Deccan conditions. These results have indicated that there is a possibility of replacing groundnut cake with artificials as top dressing material and that there is also a possibility of reducing the bulky manure requirements. Now it is necessary to work out exactly with what mixture of fertilisers groundnut cake can be replaced and what is the minimum quantity of bulky manures that is necessary to maintain the required physical and biological condition of soil. These requirements will have to be worked out on different soil types and under different climatic conditions for different cropping patterns. Therefore it is proposed that experiments should be laid out on different farms with following treatments.

- |   |  |
|---|--|
| 1. Usual dosage of F.Y.M. or compost  | Recommended dosages of N, P and K.   |
| 2. No bulky manure but F.Y.M. or compost equivalents of N, P, K and other mineral elements in the form of inorganics. | Do.  |
| 3. No. F.Y.M. or compost  | Do.  |
| 4. Half the recommended dosage of F.Y.M. or compost. Receiving half in the form of inorganics.                        | Recommended dosages of N, P and K as inorganics equivalent half the recommended dosages of F.Y.M. or compost.  |
| 5. 1/4 of the recommended dosage of F.Y.M. or compost. Receiving 3/4 in the form of inorganics.                       | Recommended dosage of N, P and K in inorganics equivalent to 3/4 the recommended dosages of F.Y.M. or compost. |



6. As in 1 but N to be supplied in the form of Groundnut cake, P and K to be made up by inorganics.
7. As in 2 with groundnut cake as above.
8. As in 3 with groundnut cake as above.

*References :*

1. Anonymous . . . . . Annual Report of Sugarcane Research Station, Padegaon for the years 1950—1954-55.
2. Arakeri H.R. (1955) . . . . . Padegaon findings in short (1950-55) Proc. Deccan Sug. Tech. Assoc.
3. Clements et al . . . . . Crop Log Technique. Hawaii Planters Records 1942 Col. 46 : 17 and 163.
4. Cooke G. W. (1954) Garner H. V. . . . . The importance of organic matter in crop production. The Journal of Agril. Sci. Vol. XIII : 27-40. 1954.
5. Las V.S. (1956) Raghvan K.S., Patel D.K. Soil changes under different cultural and Manurial Practices in Deccan Canal area—International Society of Sugarcane Technologists 9th Congress (India) (Under print.) 1956.
6. Rege R.D. (1951) . . . . . Can we dispense with bulky manures in Sugarcane culture. Proceedings of the 8th Convention of the Deccan Sugarcane Technologists' Association (India) Part I: 25-33-1951.

*Role of organic manures and chemical fertilisers in crop production and maintenance of soil fertility*

by

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The actual role of organic manures in maintaining soil fertility has been the subject of controversy for some years. Keen (1946) held the view that the beneficial effect of organic matter is not so much in supplying plant nutrients as in the improvement in the physical condition of the soil. On the other hand, Viswanath (1953) on the basis of his earlier experiments was of the opinion that organic manures and organic matter function directly in plant nutrition in a manner analogous to that of vitamins in animal nutrition and that a closer and direct connection exists between the micro-organisms in the soil and plants growing in them and that micro-organisms liberate from the added organic matter and from their bodies an active constituent which is absorbed by the plant and passed on to the seed, thus influencing the nutritive and reproductive value of the seed. Work done at I.A.R.I. on the quality of crops has shown no significant difference between the organic manured crop and the crop fertilised with inorganics.

One of the important functions of the organic matter appears to be to build up a structure resistant to erosion. Stewart (1946) stated that "in many of the heavy deltaic areas under paddy where the application of green leaf and similar organic matter is of particular value, the beneficial effects appear to be associated with the improvement of tilth and other physical properties rather than of chemical

properties of the soils, while in many texturally lighter soils, such as those in Mysore and in some of the paddy areas of Travancore and Cochin, both the physical and chemical improvements appear to be involved." The value of auximones, vitamins and such compounds in compost which are said to improve the quality of the crops and confer immunity from disease to plants require further confirmation.

Although organic manures supply a number of nutrients, including minor elements, it is not a balanced fertiliser and requires to be reinforced with inorganic fertilisers particularly of phosphate. Recent work in I.A.R.I. has shown that application of phosphate with bulky organic manures is more beneficial particularly in acid soils as this has been found to minimise fixation.

Apart from the evidence obtained in other countries, experiments conducted in India show that the use of suitable and balanced fertiliser mixtures give good crop yields, comparable to those obtained by the application of organic manures. In the permanent manurial experiments at Pusa (Bihar) during the period (1908-30) it was found that complete fertiliser treatment gave yields which were equal and in some cases more than those obtained by applying F.Y.M. or green manures. The new manurial series at Pusa laid out in 1932 confirm the above observation. On the basis of the permanent manurial experiments at Coimbatore, Sanyasi Raju (1952) showed that when the total yield of all the crops is taken into account, the following is the descending order of treatments in their responses. N + P + K, N + P, cattle manure, K + P, P, K, N and no manure. With respect to microbial populations, it has been observed that moisture is the chief factor in increasing the microbial population of soil by manuring. With sufficient amounts of moisture available, cattle manure nearly trebled the microbiological population of the soil. The N+P+K treatment was intermediate between the no manure and cattle manure treatments.

Carpenter (1938) observed that with tea in Assam, the sulphate by ammonia is at least as efficient as, if not more than an equivalent of organic manure in maintaining the quality and quantity of the crop.

In the permanent manurial experiments at Kanpur considerable deterioration in soil has been observed in plots treated with sodium nitrate plus super. Cowdung and sheep penning treatments have preserved the soil from deterioration. The deleterious effect observed with the fertilisers might have possibly resulted due to the continued use of sodium ion. Deterioration of soil has been found to occur by continued use of inorganic fertilisers unless supplemented by organic manures, (Kalamakar and Sirpal Singh quoted by Bures pp. 59). This might have resulted due to improvement of other nutrients and could possibly be rectified by balanced use of fertiliser.

Recent experiments conducted at I.A.R.I. in different centres of the country representing the different soils types, gave the following results :—

*Wheat.*—(1) The average response to 20 lbs. of inorganic nitrogen was 2 to 3 maunds.

(2) With increase in the nitrogen level from 20 to 40 lbs. per acre, an average additional response of about one maund per acre was obtained.

(3) Generally there was no significant interaction between nitrogen and phosphate.

(4) The response to phosphorus was small, the average response being about 1.5 mds. With increase in the dose of P.O. from 20 to 40 lbs./acre, an additional response of nearly one md. was obtained.

*Paddy.*—(1) The average response to nitrogen was about 3 mds./acre.

(2) With increase in the nitrogen dose from 20 to 40 lbs./acre there was on the average an additional response of 2 to 3 mds. per acre.

(3) The average response for 20 lbs. P.O. was about 2½ mds. per acre and for 40 lbs. P.O., there was an additional response of about one md./acre.

Sethi (1940) presenting data on the manuring of sugarcane showed that when F.Y.M. was supplemented by ammonium sulphate, significantly higher yield were obtained over F.Y.M. alone, indicating the necessity for application of available form of nitrogen. Castor cake gave better yield than F.Y.M. but was not superior to F.Y.M. plus ammonium sulphate. At Mysore a mixture of groundnut cake plus ammonium sulphate was found to be better than ammonium sulphate. It has been found at I.A.R.I. that addition of phosphate to bulky organic manures increased the microbial activity. From the recent Agronomic trials with wheat and paddy conducted throughout India, generally there was no significant evidence of interaction between the fertilisers and the Farm Yard Manure. Agarwal (1952) however stressed the superiority of a combination of inorganics with organics over the inorganics alone on the basis of the results obtained in the permanent manurial experiments at Kanpur.

The agricultural practices of the country, developed as a result of experience gained through centuries, aimed for the maintenance of soil fertility by following :—green manuring, application of F.Y.M., river silt or wood ashes and inclusion of legumes in the cropping systems. In few cases where this was followed the crop yields were no doubt maintained. But due to inadequacy of the available organic manures, a large area was cropped for centuries without the addition of any manures, thus impoverishing it considerably. There is a general feeling that while areas under food crops have more or less remained stationary, there has been a perceptible and steady decline in production. Panse (1952) after a critical examination of all the factors involved came to the conclusion that yields show an increase for certain crops in certain States, a decline in certain other, while in the remaining States no significant change is noticeable. For rice, considering all the States together, there has been a lowering of yield, except in Madras, due to possible expansion of the area. For cotton, there has been a steady increase in yields in Punjab and Madras while it is stationary in M.P. In the case of

sugarcane, the yield rates recorded a steady rise. These results indicate that due to increasing use of fertiliser the declining trend in the yields is slowly changing and with the extensive use of fertilisers planned in the Second Five Year Plan, there is likelihood of increasing the average yields, per acre considerably.

From the experiments so far conducted in India and abroad, there is clear evidence that bulky organic manures, if applied adequately, give increased yields and maintain the soil fertility. However, due to inadequacy of these manures, concentrated fertilisers are finding extensive use to supplement them. Experiments with fertiliser both of long-term and short-term nature clearly demonstrate their beneficial effect, if properly balanced. Although the experiments generally indicate no interaction between inorganic and bulky organic manures, from a practical point of view a suitable combination of organic forms appear to be superior to either of them singly. It is a good Agronomic practice to give in addition a basic dose of organic manure particularly in irrigated tracts so as to build up the soil tilth and structure.

In order to decide the relative merits of manuring with organics and inorganics, there is urgent need for starting permanent manurial experiments on typical soil climation regions, using at a particular centre the same pure variety, if the object included the quality of crops as well, throughout country. The seed produced from the same plot may be resown again and again from year to year. It is by only this way that the relative humidity of organic manures and inorganic fertilisers can be established.

*References :*

1. Carpenter . . . . . : 1938 Emp. Jour. Expt. Agri. (1.4)
2. Keen . . . . . : 1946 Organic versus inorganic manures in land improvement and crop production.
3. Panse . . . . . : 1952 Trends in area and yields of principle crops in India (special article)
4. Sanyasi Raju . . . . . : 1952 The role of organic manures and inorganic fertilisers in soil fertility Madras Agril. Jour. Vol. xxxiv, March, 1952.
5. Sethi . . . . . : 1940 Manuring of paddy, I.C.A.R. Misc. Bull-No. 38
6. Stewart A. B. . . . . : 1947 Report on soil fertility investigation in India with special reference to manuring.
7. Viswanath B. . . . . : 1953 Proc. Nat. Inst. Sci. India; Vol. six, No. 1, 1953.
8. Bhownick H. D. & Raychaudhri S. P. . . . . : 1953 Proc. Nat. Inst. Sci. of India, Vol. xix, No. 1, p. 35 to 43.

*Role of Organic Manures and Chemical Fertilisers in crop production*

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The value of organic manures as means of enriching the soil in organic matter and humus is well established. Humus improves the physical condition of all types of soil, provides a source of energy

for soil organisms and is a store of slowly available Nitrogen. However, the quantity of organic manures actually available for application is not sufficient and only a fraction of the cultivated area can derive benefit from these manures. Further more, Farm Yard Manure which is the chief source of bulky organic manure cannot be regarded as a balanced and complete manure. Hence it is essential to supplement these manures with inorganic fertilisers for increased crop production. The effects of inorganic manures are more or less immediate and exerted over a short period. For manuring soils with inorganics there must be sufficient moisture in the soil. If this is lacking, manuring with inorganics does more harm, than good. The protagonists of the organic manures have levelled a number of charges that the continuous application of inorganic fertilizers may bring about adverse effects on soil and its properties affecting structure, tilth etc. In his article on the "Balanced manuring", Sir William Ogg, Director of the Rothamsted Institute, has refuted the above allegations with suitable illustrations, and pointed out that the inorganic manures compare well with organics in their performance. Arguments have also been advanced that the quality of the produce from plots manured with organic manures was superior, but later work does not seem to confirm this finding. It is now considered that a judicious combination of organics and inorganics is desirable for sustained Agriculture and increased crop production. There is a great need for a suitable organisation for the supply of inorganic fertilizers in time and in sufficient quantities.

*The role of organic manures and chemical fertilizers in crop production and maintenance of soil fertility*

by

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*Introduction.*—Of the numerous complex factors determining soil fertility, the part played by organic manures and chemical fertilizers in crop production is of considerable importance. The results of long-term experiments conducted at Kanpur (Kalamkar and Singh, 1935), Pusa (Menon and Bose, 1937), Coimbatore (Raju, 1952), with manures and fertilizers have led to important conclusions on the subject under review. The main criticisms against these experiments have been that the treatments were not randomised and lacked in adequate number of replications. In this paper are discussed the results of an experiment conducted at Pusa (North Bihar), after rectifying the defects of the old experiments (Sen and Kavitkar, 1955; 1956). The experiment was started in 1932 and laid out in 10 randomised blocks with 10 treatments as indicated below:—

1. No manure (control)
2. Farm yard manure at 8000 lb. per acre = 40 lb. N per acre (total amount applied in the last week of April or first week of May)
3. Rape-cake at 40 lb. N per acre (half applied just before maize sowing and half applied at the last interculture of maize)
4. Sulphate of ammonia at 40 lb. N per acre (n)
5. Sulphate of potash at 50 lb.  $K_2O$  per acre (K)
6. Superphosphate at 80 lb.  $P_2O_5$  per acre (p)
7. Sulphate of potash at 50 lb.  $K_2O$  +superphosphate at 80 lb.  $P_2O_5$  per acre (pk)

8. Sulphate of ammonia at 40 lb. N + sulphate of potash at 50 lb.  $K_2O$  + Superphosphate at 80 lb.  $P_2O_5$  per acre (npk)
9. Sulphate of ammonia at 40 lb. N + superphosphate at 80 lb.  $P_2O_5$  per acre (np)
10. Sulphate of ammonia at 40 lb. N + sulphate of potash at 50 lb.  $K_2O$  per acre (nk)

The fertilizers were applied half before *Kharif* sowing and half before *rabi* sowing.

The rotation followed was four-year eight-course : maize-oats-maize-peas-maize-wheat-maize-gram.

The soil of Pusa is Gangetic alluvium, mostly light loam and highly calcareous in nature. The total nitrogen content varies from 0.032 to 0.045 per cent., organic carbon from 0.26 to 0.37 per cent., while the available  $P_2O_5$  contents are 0.0039 to 0.0068 per cent. The calcium carbonate content is very high, being 35 to 40 per cent. The pH of the soil is 8.0 to 8.1.

The crops in North Bihar are grown under rainfed conditions. No irrigations were given to any of the crops in this experiment. The average annual rainfall from 1932 to 1952 was 44.3".

The results obtained from this long-term manurial experiment during the period 1932-1952 (20 years) have been summarised and discussed with respect to crop production and maintenance of soil fertility.

TABLE I  
Crop Production  
(Yield in maunds per acre)

Treatment	Crops				
	Maize	Oats	Peas	Wheat	Gram
No manure . . . . .	3.69	6.23	3.12	4.20	5.53
Manures					
F.Y.M. . . . .	7.35	12.74	6.93	7.42	8.67
Rape-cake . . . . .	9.30	10.66	5.46	6.27	7.08
Fertilizers					
n . . . . .	6.00	8.07	3.01	6.03	4.49
k . . . . .	4.10	7.28	3.56	4.39	4.70
p . . . . .	4.49	7.73	5.48	4.56	7.58
pk . . . . .	3.72	6.44	5.23	3.80	6.46
npk . . . . .	6.87	12.54	5.31	7.13	6.51
np . . . . .	7.01	12.13	5.68	7.44	7.33
nk . . . . .	5.97	8.88	2.97	6.11	4.53
S. Em . . . . .	+0.40	+0.64	+0.42	+0.28	+0.39
C.D. at 5 per cent . . . . .	-1.13	-1.80	-1.19	-0.78	-1.09
C.D. at 1 per cent . . . . .	1.50	2.38	1.58	1.04	1.44

TABLE II  
Main effects and interactions in maunds per acre

Effects	Crops				
	Maize	Oats	Peas	Wheat	Gram
N . . . . .	**2.46	**3.49	-0.11	**2.44	-0.35
P . . . . .	*0.58	**2.10	**2.26	**0.55	**2.15
NP . . . . .	0.38	**1.77	0.25	**0.67	0.25
K . . . . .	-0.14	0.24	-0.06	-0.20	-0.68*
NK . . . . .	0.04	0.36	-0.15	0.08	0.29
PK . . . . .	-0.32	-0.69	-0.25	-0.33	-0.29
NPK . . . . .	0.26	0.49	0.09	0.14	-0.14
S.E. . . . .	+0.28	+0.45	+0.30	+0.20	+0.27

\*Significant at 5 per cent level.

\*\*Significant at 1 per cent level.

In table I, the grain yields relating to maize, oats, peas, wheat and gram are shown in maunds per acre, treatment-wise. It will be observed that between the two organic manures, rape cake has given higher yields of maize than farm yard manure. Farm yard manure on the contrary raised the yields of all the *rabi* crops viz. oats, peas, wheat and gram. This may be due to the fact that the nutrients in farm yard manure which was applied before *kharif* sowing were not fully available to maize and by the time *rabi* crops were sown, the manure became effective. The np and npk treatments have also effected increases in yield of all the crops, next to organic manures. The n and nk treatments also increased the yields of maize, oats and wheat, but superphosphate (p) alone was beneficial to peas and gram only. Sulphate of potash (k) was not at all effective on any of the crops.

Among the fertilizers, thus the treatments containing nitrogen raised the yields of the cereal crops, and those containing superphosphate raised the yields of the leguminous crops. This is also supported by the study of main effects and interactions of nitrogen, phosphorus and potash (table II). Among the main effects and interactions, the response to nitrogen is significant for maize, oats and wheat alone, but the response to phosphorus is significant for all the crops, peas and gram responding best to this treatment.

In this connection, the results obtained from the permanent manurial experiments conducted at the various research stations in this country, namely at Pusa (Old Series), Kanpur and Coimbatore are worth mentioning. At Pusa (Menon and Bose, 1937), the analysis of the yield data showed that in the case of maize, farm yard manure at 30 lb. N per acre and complete fertilizer treatment on the basis of 20 lbs. N per acre in farm yard manure gave the best yields. The effect of rape cake at 20 lbs. N per acre was not as good as that of

farm yard manure at 30 lbs. per acre. Superphosphate showed better effects next to these treatments. Potash by itself did not show beneficial effect. At Kanpur (Kalamkar and Singh, 1935) sheep dung gave highest yield of wheat. Cow-dung was next in order of merit. The complete fertilizer treatment also gave high yields, comparable to the organic manures. The results obtained at Coimbatore (Raju 1952) with *ragi* (*Eleusine coracana*) *cholam* (*Andropogon sorghum*), wheat, *panivaragu* (*Panicum miliaceum*) and *cumbu* (*Pennisetum typhoides*) showed that the fertilizer treatments npk and np and cattle manure were better than n, p, k, nk and pk. These results, as well as those discussed earlier show that organic manures and fertilizers npk and np are equally beneficial in increasing the yield of cereal crops. The legumes (gram and peas) responded best to the application of superphosphate alone.

*Maintenance of soil fertility.*—All the treatments gave highest yields during the first year of the experiment, but the yields subsequently fell off gradually, although some slight fluctuations in yield were noticed in some years during the period of 20 years. The rates of deterioration given in table III indicate that there was a steady fall in yield of all the crops under all the treatments. The rate of deterioration in the rape cake treatment is significantly the highest for the maize crop, and comparatively less in the farmyard manure, np and npk treatments.

TABLE III  
Rate of deterioration in maunds per acre

Treatment	Crops				
	Maize	Oats	Peas	Wheat	Gram
No manure.	-0.15	-0.72	-1.27	-0.28	-1.50
Manures.					
F.Y.M.	-0.20	-1.16	-1.92	-0.93	-2.24
Rape cake	-0.32	-1.78	-1.66	-0.41	-2.12
Fertilizer.					
n	-0.18	-1.04	-1.12	+0.19	-1.53
k	-0.16	-1.21	-1.34	-0.36	-1.38
p	-0.17	-1.15	-2.28	0.37	-2.83
pk	-0.14	-0.56	-2.29	-0.30	-3.03
npk	-0.23	-2.14	-1.81	-0.59	-2.70
np	-0.25	-1.55	-2.05	-0.07	-2.76
nk	-0.18	-0.77	-1.08	-0.07	-1.44
S.E.	+0.02	+0.35	+0.18	+0.16	+0.35
C.D. at 5 per cent	0.04	0.97	0.52	0.46	0.99
C.D. at 1 per cent	0.06	..	0.69	0.61	1.32



TABLE IV

Rate of deterioration for main effects and interactions in maunds per acre

Effects	Crops				
	Maize	Oats	Peas	Wheat	Gram
N . . . . .	** $-0.058$	$-0.46$	* $0.28$	$0.20$	$-0.08$
P . . . . .	* $-0.029$	$-0.42$	** $-0.90$	$-0.20$	** $-1.36$
NP . . . . .	* $-0.027$	* $-0.52$	$0.08$	$-0.18$	$-0.04$
K . . . . .	$0.011$	$-0.06$	$0.06$	$-0.20$	$0.02$
NK . . . . .	$-0.005$	$-0.10$	$0.10$	$-0.20$	$-0.10$
PK . . . . .	$0.015$	$-0.06$	$0.06$	$-0.02$	$-0.08$
NPK . . . . .	$-0.008$	* $-0.48$	$0.04$	$-0.10$	$-0.10$
S.E. . . . .	$+0.011$	$+0.24$	$+0.14$	$+0.12$	$+0.26$

\*Significant at 5 per cent level.

\*\*Significant at 1 per cent level.

The npk treatment gave the maximum rate of deterioration in oats, and farm yard manure indicates highest rate of deterioration in the wheat yields. The p and pk treatments show the highest rate of deterioration in the peas and gram yields. This study indicates that the treatments which gave high yields exhausted the soil quickly.

This rate of deterioration worked out in table IV for the main effects and interactions of nitrogen, phosphorus and potash also support the same contention as stated above.

*Percentage rate of deterioration in yields.*—The relative rate of deterioration in the *kharif* crop maize and *rabi* crops oats, peas, wheat and gram under the various treatments can be studied from table V. It will be observed from this table that the farm yard manure has shown comparatively lower percentage rate of deterioration in case of maize, oats, peas and gram crops than the rape cake treatment. In general, it can be said that between the two organic manures, farm yard manure raised the yields of all the crops and showed low percentage rate of deterioration, except in case of the wheat crop.

TABLE V

*Percentage rate of deterioration in yields*

Treatments	Crops				
	Maize	Oats	Peas	Wheat	Gram
No manure . . . . .	8.08	11.58	40.68	6.77	27.15
Manures:					
F.Y.M. . . . .	5.54	9.14	27.67	12.48	25.86
Rape cake . . . . .	6.82	16.69	30.39	6.55	29.91
Fertilizers :					
n . . . . .	6.10	12.86	37.14	3.18	34.17
k . . . . .	7.60	16.62	37.73	8.28	29.25
p . . . . .	7.74	14.90	41.62	8.13	37.26
pk . . . . .	7.28	8.63	43.74	8.00	46.93
npk . . . . .	6.76	17.04	34.00	8.26	41.46
np . . . . .	7.00	12.81	36.13	0.98	37.64
nk . . . . .	6.14	8.64	36.30	1.19	31.68

Among the fertilizers, np and npk raised the yields and also showed high percentage rate of deterioration, except in case of wheat where np treatment gave the least percentage rate of deterioration. The same is true for phosphatic treatment. They raised the yield of peas and gram and also exhibited high percentage rate of deterioration.

*Summary and conclusions.*—The results of 20 years experimentation of the permanent manurial experiment (new series) conducted at Pusa (Bihar) have been presented and discussed in respect of the role played by the organic manures and fertilizers in crop production and maintenance of soil fertility.

1. Rape cake and farm yard manure were useful in raising crop yields.
2. Among the fertilizers, the treatments containing nitrogen were in general found to be beneficial in increasing the yields of cereal crops, but np and npk treatments showed increase in yields of all the crops in general.
3. Superphosphate alone was found effective on legumes; it showed encouraging results with cereal crops as well.
4. Sulphate of potash was not found to be effective on any of the crops.

5. All the treatments, organic manures as well as fertilizers, indicated steady deterioration in yields of all the crops, indicating thereby that none of the treatments could maintain soil fertility. In general, the treatments which raised the yields exhausted the soil quickly.

6. Farm yard manure, however, exhibited comparatively less percentage rate of deterioration in yields of maize, oats, peas and gram and gave higher yields of these crops as well.

7. The np and npk treatments raised the yields of all the crops, but indicated high rate of deterioration in yields.

8. Superphosphate (p) raised the yields of peas and gram and gave the maximum rate of deterioration.

#### References

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|----------------------------------|------|--|
| 1. Kalamkar, R. J. & Singh, S.   | 1935 | A statistical examination of the yield of wheat at the Cawnpore Agricultural College Farm, <i>Indian J. Agric. Sci.</i> 5 : 346-365  |
| 2. Menon, T. V. G. & Bose, S. S. | 1937 | A statistical study of the yields of the permanent manurials, <i>Pusa. Ind. J. Agric. Sci.</i> 7: 193-204  |
| 3. Raju, M. S.                   | 1952 | The role of organic manures and inorganic fertilizers in soil fertility <i>Madras Agric. J.</i> 39 : 130-147.  |
| 4. Sen, S. & Kavitkar, A. G.     | 1955 | Pusa Permanent Manurial Experiment (New Series)—Studies of the Maize Yields in Relation to the Preceding Crops in the Rotation. <i>Jour. Indian Soc. Soil Sci.</i> Vol. III : 113-121. |
| 5. —————                         | 1956 | Statistical Studies of the Crop Yield Data of the Pusa Permanent Manurial Experiments—New Series. I. Study of Maize Yields. <i>Indian J. Agric. Sci.</i> 26 (1).                       |

### *Role of organic Manures and Chemical Fertilizers in Crop production and maintenance of Soil Fertility—General consideration*

by

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**Introduction.**—Soil primarily is managed as a medium for satisfactory growth of plants. The native soil fertility is lost in three ways, namely, by soil erosion, by leaching of plant nutrients and by crop production. The first two are more or less physical processes and means are to be adopted to prevent erosion and leaching of nutrients from the soil. Without proper measures to control these factors no amount of addition of organic manures and chemical fertilizers can keep the soil fertility well maintained at an optimum level.

Soil as a medium of plant growth is a four phase system. The 'solid phase' consists of innumerable minerals and organic substances which are not in a dissolved state but are constantly subjected to

weathering agencies and are being broken down to simpler substances. This is particularly so of the organic substances and less so of minerals in the soil. In a loamy soil solid phase occupies 1/2 of the space, the rest of it being pore space filled with air and water. Clay and organic matter determine the degree of pore space. Thus sandy soils have approximately 33%, silty loams 50% and clays about 60% pore space. A good soil is said to be rich in organic matter when it form 5-10% organic matter. Soils poor in organic matter have less than 1% organic content.

The water holding capacity of the soil determine the maximum limit of liquid phase. This is usually 50% of the total pore space in the soil. The soil water contains soluble salts which vary from 100 to 1000 P.P.M. of dry soil. When the concentration reaches 2000 P.P.M. the soil solution becomes toxic for plant growth. That is what happens in saline and alkaline soils. It is, therefore, desirable that the liquid phase of the soil should not be very concentrated so that plant growth may not suffer. That is why adequate water supply for crop production is so essential.

The gaseous phase occupies rest half of the pore space in the soil at the limit of field water holding capacity. This varies inversely with the water in the soil. The soil normally contains 10 or 20 times more carbon dioxide than the air in the atmosphere. This is due to the decomposition of organic matter by micro-organisms which release  $\text{CO}_2$ . Excess of  $\text{CO}_2$  dissolved in water proves toxic because plants are unable to obtain enough oxygen for respiration.

The fourth phase of soil specially depends upon the organic matter and is to some extent conditioned by air supply and kind of minerals in the soil. Bacteria, fungi, actinomycetes and soil fauna all require oxygen, in some cases  $\text{CO}_2$ , soil moisture and nutrients for their growth. In the decomposition processes, living phase is very important and yet the living phase by itself is conditioned by the other three phases.

Now in the soil the solid phase and liquid phase remain in equilibrium. It is the solid phase which determines the pH value of the soil and the concentration of salts in the liquid phase. The base exchange phenomena control the exchange of ions from the solid to the liquid phase and *vice versa*. While cation exchange is important from the point of view of such ions as  $\text{K}_2\text{O}$ ,  $\text{CaO}$ ,  $\text{Na}_2\text{O}$ ,  $\text{MgO}$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{MnO}$ , the anion exchange is important from the aspect of the release of such anions as  $\text{NH}_4$ ,  $\text{NO}_3$ ,  $\text{SO}_4$ ,  $\text{P}_2\text{O}_5$ ,  $\text{Cl}$ ,  $\text{SiO}_2$ , etc.

Most soils in the solid phase are rich in minerals which the plants take up, the availability is largely determined by the pH of the soil which again is conditioned by the predominance of some cations or anions over the others. The elements of nitrogen, phosphorus, potassium, magnesium sulphur and calcium are available to a large extent between the pH 6.5 and 8.0. Phosphorus in fact begins to become less available when the pH rises above 7.5. On the other hand iron, manganese, boron, copper and zinc are readily available within the pH range of 5.0 to 6.5. The availability decreases

as the medium becomes alkaline. That is why it is so important to lime the soils when it is acid and decrease alkalinity when soil is saturated with bases (Trong-1953).

Thatcher (1934) classified chemical elements required for plant growth according to the functions they perform in the plant system. These are as follows:—

Crop	Functional activity	Name of elements.
I.	Energy Exchange . . . . .	Hydrogen and oxygen.
II.	Energy Stores . . . . .	Carbon, Nitrogen, sulphur & phosphorus.
III.	Translocation regulators . . . . .	Sodium, potassium, calcium & magnesium.
IV.	Oxidation-reduction regulators . . . . .	Manganese, iron (Cobalt, molybdenum & nickel), copper and zinc.

These elements may be regarded as essential for plant growth. Of the elements taken up from the soil nitrogen, phosphorus and potassium are by far more important than other elements. Potassium can to some extent substitute sodium and magnesium in its functional activity but *vice versa* it does not happen. The amounts of elements in the group IV are required in such minute quantity that few soils are unable to meet the requirements for crop production. Sulphur although belonging to group II is also required in very small amount. Thus the major needs of the crop are of nitrogen, phosphorus and potassium.

*Sources of Nitrogen supply and relative response.*—Nitrogen in the soil mostly occurs in organic combinations, as complex proteins, amino acids and similar forms. Some of the nitrogen, also exists in colloidal form and is subject to decomposition. The simpler compounds from which nitrogen is readily taken up by plants are ammonium salts, nitrite salts and nitrate salts. (Lyon, Buckman & Brady-1953). Few plants can absorb amino acids or nitrites. Most of them take up nitrogen either as ammonical or nitrate ions. Therefore all the materials whether organic manures or chemical fertilizers must be at first reduced to ammonical salt or nitrate salt before its nitrogen is taken up by plants.

Most of the bulky organic manures such as farm yard manure, compost, straw, or green manures have carbon to nitrogen ratio of 60-70:1. The nitrogen of these manures remains locked up until the C:N ratio is reduced to 30:1. Maximum availability occurs when the C:N ratio is further reduced to 10-12:1. It takes less time for bulky manures to decompose and release nitrogen, phosphate, potash and other nutrients when they have high content of water—That is why green manures are so readily decomposed and straw decomposition is a long drawn out process. It takes over 12 to 14 weeks before C:N ratio of the farmyard manure is brought down below 30:1 while for green manure 8 weeks is enough to reduce it to much below 30:1. It is, therefore, that the succeeding crop is able to make use of nitrogen from green manures more quickly than farmyard manure and the response is as high as with ammonium sulphate.

The concentrated organic manures such as cakes, blood manure and pondrette have a fairly C:N ratio and, therefore, make available nutrients so readily for crop growth.

Most of the organic nitrogen is in the protein form and is taken up by micro-organisms, in the process of decomposition to build up their own bodies and multiply rapidly. When the availability of carbonaceous matter decreases, this protein nitrogen is released in the soil as amino acids which further readily decompose into ammonical nitrogen. This is then absorbed on the surfaces of organic and inorganic colloids.

On the other hand the nitrogen of chemical fertilizers is either as ammonical, nitrate or amino nitrogen. The ammonical nitrogen is absorbed on the surface of organic and inorganic colloids. The amino nitrogen (urea) is transformed into ammonical nitrogen and is stored up in soil or is further transformed into nitrite or nitrate nitrogen. The nitrate nitrogen is either absorbed by plants, leaches down, taken up by bacteria, when excess organic matter is present, or is further reduced to elemental nitrogen and escapes into soil atmosphere.

It is thus obvious that nitrogen of organic manures as well as of chemical fertilizers must be either in ammonical or nitrate nitrogen form before it is made use of by the plants. Secondly, in order that organic manures should make available nitrogen, they must substantially lose carbon in the decomposition. The response will vary inversely with the state of decomposition of the organic manures. Thirdly, for organic manures the soil must have sufficient soil moisture for the process of decomposition to proceed, to hasten the release of nutrients for use of crops. Fourthly organic manures (concentrated) with narrow C:N ratio will readily release nutrients in a short period. Fifthly, application of bulky organic manures together with nitrogenous fertilizers will hasten decomposition but will at the same time retard use of inorganic nitrogen immediately by the plants. Sixthly, when organic manures are applied to the soil they increase the water-holding capacity but as decomposition proceeds the extra water held will decrease in proportion the organic matter has burnt out of soil. Seventhly, the rate of release of nutrients from organic manures will be much more slow for plant use than from inorganic fertilizers. In other words major portion of the nutrients may not be available for crop growth in its life cycle and some are available for the succeeding crop. The same may happen with inorganic fertilizers. Some of the inorganic nitrogen and other elements may be taken up by microorganisms for soil's living processes. Lastly, the addition of organic matter has a steadying influence on the loss of nitrogen from the soil.

Considerable experimental evidence has accumulated in recent years to substantiate the above conclusions. Acharya's (1940, 1945, 1946 and 1947) work has shown conclusively that rapid liberation of nitrogen occurs when C:N ratio is close to 12:1. Pot experiments showed that undecomposed mixed refuse with ratios wider than 30:1 produced depressing effect on yield of *ragi* and *jowar* on red

loam soil. Mukerjee, Pramanik and Mishra (1950) conducted nitrification studies on various material. The maximum nitrification in 14 weeks was as follows :—

Ammonium Sulphate	70.5 per cent
Groundnut cake	52.7 per cent
Castor cake	40.7 per cent
Farm yard manure	13.1 per cent

The further nitrification of ammonium sulphate was prevented by the inhibiting effect of lowered pH from 7.4 to 6.8 of the soil. Panse (1945) worked out response curves of data obtained at Indore on cotton crop. He fitted linear, polynomial and Mitschevlich curves for responses to ammonium sulphate, groundnut cake and farm yard manure. The response in terms of Mitschevlich curves are summarised as under :—

*Response (increase in yield of)*

[In lbs. per acre]

Dose of nitrogen lbs./acre	Ammonium sulphate		G.N. Cake		Farm yard Manure	
	Total	Per lb.	Total	Per lb.	Total	per lb.
10	27	2.70	48	4.80	20	2.00
20	52	2.60	81	4.05	29	1.45
30	72	2.40	103	3.43	34	1.13
40	94	2.35	118	2.95	36	0.90
50	112	2.24	128	2.56	37	0.74

Obviously response to farm yard manure is extremely low, compared to groundnut cake or ammonium sulphate. The rate of response per lb. of nitrogen falls off more rapidly in case of farm yard manure than it does with cake or ammonium sulphate as the dose of nitrogen is increased. In fact in cakes it falls off more rapidly than in case of ammonium sulphate. Obviously high doses of organic manures from the aspect of nutrition of cotton crop are less effective than inorganic fertilizer.

A summary of the results of experiments conducted up to 1931 to compare the responses with ammonium sulphate and farm yard manure of the data summarised by Vaidyanathan (1933) is given as under :—

*Response per lb. of nitrogen in relation to soil type*

Crop	Alluvial soil		Black Cotton soil		Red & laterite soil	
	A/S	F.Y.M.	A/S	F.Y.M.	A/S	F.Y. M.
Paddy.	6.3(20)	6.3(11)	9.4(19)	15.5(2)	18.8(12)	9.7(2)
Wheat	14.3(19)	6.2	5.3(18)	4.4	2.2(15)	..
Maize	15.0(2)	7.8	..	9.4	30.0	..
Jowar	..	..	8.5(15)	4.0	4.1(22)	3.5

The comparison of responses with four principal grain crops indicated that responses, in general, were higher with ammonium sulphate than with F.Y.M. except with paddy on alluvial soils where responses were equal. Vishwanath (1937) found that out of 72 experiments conducted with farm yard manure with or without artificials 32 did not show significant increase and three gave negative results only 37 gave significant increase in yield of crops. As against 72 experiments with farm yard manure, 42 experiments were conducted with inorganic nitrogenous fertilizer only 2 did not show increase in yield and rest 40 experiments gave increased outturn per acre out of which 50% gave significant increase over control.

Rege (1941) summarised experimental work done on sugarcane from 1932-39 and concluded that farm yard manure is quite inferior to oilcakes or ammonium sulphate because its nitrogen is not assimilated during the growing season of the soil. In Deccan Canal tract it has more value as soil improver than supplier of nitrogen. From a summary of experiments conducted on paddy Sethi, Ramiah & Abraham (1952) concluded that relative responses of nitrogen in F.Y.M. and ammonium sulphate are 3.5 lbs. and 10-15 lbs. of grain yield per acre. Chandnani (1954) has shown that for alluvial soils of Delhi the optimum dose of farm yard manure is 10-15 tons per acre applied 7-8 weeks before seeding. The relative availability of nutrients from farm yard manure is low. The mean response per lb. of nitrogen in farm yard manure worked out to 2.9 lb. of grain while with ammonium sulphate it was 16.8 lbs. at 20 lbs. N level and 9.9 at 40 lb. N level.

There is undoubtedly residual effect of farm yard manure which is cumulative in its effect. Analysis of Kanpur Permanent Manurial series for the period 1885-86 to 1913-14 exhibited that if the fertilizers were well balanced they maintained as high yield as the application of sheep dung at the rate 100 lbs. N/acre. The annual variation in yields was highest in plots untreated with nitrogen (Kalamkar & Sripal, 1935). The analysis of Pusa Permanent Manurial experiment have indicated (Menon & Bose, 1937 and Basu & Menon, 1937), that complete fertilizers (N.P.K.) equivalent to F.Y.M. containing 30 lb./N gave same yield, from 1908-09 to 1929-30, for maize and oats but not for pigeon pea. The fertilizer actually reduced the yield of pigeon pea. Farm yard manure containing 30 lbs. N was sufficient to prevent slow deterioration in yields of maize. While lower doses of 10 and 20 lbs. N in Farm yard showed an average annual diminution of 20 lbs. in grain yields of maize, Chemical fertilizers, including NPK, showed appreciable deterioration. Quite high annual diminution in yields were observed in legume and green manure without phosphate (in rotation) treatments in respect of maize yields, oats and arhar, which received residual effect of fertilizers, did not indicate definite trends pertaining to deterioration of their yields. Further analysis of maize data of Pusa Permanent Manurial New Series has indicated that annual variation has been small on plots of nitrogen alone or in combination with P, K & PK. The main response to nitrogen was highly significant and positive throughout the period. Rape Cake gave higher yields than F.Y.M. while N.P.K. treatment was as good as F.Y.M. (Sen & Kavitker 1955). Recent review of Permanent Manurial series at Coimbatore States, "Perhaps the most important result of these manurial experiments is that the supply of nitrogen and phosphoric acid is most essential



for all the crops tried so far. Another conclusion is that cattle manure is quite as good as and often slightly superior to complete artificial fertilizer. It has also been noted that as a result of continuous application of artificials, the clay fraction is slowly getting altered, the effect of potassium sulphate being particularly noticeable in this direction."

Vishwanath (1937), Gadgil (1937), Patel (1937), Bal (1937), Bose and Menon (1939), Rege (1941), Mitra & Gupta (1945), Parr & Sen (1948), John (1949), Fotider (1949), Hanumantharao (1950), Mukerjee and Agarwal (1950), Sethi Ramiah & Abraham (1952) and Mirchandani & Khan (1953) have all shown the profitableness of green manuring the various crops. Beneficial results have been obtained with rice, sugarcane and wheat. Still better results have been achieved with green manures top dressed with phosphates. The response with green manure was as high as with about 40 lbs. of nitrogen applied as ammonium sulphate. The permanent manurial experiments at Pusa have shown that dressed with phosphate the green manuring of oats crop maintained the level of yields of all crops in the rotation. The suitable green manure crops are Sannhemp, *Guar*, cow-beas for what; for sugarcane it is Sannhemp and for rice *Sesbania Speciosa* in Southern India and *S. esculentus* in Northern India. For the second crop of paddy pillipersara is the suitable green manure. On higher soils green manure is more effective than fertilization of crops with inorganics. But green manuring is only successful where rainfall is above 40" and/or there is assured supply of irrigation for crop production.

Experiments conducted with cakes as against ammonium sulphate have shown that on the average under rainfed conditions cakes are superior to ammonium sulphate. Under other conditions they are as effective as ammonium sulphate. Vishwanath (1937) summarising experiments conducted with Cakes noted that in 17 experiments, out of 18 increase in yield was reported in 11 it was significantly greater than no manure treatment. Panse (1945) compiled data of experiments on cotton and showed that application of groundnut cake generally showed even a greater response than ammonium sulphate, Panse, Sahasrabudhe & Mokashi (1951) observed that drilling of groundnut under rainfed conditions gave higher response than broadcast application. With groundnut cake the response was better at low and medium fertility but at high fertility the response was greater with ammonium sulphate. These interesting data are presented as under :—

*Response to nitrogen for various levels of soil fertility*

Crop	No. of trials	Mean response in lbs. of Kapas per lb. of nitrogen	
		Ammonium sulphate	Groundnut Cake
Low fertility	13	11.4	7.2
Medium fertility	30	2.1	6.1
High fertility	27	41.8	21.6
All trials	70	14.9	9.1

Obviously the different tended to increase in favour of groundnut cake with the fall in level of fertility.

From the summary of results prepared by Sethi, Ramiah & Abraham (1953) it is observed that in Madras and Andhra States equivalent response is indicated by cakes and ammonium sulphate. In years of drought *neem* cake proved better than G.N. cake, castor cake and safflower cake. Similar results were noted in West Bengal, Bombay, Mysore, Uttar Pradesh, Madhya Pradesh and Assam. Its optimum dose appears to be 40-60 lbs. N per acre.

In general it may be stated that cakes as a source of nitrogen are as effective as ammonium sulphate if not slightly higher on alluvial, black cotton and red soils of India. The relative effectiveness decreases as soil fertility increases under rainfed conditions.

Town compost as a source of nutrient supply has been tested in a few experiments. The average response, according to Acharya (1947) from the experiments conducted in the States of Orissa, U.P., Bombay, Madras and Bihar, was as good as farm yard manure. The mean response with wheat, in experiments conducted at Bastauli was 5.1 lbs. and with barley it was 4.4 lbs. per lb. of nitrogen. These results have been confirmed by Lal (1947) in Uttar Pradesh.

*Sources of Phosphate supply and relative response.*—The phosphate in the soil in the form of mineral mostly exists as apatite, as the original source. The secondary sources are Ca, Fe, Al phosphates. Besides phosphorus is found in organic combination such as phytin and nucleic acid. There are more complex and less active forms. The simpler and more available forms are phosphates of Ca, K, Mg etc. and soluble organic forms. Phosphorus in plants is taken up as  $PO_4$  ions (Tyan, Buckman & Brady, 1953). Recent investigations have shown that plants take up almost half of the phosphorus from the organic fractions of the soil.

The phosphate in soil exists in three categories namely (a) readily available, (b) moderately available and (c) slowly or difficultly available. In the soil  $PO_4$  ions probably exist attached to aluminium and iron hydroxides and silicates as an exchangeable anion and a small amount of these is in category A. In fact most of it is in category B. Most of it attached to iron hydroxide and all existing as apatite, belong to category C. (Trong—1953).

The applied inorganic phosphates are readily fixed in the soil as calcium phosphate or as organic phosphates. Some of the phosphate is also absorbed by colloids and is retained in the soil as colloid bound.

The organic bulky manures contain from 0.25 to 0.75% P<sub>2</sub>O<sub>5</sub> as organic phosphate. The release of phosphate for plant use depends upon the rate of decomposition of organic matter which in turn is conditioned by C:N ratio. With release of 5 parts of nitrogen there is release of 1 part of phosphate for plant use. Thus the availability of phosphate is almost bound up with the release of nitrogen for crop use. Experiments conducted with berseem at I.A.R.I. have shown that

effectiveness of organic phosphorus in F.Y.M. is as good as of superphosphate. The comparative results obtained by Sen & Banis (1955) are tabulated as under :—

*Comparative efficiency of F.Y.M. and super phosphate*

Berseem green fodder	Doses of P <sub>2</sub> O <sub>5</sub> lb./acre						No manure treat- ment	C-D. at 5%
	F. Y. Manure			Superphosphate				
	16	32	64	16	32	64		
Yield Mds./acre	196.50	298.34	348.56	210.97	271.64	348.19	127.70	60.75

These results show that bulky organic manures have a high value as source of organic phosphorus for use of crops. It is however, not clear how far it stands good for other crops. This is further borne by the results of Permanent Manurial experiments conducted at Pusa, Kanpur and Coimbatore. The rate of deterioration with F.Y.M. was the same as for N.P.K. fertilizer. So that phosphate from the farm yard manure was sufficient to maintain the fertility level in the field. This is borne out by the fact that a green manure crop at Pusa was not successful without the addition of phosphate.

The role of superphosphate bone meal, etc., as inorganic materials for supply of phosphorus for crop production, has been discussed in a separate paper contributed for these meetings.

*Source of Potash supply and relative response.*—Most of the Indian soils are richly supplied with potash. The original minerals present in the soil are feldspars and mica. Besides complex secondary aluminium silicates such as clays of illite type are sources of K ions. The mineral potassium in the solid phase is always in equilibrium with potassium in the liquid phase. Under limited rainfall conditions the feldspars and micas predominate and these serve as reserve of potassium for plant growth. The hydrous mica and biotites belong to category B, i.e., moderately available potassium (extracted with dilute acids). The readily available potassium exists in the form of exchangeable potassium (Lyon, Buckman & Brady, 1953).

Bulky organic manures contain from 0.5 to 1.0% K<sub>2</sub>O. This K<sub>2</sub>O is readily made available on decomposition for crop production. On decomposition potassium goes into base exchange complex and in the liquid phase is made available for crop growth. Very little of it is fixed in the soil as moderately or difficultly available forms. Normally 5-10 tons of farm yard manure, compost or other bulky manures are applied to crops. This adds 50 to 100 lbs. of K<sub>2</sub>O. Of this, according to Lyon, Buckman & Brady (1953), half of it is available for use of crop during one crop growing season. So that natural availability is from 25 to 50 lbs. per acre. Most crops have very high requirements of potash. On highly deficient soil, therefore, potassium as a supplemental dose is required for crop use, when bulky organic manures are not in common use. If the carbonaceous matter is high in the soil and microorganic activity is high the availability may be low for plant use.

The fixation of potassium is not the same as the fixation of phosphate. The potassium is fixed in the soil in category B when there is excess lime in the soil. It may also be fixed in the process of drying and wetting. But this fixation is very temporary. Sometimes Colloidal complex may be the factor attributing to the fixation of potassium in the soil. This fixation is also temporary fixation. The release is equally quick when readily exchangeable potassium is exhausted by crop use. Bray & Deturk (1939) in Illinois soils, found a release of 288 lbs. of potassium per acre in six months.

The common inorganic sources of potash supply are Potassium sulphate (48% K<sub>2</sub>O) and potassium chloride (60% K<sub>2</sub>O). When these are applied to the soil, these either go into base exchange complex or are temporarily fixed in the soil and the release of potassium takes place as plant take up potassium. More potassium fixation occurs in soil with clay of montmorillonite and illite than soils which have predominance of Kaolinite clay minerals. Most sandy soils are likely to show deficiency of potassium because of excessive leaching of potassium from such soils (Lyon, Buckman & Brady, 1953).

Potash removal by crop is usually in direct relationship to the availability in the soil. Luxury consumption of potassium is well known. Heavy doses of potash applied may, therefore, be not economically utilized by the crops.

*Value of organic manures as soil amendment.*—There is general belief that organic manures besides having fertilizing value impart physico-chemical properties to the soil and, therefore, keep it in good heart. Therefore value of organic manures is considered from the following point of view :—

1. Fertilizing value of carbon inorganics.
2. Fertilizing value of minor elements in organics.
3. Improvement in water relations of plants.
4. Improvement in soil aeration.
5. Organics as colloidal matrix.
6. Cumulative effect of organic manures.

Gericke (1949) from the experimental evidence has determined the effect value 'C' of the growth factor organic matter. Its value is 0.003 as against 0.122 for the available nitrogen for plant use. This is attributed to improvement in water economy. Kristena (1951) has reported that true solutions of humic acid at low concentrations stimulate but at high concentrations retard growth. The small fractions absorbed stimulate oxidising systems and, therefore, greater absorption of minerals takes place. The response is more marked in early stages. German soils in 60 years, have on the average, received 421 dz/hectare of organic manures and their humus content has gone up by 0.2%. According to Gericke the same result could have been achieved by addition of 60 dz/hectare of 'Stable' humus (consisting of basis silicates, inorganic P, Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub> etc.) in one year. According to Barbiar (1948) the organic matter that originates in the soil itself is much more likely to improve the

physical properties than humic material, which imparts physico-chemical properties to the soil, stabilised outside the soil, as bulky organic manures. In the decomposition processes fungi give out micellia. These extra-cellular processes improve the physical property and may be the chief factor in forming water stable aggregates (Fraser, 1949). The organic matter necessary for the maintenance of the structure of Dutch soils is estimated to equal to that of roots and stubble of cereals. Although organic matter changes the physical characters of the soil, its accumulation does not change the inherent characters of the soil (Najmer, 1951). This is supported by the fact that one lb. of Krilium, an organic electrolyte, builds up more water stable aggregates than 10 tons of farm yard manure applied to the soil. Shri Khande (1933) found that it is not the fungi which produce the material (crumb forming compounds) that had aggregating power but the bacteria which released mucilagenous substances. These products are dark coloured and gunny and readily combine with clay particles to form clay-humus aggregates. Thus the decomposition of organic matter has to proceed very far before structure is built in the soil (Geltser-1940). Pennington (1947) observed under electron microscope that several soil bacteria had clay particles clustered around them and some crumbs were aggregates of these tiny granules.

Organic matter is most important from the aspect of 'living phase' of the soil. Several transformations of nutrients take place through the agency of microorganisms. Nitrogen phosphorus and sulphur cycles are entirely dependent upon the supply of carbonaceous materials. The solubility of several of the nutrients and release of several others from minerals are the products of metabolism of microorganisms. The maintenance of a level of CO<sub>2</sub> concentration results in an increased availability of certain elements. Availability of potassium, manganese, iron, copper, zinc, boron and molybdenum depends upon microorganic transformation. With excess of organic matter these may be fixed but with just adequate quantity these may be transformed and released for crop growth. These may undergo oxidative or reductive transformations by heterotrophic or autotrophic organisms with the result, that availability of the elements may be greatly changed' (Norman, 1953).

### *Role of phosphate in crop production*

by

P. C. Raheja

#### *I. Introduction*

The fertilization of crops with phosphate has not received the attention it deserves. In several countries like the United States of America, Japan, U.K. etc., phosphatic fertilisation is regarded as Key to fertility and high doses of these fertilizers are applied to almost all crops. In the United States of America the total consumption of 22 million tons of fertilizers used, phosphates account for 10 million tons, which works out to 45% of the total used there. In India the present consumption is rated at 50,000 tons per annum which is very insignificant to actual requirements for high crop production.

The experimental researches on availability of phosphorus from applied fertilizer have been carried out on extensive scale to study the factors that would conduce to less "phosphate fixation" in the soil so as to increase the relative efficiency of every ton of such fertilizer applied for crop production. Interesting studies have been made by Mattson & Kerlsson (1938) in this direction. They have distinguished between *Colloid-bound* phosphorus and *Saloid-bound* phosphorus. Mcahlife *et al.* (1947) used  $P_2O_5$  ions and  $P_2O_6$  ions to study ionic exchange between *saloid-bound* phosphorous and *Colloid-bound phosphorus* and have shown that only a small proportion of phosphate ions retained by the soil are readily exchanged with similar ions by the liquid phase. Phosphorus is principally retained by Clay fractions. Burd (1942) has shown that addition of organic matter turns applied phosphate from inorganic to organo-phosphate and the latter is far more available than the inorganic phosphorus. Soil reaction studies have shown that phosphorus is least fixed within the range 6.5 to 7.5 pH. The fixation is very high below pH. and within the range 7.5 and 8.5 pH. Addition of lime to neutralise acid increases availability of phosphorus for crop use. (Troug, 1953). McGeorge and Breazeale (1931) have observed that  $CO_2$  supply is essential in maintaining phosphate-availability in calcareous soils. Obviously addition of organic matter on such soils is important from the point of view of ready availability of this nutrient.

In India the research on the use of phosphatic fertilizer dates back to 1905 when permanent manurial experiments were started at Kanpur, Pusa, and Coimbatore. Experiments extending over 10 years were conducted at Power Kheda (M.P.), Akola (M.P.), Nagpur (M.P.), Lauhandi (M.P.), Palur (Madras), Dharwar (Bombay), Surat (Bombay), Lyallpur (Punjab), Partapgarh (U.P.) and Jorhat (Assam). The results of these experiments have been tabulated by Vaidyanathan (1933). On the value of phosphatic fertilization for Indigo Davis (1914) conducted studies over a long period. Leather (1911-12) and later on Das (1944 to 45) worked on the Chemistry of phosphate fixation in Calcareous soils. Besides this experimental work, a very large number of experiments have been conducted all over the country on different crops to assess the fertilizing value of phosphatic manures for crop production.

The All-India Agronomical Scheme of fertiliser trials on wheat and paddy has further given data to support some of the results already reported by various authors. Side by side the phosphate status studies of various soil types have been taken up by use of radioactive isotope  $P_{32}$  at I.A.R.I. to determine the relationship between phosphate uptake by paddy and wheat crops in respect of various soil types. These experiments have been started in green house and the uptake of phosphate is being correlated with field response to application of superphosphate at 20 and 40 lbs.  $P_2O_5$  per acre with and without nitrogen in the various agro-climatic regions of the country.

## II. Response to phosphatic fertilizers

The three sources of phosphate with which experiments have been conducted are :—

1. Superphosphate.
2. Bone meal.
3. Other phosphates including mixed NP fertilizers.

Experiments conducted with superphosphate far exceed those with bone meal, other phosphatic fertilizers or mixed fertilizers. The experiments with bone meal have largely been confined to acid soils in the country, but with superphosphate these have been conducted throughout India.

1. *Superphosphate*.—Most experiments have been conducted with single superphosphate (16% P.O.) upto 1931. From 1931 double (37% P.O.) and triple (43% P.O.) also came in the market and experiments were conducted with all the three materials. Generally the differential responses with these source materials have been indistinguishable.

Responses to superphosphate in various soil types were worked out from the data reported by Vaidya Nathan (1933), which are tabulated as under :—

TABLE I  
*Response to superphosphate in various soil types*

Crop	No. of experiments	Soil type-Response in lbs./acre per lb. of nitrogen			Mean response lb.	Mean response of positive value lb.
		Alluvial soil	Black soil	Red & Laterite soil		
Paddy . . .	22	12.6(3)	21.0(12)	6.9(7)	15.4	15.5
Wheat . . .	19	9.5(14)	2.3(5)	..	7.6	8.8
Cotton . . .	31	-3.9(6)	1.4(24)	1.0(1)	0.4	2.8
Ragi . . .	4	..	..	-2.8(4)	-2.8	-2.8
Jowar . . .	1	..	..	2.0(1)	2.0	2.0
Sugarcane (Gur) . . .	5	13.2(5)	..	..	13.2	13.2
Gram . . .	1	..	..	10.7(1)	10.7	10.7
Mustard . . .	1	2.5(1)	..	..	2.5	2.5
Maize . . .	1	-0.4(1)	..	..	-0.4	-0.4
Potato . . .	4	9.7(4)	..	..	9.7	9.7
Soybean . . .	1	..	6.8(1)	..	6.8	6.8
Sannhemp (Fibre) . . .	1	..	1.8(1)	..	1.8	1.8
Linsced . . .	1	..	0.0(1)	..	0.0	0.0
Groundnut . . .	6	..	7.6(6)	..	7.6	7.6

Highest response was obtained on black soils which worked out 21 lbs. of paddy yield per lb. of P.O. on the average for 12 experiments. The response on alluvial soils was also quite appreciable (12.6 lbs.) but it is based on 3 experiments. Least response was shown on red and laterite soils. The mean response for 22 experiments is 15.4

lbs. of paddy yield per lb. of  $P_2O_5$ /acre. On alluvial soils again quite high response was indicated with wheat crop. The average for 14 experiments is 9.5 lbs. With wheat the response was low on black soils. This was so because the wheat crop was raised under dry farmed conditions and, therefore, the response was limited by low moisture supply.

The responses in cotton, *ragi*, *jawar* were either negative or small. But with sugarcane it was fairly high. Every lb. of phosphate increase 13.2 lbs. of *gur* yield per acre or about  $1\frac{1}{2}$  mds. of cane per acre. Potato and groundnut are the other crops which have shown good responses. The number of experiments in their cases were 4 and 6 respectively. On other crops the experiments were very few. Thus it is obvious that phosphatic fertilizers had shown quite appreciable response in quite a large number of crop even prior to 1931.

The analysis of Pusa Permanent manurial experiments reported by Menon & Bose (1937), Bose & Menon (1937) & Parr and Sen (1948) conclusively showed that in the North Bihar Calcareous soils superphosphate is the first limiting factor amongst the nutrients which restricts growth of crops. The superphosphate showed response in legumes, maize and oats. Only crop with which response was not obtained was *pigeon pea* (*Cajanus Cajans*). It appears superphosphate being acidic encouraged wilt disease. The rate of deterioration in yield of crops was substantially reduced by use of N and  $P_2O_5$  as ammonium sulphate and superphosphate.

More recently Sen & Kavitkar (1955) have reviewed 20 years' data of maize from the Permanent Manurial experiments, New Series started at Pusa in 1932. There they observed that use of ammonium sulphate alone proved much less productive than N.P.K. or N.P. The annual variation and slow deterioration was also less in these two treatments compared to N, P, K and PK treatments.

Kalamkar & Sripal (1935) reported on the results of Kanpur permanent manurial experiments. They observed that instead of the slow deterioration in fertility of soil, the plots receiving fertilizer application of nitrogen and nitrogen + phosphate showed an upward tendency up 1900. If the fertilizers were balanced they maintained as high yield as the application of sheep dung at the rate of 100 lbs. N per acre annually. The results significantly brought out the need of phosphatic fertilization to the soil, superphosphate being better than bone dust.

The data of Coimbatore Permanent manurial experiments have indicated that the response to phosphate in combinations of NP., N.P.K. PK and P alone and cattle, dung at 5 tons per acre have been very marked in *ragi*, *cholam* and *pannivaragu*, while on wheat & Cotton the treatments more effective were NP, NPK and cattle dung. Obviously the soil at Coimbatore showed very high response in crop production by fertilization with phosphate, next to nitrogen and then to potash in combination with phosphate.

At Powerkheda on light clay loam soil (Morand II) a phosphate fertilizer experiment was conducted with wheat crop from 1902 to 1930. Direct application had little effect, but when applied to green



manure crop and drilled with seed in a green manure field the response was appreciable. So that light clay loam soil of Powerkheda is deficient in phosphate but requires organic matter to prevent its fixation in the soil.

An experiment conducted on black cotton soil of Akola was run from 1908-09 to 1921-22 with cotton as indication crop. Response to phosphate was 27%, nitrogen—21%, potash—11%, N.K.—37% N.P. 60% and N.P.K. 59%. This showed that the response was more or less additive and that soil is highly deficient in phosphate, less so in nitrogen and least in potash. At Nagpur the fertility of soil was kept maintained when N.P.K. was applied regularly for 15 years. The next better treatment were NP and N. At Akola in a similar experiment with cotton N.P. and N.P.K. were equal in maintaining soil fertility, the response with N.K. being less than N.P.

Parr and Bose (1944, 1945 & 1947) have reported results of experiments conducted on berseem and its residual response on wheat and berseem. The response with berseem crop varied with the dose of nitrogen and subsequent residual response was in proportion to the doses of superphosphate applied to berseem crop. The response of P<sub>2</sub>O<sub>5</sub> in F.Y.M. was as high as in superphosphate, if not a little higher, in view of the nitrogen content in the manure. Desai & Parr (1950) estimated that berseem fixed 3 lb. of nitrogen for every lb. of P<sub>2</sub>O<sub>5</sub> dressed to the crop. Sen & Bains (1951 & 1954) recorded that P<sub>2</sub>O<sub>5</sub> and CaO content of fodder is materially increased, thereby improving the quality of fodder for feeding purposes. Besides fixing nitrogen the available phosphate content of the soil was also increased. Dabadghao, Sen & Bains (1952) found that application of ammonios a mixture of super and ammonium sulphate to ley of rhodes grass and lucerne increased the yield and quality of fodder. While lucerne yield was increased by superphosphate that of rhodes grass by ammonium sulphate.

Panse *et al* (1947) reported that in black cotton soil tract Super phosphate applied singly did not produce a sensible response; the average of 16 trials with wheat crop being only 0.4 lbs. per lb. of P<sub>2</sub>O<sub>5</sub> per acre. In the Gangetic alluvium tract, although the response was higher than black soil tract, it was not consistent and gave an average response of 1.9 to 2.5 lbs. per lb. of P<sub>2</sub>O<sub>5</sub> per acre. An examination of the responses in individual years showed that response in particular to phosphate depended upon the amount of rainfall received during the growing season. In black cotton soil tract phosphate played a beneficial role as supplement to nitrogenous fertilization of irrigated wheat. N:P. in the ratio of 1:1 enhanced the response of nitrogen at Labhandi but not at Chhindwara. At Jalgaon a calculated average response of 16.5 lbs. per lb. of nitrogen in the presence of various quantities of phosphate was obtained as against 8.6 lbs. in the absence of phosphate.

The Expert Committee on Manures and Fertilizers (1953) reported that on Calcareous soil of Pusa a response of 5.6 lbs. per lb. of P<sub>2</sub>O<sub>5</sub> was reported by application of 40 lbs. P<sub>2</sub>O<sub>5</sub> during 1933-49 and a response of 0.5 lbs. per lb. of P<sub>2</sub>O<sub>5</sub> during 1934-37 under rainfed conditions. At Aligarh on nitrogen deficient loamy soils, a response

of 13.3 lbs. was obtained per lb. of  $P_2O_5$  with a dose of 18 lbs.  $P_2O_5$  as Superphosphate. At Jullundhar experiments conducted from 1946 to 48 response was only 1 lb. but at Gurdaspur in 22 trials a response of 7.7 lbs., 4.9 lbs. per lb. of  $P_2O_5$  were realised with 30, 40 & 62 lbs.  $P_2O_5$  doses added as superphosphate under irrigated conditions.

Yates, Finney and Panse (1953) summarising the field experiments conducted with superphosphate on experimental farms and on cultivators' fields, obtained the standardised response of 1.2 mds. of wheat grain for 20 lbs.  $P_2O_5$  per acre which is 6.0 lbs. of grain yield per lb. of  $P_2O_5$ .

2. *Bone meal*.—Prior to 1933 a large number of experiments had been conducted with bone meal as source of phosphorus for crop production. From the data collected by Vaidya Nathan (1933) responses worked out are given below :—

*Response to bone meal in various soil types*

Crop	No. of experiments	Soil-type			Mean response lb.	Mean response of positive values lb.
		Alluvial soil	Black soil	Red & laterite soil		
Paddy . . . .	183	5.7(32)	8.3(28)	9.5(123)	8.6	8.7
Potato . . . .	4	..	..	6.4(4)	6.4	6.4
G-Nut . . . .	3	..	3.7(3)	..	3.7	3.7
Sugarcane . . . .	2	-36.6(2)	..	..	-36.6	11.3

Of the total number of 183 experiments conducted on paddy 123 were laid out on red and laterite group of soils; 32 on alluvial soils and 28 on black soils. The responses on these soils were 9.5 lbs. for red and laterite soils; 8.3 lbs. for black soils and 5.7 for alluvial soils. The responses with potato and groundnut were smaller and it was erratic with sugarcane.

Vishwanath (1937) reported that out of 15 experiments conducted with bone meal 12 showed a significant increase in crop yields; one experiment with not significant increase and two with negative response. On alluvial soil of Delhi, Sen and Bains (1951) have shown that bone meal is much less effective than superphosphate or ammophos with berseem as indicator crop. Chandnani and Obhrai (1954) observed that bone meal compost, bonemeal agrosphosphate were equally good but inferior in response to ammophos. The bone meal showed some effect, on the subsequent crop of maize.

In the All India Scheme of fertilizer experiments conducted at 40 centres response has indicated almost at all centres. At the paddy centres and 12 wheat centres which have clear cut demarcation, the results were as follows :—

*Response to 20 lbs. P.O./acre*

Crop	Extra Grain yield in			Red loam
	Alluvial soils	Black soils	Medium	
Paddy . . . .	2.49(22)	2.09(149)	1.62(137)	
Wheat . . . .	2.07(326)	1.18(231)	..	

The response on undifferentiated soils and mixed red and loam soils, desert soils, etc., which constitute the rest of 19 centres have been left out of consideration. These responses are for the two years' data on wheat and paddy Crops.

The response of paddy was somewhat higher on alluvial and medium black soils than of Wheat Crop. The responses were highest on alluvial than on medium black or red loam soil. Total number of experimental plots with paddy on which superphosphate had been applied were 1333 at the 19 centres in two years' period. The average response for 1333 experiments, for all soil types worked out to 3.3 mds. of extra paddy yield per acre for 20 lbs. P.O. and 4.9 mds. for 40 lbs. P.O. per acre. The wheat centres are 20 and there is one centre on which experiments on *Jowar* crop are conducted. At the 20 wheat centres the responses 20 & 40 lbs. P.O. each for 800 experiments were 1.9 mds. and 2.95 mds. per acre. These responses have definitely established a widespread deficiency of phosphate on major soil types of India.

3. *Other phosphatic materials.*—The work with other phosphatic materials has been conducted to a limited extent. These are ammophos, niciphos basic slag, renohyperphosphate, agrophosphate, selectophosphate and magnesium phosphate. The first two are mixed nitrogen and phosphatic fertilizers in which the two complement each other. Cliff (1937) gave trial to niciphos II and found it a very effective fertilizer for sugarcane. Experiments with ammophos have been conducted at I.A.R.I. From these experiments Sen & Bains (1951); Dabadghao, Sen & Bains (1952) and later Chandnani & Obroi (1954) found it as an excellent source of fertilizer. Sen & Bains (1951) observed that basic slag has a definite fertilizer value and can prove a valuable source of phosphatic fertilizer provided cheap grinding of the material could be undertaken at site. Chandnani & Obroi (1954) did not find much fertilizer value of renohyperphosphate, agrophosphate and Selectophosphate on Calcareous alluvial soils of Delhi. Magnesium phosphate also depressed yield of succeeding maize crop.

### III. Phosphate & Green Manuring efficiency

Bal (1936) observed that response to Sannhemp green manuring was increased much more by adding phosphate than nitrogen. Vishwanath (1937) found that out of 10 experiments conducted with green

manure dressed with phosphate 8 gave significantly higher yield of crops. Parr and Sen (1948) after analysis of 36 years data of Permanent manurial Experiments at Pusa reported that Sannhemp green manuring in conjunction with superphosphate has given very striking results. Green manure alone failed badly while superphosphate alone was not effective as when used in combination with green manure. Aggarwal and Verma (1951) conducted experiments at Kanpur of similar nature and concluded that in phosphate rich soils the addition of 50 lbs. P<sub>2</sub>O<sub>5</sub> to green manure did not increase the yield of wheat over green manure alone. Panday (1955) noticed that application of phosphate to 'guar' green manure crop appreciably increased the yield of wheat grain. Addition boron & molybdenum further increased the yield by 2.5 mds. Phosphate was applied at the rate of 60 lbs. P<sub>2</sub>O<sub>5</sub> per acre. There was definite narrowing down of C:N ratio in treatments where 'guar' was treated with phosphate alone or phosphate and micronutrients.

#### IV. Increase in phosphate efficiency by placement

Das (1945) observed that application of superphosphate 4 to 6" deep gave the maximum production of mustard and *ragi* in Calcareous soils of Pusa. Singh *et al* (Quoted by Stewart, 1947) conducted experiment with wheat and noticed by deep placement the response was so high that it caused lodging in the crop. Thus while straw increased, the increase in grain yield was small by placement as compared to broadcast application on superphosphate. Verma (1952) reported that drilling the fertilizer 1" below the seed tubers gave an increase of 7.8% over broadcast application while fertilizers placed in hands on both sides of the tubers gave an increase of 14.5%. Raheja & Singh (1952) found 33% increase in field of maize crop by placement of fertilizers by drilling 2½" below the seed, over broadcast application. Bose (1955) compared the treatments of band placement; drilling fertilizer below seed and broadcast application. The superphosphate was applied at the rates of 20 and 40 lbs. P<sub>2</sub>O<sub>5</sub> per acre with a basal dressing of 30 lbs. nitrogen. He observed that hand placement and drilling gave 1.80 and 1.68 mds. extra yield of grain over broadcast application of fertilizers.

#### *Fertilizer use in dry farmed areas*

by

P. C. Raheja and K. S. Yawalkar

**1. General.**—Of 240 million cultivated acres, 77 million acres in Southern and Northern India are virtually dry areas. They have restricted rainfall 20 inches and below. The soil fertility status of these areas is comparatively low. Most of the monsoon rain comes during the period July to September. Hardly an inch or two may be received in the winter season. Majority of this area is sown under Rabi crops principally wheat, barley or these in mixture with gram, linseed or sarson. Owing to low fertility of land and the high annual loss of soil by erosion, the average yields of most crops are low. Even the yields of Kharif crops are by no means high. The distribution of rainfall is another factor which contributes to lowering of yields in these areas. The farmers have not yet taken to practices which conserve moisture in the soil particularly on lands which

have a gradient. In Southern India, some of the soils have a very shallow depth. The moisture conserved in the soil from the rainfall in the monsoon season is comparatively very little.

In 1932, the Indian Council of Agricultural Research initiated a scheme of experiments on dry farming in the different regions of India. The results of these experiments have been summarised by Kanitkar (1944). These experiments have not thrown much light on the use of fertilizers for improving the yields of crops under such adverse climatic and soil conditions.

**2. Review.—(a) Nutrient requirements.**—It is well known fact that higher fertility status of the soil conduces to the relative low water requirements of the crop. In other words each 100 pounds of water is much better utilized when the soil is fertile than under conditions of low fertility. This has been established by several workers. Leather's (1909) work in Pusa in pots as well in fields established beyond doubt that the water requirements of wheat crop were very much reduced. This was confirmed in later investigations by Montgomery and Kisselbach (1910) who conducted experiments on the water requirements of corn showed that its water requirements were lower on fertile than on infertile lands. Addition of manure to infertile soil reduced the water requirements to appreciable extent.

The manurial experiments conducted at Sholapur on two soil types, namely, medium deep and light shallow for six years (1935-41) showed (table I) that on medium black soil the response to manuring with farm yard manure or green manure sunn was quite appreciable in grain yield compared to light shallow soil.

TABLE I

Soil type	Control		Farm Yard manure		Sunn green manure	
	Grain	Straw	Grain	Straw	Grain	Straw
Medium deep Soil	249	767	307	804	292	764
Light shallow Soil	28	198	32	224	69	247

More elaborate experiments were carried out at Bijapur for six years on 2 types of soils, namely, the deep black and the loamy soil. The results of these experiments have shown that under both soil types, distinct benefit of the addition of farm yard manure was observed when it was harrowed or ploughed under in the soil.

At the dry farming station, Rohtak, experiments conducted over a period of 4 years (1936-40) indicated an increase in grain yield from 15 to 40% according to the doses of the manure.

Mathew and Cole (1938) have summarized the results of all dry land experiments conducted in the United States of America. They have shown that as a general rule the nitrates released during proportion of seed-bed and during the period of moisture conservation in dry land areas are sufficient to produce quite a large crop. Additions of manure and fertilizers caused vigorous vegetative growth and the moisture in the soil was insufficient to support such growth. In most of the seasons this reduced grain yields.

Jenkins (1951) surveying the manurial work in Australia noted with great satisfaction that very solid evidence had been obtained on the use of phosphatic manures proving beneficial for wheat crop and different tracts of the Australia wheat belt. In northern districts of Victoria, at the Dookie Agricultural College, the results showed that increasing doses of superphosphate proved beneficial for the wheat crop. The experiment results are summarised in Table II below:—

TABLE II

Treatment per acre	Average yield* (9 years 1927-35) Yield in bushels	Average yield* 11 years 1935-46 per acre
No manure . . . . .	18.0	21.9
Super $\frac{1}{2}$ Cwt. . . . .	22.0	27.7
Super 1 Cwt. . . . .	23.5	29.6
Super $1\frac{1}{2}$ Cwt. . . . .	24.6	30.6
Super 1 Cwt. plus potash 1 Cwt.	23.9	
Super 1 Cwt. plus Potash		
$\frac{1}{2}$ Cwt. + nitrate of soda $\frac{1}{2}$ Cwt..	23.3	
Super 1 Cwt. + F.Y.M. 10 Cwt. .	22.6	

\*Two course rotation—Fallow—Wheat.

It is the addition of superphosphate alone up to  $1\frac{1}{2}$  Cwt. increased wheat yield from 18 to 24 bushel in the first period and 21 to 30.6 bushel in the second period. Addition of potash and nitrate of soda did not improve the yields. Farm yard manure slightly depressed the grain yield. These results have been fully confirmed by district trials on wheat growers' lands in the same tract.

For 33 years, experiments by the Longeronog Agricultural College indicated that application of superphosphate up to 200 lbs. was decidedly beneficial in improving yields of wheat crop.

TABLE III

Treatment per acre	Av. yield of wheat per acre bushels
No manure . . . . .	33.4
Super $\frac{1}{2}$ Cwt. . . . .	37.2
Super 1 Cwt. . . . .	38.8
Super 2 Cwt. . . . .	39.5
Super 1 Cwt. & lime 5 Cwt. . . . .	38.0
Super 1 Cwt. & lime 10 Cwt. . . . .	37.5
Super 1 Cwt. & nitrate of soda 40 lbs. . . . .	36.5
Farm yard manure 10 tons . . . . .	34.1

Neither the addition of lime nor nitrate of soda enhanced the yields. Farm yard manure application at the rate of 10 tons per acre only slightly improved the crop yield. These stations fall within the dry farming belt of Australia. In this region, rainfall seldom exceed 20 inches but a fair amount is received during the wheat growing season in contrast to the monsoon rains in most of the dry farming regions of India. Commending this for adoption in Bombay State, Jonkins (1951) stated, "Experience in Australia, however, has convinced me that there is very great need for further scientific research work on the use of artificial fertilisers in economically increasing crop yields under Indian conditions particularly in connection with the use of phosphatic manures in cereal crop growing.

(b) *Methods of application.*—In recent years, considerable work has been done in methods of application of fertilizers. The past experience had shown that a good quantity of nutrient may not be available when it is applied broadcast. This is particularly true for the phosphatic manures.

In recent years, an ion and cation exchange phenomena have been studied in detail. While nitrate ion easily leaches down as it enters into solution, the  $\text{NH}_4$  ion goes into the base exchange complex immediately after application and gets absorbed on the soil particles. The latter does not necessarily increase the osmotic concentration of the Soil solution as much as nitrate ion does. The  $\text{PO}_4$  which is chemically fixed in the soil, is quickly absorbed on the soil particles or is biologically fixed in the soil. Therefore, the availability of these ions is very much different under varied conditions of soil mixture. It is likely that  $\text{NH}_4$  and  $\text{PO}_4$  will be much better utilized by the crops under conserved soil moisture conditions. Under dry farm conditions where monoculture is practised nitrates available in the soil usually are found in adequate amount for the crop and are more readily absorbed by root system. If excess of nitrate is applied this is also readily absorbed by the plants in early stages which increases the vegetative growth of the crop. This exhausts the soil moisture early in the life cycle of the crop and in consequence grain formation suffers. On the other hand, application of ammonium sulphate will take time before it is mineralised into nitrate and taken up by the crop.

The release of phosphate is rather slow in most of the soils and even the application of medium doses of fertilizers will not do much harm under dry farming conditions.

For dry farmed areas, therefore, application of phosphate and nitrogen is done in mixture with the seed. These are drilled together in the furrow. The availability of phosphate is more under these circumstances. The plant takes up nitrogen with adequate quantity of phosphate which maintains a good equilibrium. This balanced nutrition, does not promote heavy fleshy growth in early part of plants life cycle. Normally the uptake of phosphate occurs early in

the life cycle and is very helpful in early maturity of grain. Russell (1948) has observed that in England phosphate showed better response in drier than in wetter seasons.

Recent experimental work with various types of fertilizers conducted in Community Project areas under T.C.M. 'Soil fertility and fertilizer use project' scheme have indicated that under dry farmed areas of Madhya Pradesh, Bhopal and Vindhya Pradesh good responses to nitrogen and phosphate are obtained as shown below :—

*Two years average (1953-55)*

Centre	State	Soil type	Response of fertilisation			
			Nitrogen		Phosphate	
			20	40	20	40
(mds. per acre)						
Satna	Vindhya desh	Pra- Mixed red & black soil	2.32	3.05	2.45	4.19
Hoshangabad	Madhya desh	Pra- Deep black soil	1.41	1.56	0.55	0.18
Obedullaganj	Bhopal	Medium black soil	4.68	6.85	1.07	2.39

The results indicated the differential effect of fertilisation on various soil types. Mixed red and black soil of Vindhya Pradesh gave equal response to nitrogen and phosphate. But deep and medium black soils indicated relatively low response to phosphate.

**3. General conclusions.**—From the foregoing, it is obvious that fertilizer use can be advocated under dry farmed conditions. With phosphate the response is likely to be indicated in most of the *rabi* dry farmed areas. Nitrogen is likely to prove more beneficial on *Kharif* crops, when applied in small repeated doses within early 2/3 part of the life cycle of the crop. The method of mixing the fertilizers with *rabi* crops seeds and drilling together has proved beneficial and should be widely adopted. Drilling the fertilizers at 2½" below the seed level for *Kharif* crops such as maize and *jowar* enhances the yield. The dose for application will depend upon the quantum of rainfall received in the area. Ammonical, or urea type of fertilizer is likely to prove more suitable than nitrate type of fertilizer as the former will readily go into base exchange complex and will not leach down into the sub-soil.

*References :*

1. Jenkins, W. J. Dry Farming in Australia (with special reference to wheat cultivation) Bombay Department Agric. Bull. No. 184, 1951.
2. Kanitkar, N. V. Dry Farming in India, I.C.A.R. Scientific monograph No. 15, 1944-
3. Mathews, O. R. & Cole J. S. Special Dry Farming problems V.S.D.A. year book 1938. 'Soil & Man'.



*Role of Organic Manures and Chemical Fertilizers in Sugarcane Production and in the maintenance of soil fertility*

by

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The use of organic manures in some form or the other has always been made wherever production of better crops was aimed at. With more intensive cropping programme and greater drain on the fertility status of the land under cultivation on account of increased demand for food and other crops, the use of inorganic fertilizers in our agriculture has increased in the recent years. Since the application of inorganic fertilizers, particularly the nitrogenous ones immediately produces outstanding results in the form of rapid growth, better tillering and higher crop yields, etc., the cultivator is becoming more and more fertilizer-minded. This holds good especially in case of the sugarcane grower since he deals with highly exhaustive crop which needs much heavier manuring than other food crops. The sugarcane research worker in Uttar Pradesh as also in other States of the Indian Union, has, therefore, been faced with the problem of assessing the comparative utility of organic and inorganic manures and their combinations, on cane yield and on the maintenance of the productive capacity of the soil. A number of both short and long term experiments on sugarcane have been conducted by the Sugarcane Research Station, Shahjahanpur and its sub-stations at Muzaffarnagar and Gorakhpur the data of a few such experiments are presented below:—

TABLE I

*Comparison of organic and inorganic manures and their combinations on cane yield at Shahjahanpur.*

Sl. No.	Treatments	Yield of cane in mds. per acre.				
		1941-42	1942-43	1943-44	Average	Increase over control
1	Control (No manure)	520.5	489.0	258.3	422.6	..
2	F.Y.M. @ 60 lb. N per acre	560.5	599.8	344.8	501.7	79.1
3	F.Y.M. @ 100 lb. N per acre	609.4	650.0	355.3	538.2	105.6
4	Amm. Sulphate @ 60 lb. per acre.	727.7	737.8	461.3	641.6	219.0
5	Amm. Sulphate @ 100 lb. per acre.	749.1	886.5	518.0	717.9	295.3
6	F.Y.M. @ 30 lb. + Amm. Sulphate @ 30 lb. N per acre.	663.3	621.3	354.8	546.5	123.9
7	F.Y.M. @ 50 lb. + Amm. Sulph. @ 50 lb. N per acre.	702.0	764.0	472.5	546.2	223.6

TABLE II

*Effect of different manures and their combinations on cane yield at Shahjahanpur*

Sl. No.	Treatments	Yield of cane (Mds.) per acre.				Increase over Control
		I year	II year	III year	Average	
1	Control (no manure)	823.6	758.8	894.6	825.7	...
2	Castor cake @ 120 lb. N/acre	1072.3	911.2	1093.3	1025.9	200.2
3	F.Y.M. @ 120 lb. N/acre	949.4	820.5	1005.7	928.5	102.8
4	Castor cake @ 60 lb. N + Amm. Sulph. @ 60 lb. N/acre.	1040.3	876.6	1047.4	985.1	159.4
5	F.Y.M. @ 60 lb. N + Amm. Sulphate @ 60 lb. N/acre	1047.3	861.3	1046.3	985.0	159.3

The above results show that the increase in yield of cane over the control is of the order of 1, 2 and 3 mds. per lb. of nitrogen added through F.Y.M., Castor cake and ammonium sulphate respectively. Thus it is obvious that F.Y.M. is inferior to oil cake (castor cake) which in its turn is inferior to ammonium sulphate in so far as their immediate effects on sugarcane yields are concerned.

As regards long term effects of organic and inorganic manures, the undernoted results of an experiment in progress at the sub-station Muzaffarnagar since 1949-50, support the general belief that bulky organic manures like F.Y.M. maintain soil fertility better than inorganic fertilisers.

TABLE III

*Results of long term manurial experiment conducted at Muzaffarnagar*

Sl. No.	Treatments	Field No. A						Field No. B					
		Yield of cane (mds.) per acre		Percentage on control		Yield of cane (mds.) per acre		Percentage on control					
		1949-50	1951-52	1953-54	1949-50	1951-52	1953-54	1950-51	1952-53	1954-55	1950-51	1952-53	1954-55
1.	Control (no manure).	464	563	631	100	100	100	323	601	621	100	100	100
2.	FYM @ 120 lb. N per acre	528	695	726	114	124	115	389	649	768	121	108	124
3.	G. Nut cake @ 120 lb. per acre	789	623	742	170	111	118	742	694	826	230	116	133
4.	Amm. Sulph. @ 120 lb. per acre	803	810	767	173	144	122	736	703	923	228	117	149
5.	Amm. Sulph. @ 60 N + FN @ 60 N per acre	619	784	761	134	139	120	586	705	825	182	117	133
6.	Amm. Sulph. @ N + G. Nut cake @ 60 N per acre	776	722	719	168	128	114	761	693	906	236	115	146
7.	Amm. Sulph. @ 40 lb. N + G. nut cake @ 40 lb. N + FYM @ 40 lb. N. per acre	645	744	763	139	132	121	645	743	912	200	124	147

It may be observed from the above results that on an equal nitrogen basis F.Y.M. has given less improvement in yield of cane over the control, than the other manurial treatments, but the degree of its superiority over the control attained during the first year of the trial is better maintained with this manure than under the other two manures during the successive crop seasons. Therefore for maintaining good level of crop yield over long periods the use of inorganics alone does not appear adequate. A proper combination of organics and inorganics is what is required to achieve that end. For obtaining significant increases in yields but over restricted periods the use of inorganic fertilisers like sulphate of ammonia is invaluable.

Thanks are due to Shri R. L. Bhoj for furnishing material for this note.

*Role of organic manures and Chemical fertilizers in crop production and maintenance and Soil fertility with reference to rice crop*

by

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India, with a population of 360 million people has to depend upon food supply from an annual cultivated area of about 250 million acres. Besides this small cultivated land per capita, the present crop yields are very low due to several causes. One of the causes of such low yields is the poor productive capacity of the soils and the absence of any general practice of manuring of crops. The soils appear to have been stabilized at a very low level of fertility and there is widespread deficiency of organic matter and nitrogen. The present average yield of about 800 lb. of clean rice per acre over the whole of area of 73 million acres is very low. But higher yields have been obtained on the Government Farms and on the lands of progressive cultivators who adopt intensive methods of cultivation. In recent crop competitions under intensive cultivation, yields of 4,000-6,000 lbs. of rice have been recorded which show the potentiality of some of the areas. Therefore with judicious application of organic manures and inorganic fertilizers, the Soil fertility can be improved and the production substantially raised.

*Soil fertility and crop responses.*—The natural fertility of the soil is usually determined by the chemical analysis of the soils—amount of available nitrogen, phosphorous, potash, the base exchange properties, etc. Collection of such comprehensive data for different soil types for the size of the country of India is likely to take several decades. Therefore under the present conditions, the schedules of fertilizer requirements for different areas will rest upon the experimental evidence of average yield responses obtained in a particular locality, soil type and environmental conditions. Such data accumulated during last two decades, pertain mostly to the agronomic experiments conducted on the Research Stations. However, during the last few years large number of such "soil test" experiments have been conducted on the cultivators fields. It is assumed that the response to a fertilizer supplying a certain nutrient is likely to vary inversely with the status of soil and its initial yielding capacity. The plant-food status of soil estimated in this

way is only expressed in qualitative or relative terms, but the great advantage of using fertilizer experiments as 'soil tests' is that the results are directly applicable in practice. Nationwide "soil test" experiments are proposed to be conducted during the Second Five Year Plan period to get more comprehensive data on the average response to various fertilizer applications under different soil, climate and water conditions. Such data will be very valuable for formulating the National Fertilizers Policy.

*Manures and fertilizers.*—The results of the manurial experiments on rice in the country have been reviewed from time to time. It has been generally established that application of both organic manures and inorganic fertilizers, particularly nitrogenous, given appreciable increase in yield, the rate of response, however, varies with the nature of the soil, its base exchange capacity, method and time of application and the season.

The application of organic manures gives a yield response which is comparable with artificial fertilizers and those besides supplying the various plant nutrients, provide organic matter which is of special importance in tropical agriculture. Growing of a green manure crop of *dhaincha* and incorporation in the rice field gives a response which is even higher than ammonium sulphate.

The average response obtained with green manuring as compared to ammonium sulphate in one of the experiment is given in the following table:—

*Average response of paddy in lbs./acre (Average of 5 seasons).*

Level of Nitrogen. Lbs. N/A	Ammonium Sulphate	Green manuring
20"	+ 420	+ 652
30"	+ 662	+ 709

No manure control plot yield—2170 lbs.

The incorporation of green leaf matter is also found to be as efficient as growing the crop 'in situ'.

As judged from the general order of responses to organic matter and the three major plant nutrients, it is clear that rice soils are mostly deficient in organic matter and nitrogen, moderately deficient in phosphate but well supplied with potash. Highest response is generally obtained with nitrogen application. The optimum level of nitrogen application varies from 30 to 40 lbs. N per acre which gives an average response of 15-16 lbs. of paddy for every pound of nitrogen.

Among the nitrogenous fertilizers, ammonium sulphate has been found to give the best response though other fertilizers like Ammonium phosphate, ammonium chloride and ammonium sulphate-nitrate could also be used as alternative nitrogenous fertilizers.

The predominant importance of nitrogenous fertilizers for increasing food production is evident, though for maximum production it is necessary that organic matter and phosphate should also be applied in conjunction with nitrogen.

*Increase in production through use of fertilizers.*—Though there is more need to gather detailed information on the optimum dose, time and method of application and efficiency of various fertilizers, the already available information on the responses to application of fertilizers indicate that with the minimum fertilizer application at the rate of 20 lbs. N per acre, a response of about 300 lbs. of rice can be expected. On this basis it can be assumed that with an application of every ton of ammonium sulphate, three tons of additional foodgrains can be expected. Since last few years the cultivators are getting fertilizer minded and the consumption of fertilizer is increasing from year to year. It is estimated that by the end of the Second Five Year Plan period the consumption of fertilizers in terms of ammonium sulphate would be about 1.85 million tons. Even if two-third of this is used for food crops, an additional production of about 3.5 million tons of foodgrain can be expected. Thus one-third of the target increase of 10 million tons of foodgrain during the Second Five Year Plan period can be achieved by use of fertilizers alone.

### *Role of Organic Manures and Chemical Fertilisers in Crop Production and Maintenance of Soil Fertility in India*

by

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An annual additional production of 10 million tons of foodgrains, i.e., 15% more than at present and corresponding increases for other crops like oilseeds, cotton, sugarcane and jute ranging from 25% to 31% above their current level of production have been targeted in the Second Five Year Plan. Most of this additional production will have to be achieved through irrigation and manuring. These manures are interlinked to some extent for irrigation of crops, where they were previously grown without irrigation not only increases yield directly, but also secures a better response to manure. Various small, medium and large schemes for supplying irrigation to hitherto un-irrigated areas have been given a high priority in the first as well as in the second plan and will make their impact on agricultural production as they get completed. As far as manuring is concerned, however, it is important to formulate a sound national policy and lay down a definite line of action at this juncture by reviewing carefully all scientific evidence, experimental and other, which is available to us, in view of widely conflicting opinions held in India as elsewhere concerning the role of organic manures and chemical fertilizers in crop production and maintenance of soil fertility.

Crops respond universally to nitrogen applied in a readily available form, as in chemical fertilizers like ammonium sulphate or certain oil cakes, provided that moisture in the soil is sufficient, either through irrigation or adequate rain-fall. The response to bulky manures like farm yard manure or compost is relatively small and

under favourable conditions may be, on equal nitrogen basis, about 1/3 to 1/2 of that from nitrogenous fertilizer depending upon whether the crop is rainfed or irrigated. There is no evidence to suggest that the combination of organic manures and chemical fertilizers confers any special benefit on crop yield beyond that to be expected from the effect of the individual components.

Crops also respond to the application of phosphate and potash fertilizers in specified areas. This response will become more general when larger crops are raised by continued use of nitrogenous fertilizers.

Long term experiments comparing farm yard manure or green manure with chemical fertilizers at Pusa, Coimbatore and elsewhere extending over a quarter of a century or more have shown that the complete fertilizer (NPK) gives yields which are equal to and in some cases more than those obtained from equivalent quantities of farm yard manure or green manure. Results from a long term experiment on canal irrigated sugarcane at Padegaon in Bombay Decan is particularly interesting, involving as it does heavy applications of fertilizers. Two series of plots, one with a basal dressing of farmyard manure and the other without it, were given annual top dressings of ammonium sulphate alone or ammonium sulphate and groundnut cake in different proportions. The pure ammonium sulphate plots in the series without the basal dressing of organic manure showed a marked deterioration, which was ascribed to lack of organic manuring. When, however, doses of phosphate and potash equal to the amount of these elements in the farm yard manure and groundnut cake were applied to these plots, in addition to ammonium sulphate, they began to give yields as high as or higher than other plots treated with farm yard manure or groundnut cake, demonstrating clearly that even with heavy doses, a complete fertiliser can maintain high yields in the absence of organic manures. At Karpur and Powarkheda (Madhya Pradesh) deterioration in yield has been observed from the continued use of Sodium Nitrate over a long period, but this is a case of the adverse effect of the sodium ion on the soil clay apart from the fact that this fertiliser supplied only nitrogen to the crop. The result should not lead to any general conclusion that the long term use of chemical fertilizers is undesirable.

The fact that high yields are maintained steadily over long periods by the use of complete chemical fertilizers is itself a sufficient answer to the argument that chemical fertilizer would ruin the fertility of the soil. Direct soil and plant analysis of the famous Rothamsted experiments extending over a century have shown that there is no evidence whatsoever that fertilizers, when correctly used, cause any deterioration of the soil or have any injurious effects on plants or earthworms or cause any deterioration in the food value of plant products<sup>1</sup>. In India results of soil analysis for the permanent manurial trials at Coimbatore have shown no evidence of any effect on the chemical composition of the soil after continuous application of chemical fertilizers for 23 years. There is also no indication of any significant effect from such use on the various physical

<sup>1</sup>The test of time proves the efficiency of commercial fertilizers—F.E. Bear Agric. J. 39.

properties of the soil. Analysis of bacterial counts showed that bacterial population was higher in plots receiving artificial manures than the "no manure" ones though not as high as that in organic manure plots. This, however, is to be expected since bacteria are intimately concerned with the processes of decomposition of organic matter and their numbers are not necessarily an index of productivity of the soil. Further, the importance of manure as a direct source of organic matter in the soil has been rather exaggerated. Any larger and dependable increase in soil organic matter will not come from the manure itself but from the greater amounts of roots and crop residues associated with good crop growth. In other words the free use of fertilizers will itself help to increase soil organic matter.

*Role of Organic Manures and Chemical Fertilizers in Crop Production and Maintenance of Soil Fertility*

by

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The problem of soil fertility has been studied from various aspects and it is fully recognised that humus plays a very important role in soil fertility. The loss of humus must be made good either by proper manuring or by suitable rotations or both. Otherwise the soil gets impoverished and leads to low yields of the crops. Therefore, the recent trend of using artificials only in growing cash crops has created a new problem of its own. The continuous use of fertilizers like sulphate of ammonia, superphosphate and sulphate of potash at this station in the Complete Nutrient Experiment which has been in progress for the last 16 years has resulted in the progressive deterioration of cane yields after the first four years; the rate of fall being greater in the plots treated with sulphate of ammonia (100 lbs. N and 200 lbs. N per acre) over the control (unmanured plots). The continuous application of concentrated nitrogenous manures like ammonium sulphate not only makes the soil reaction acidic but also decreases the total number of soil microorganisms; *Azotobacter chroococcum* and hampers nitrogen fixation. The continued cropping of sugarcane in the absence of organic manures further exhausts the fertility of the soil and lowers the C/N ratio. The status for Ca, Mg, total exchangeable bases, exchangeable Ca & Mg has also been reduced. Sulphate of ammonia, however, when compared with organic manures at equal nitrogen level in fields in different years has given the best crop yield and profit. It has further been observed that under the conditions obtaining at the Sugarcane Research Station, Shahjahanpur potassic and phosphatic fertilizers have no response with regard to cane yield and juice quality.

It is a well known fact that the soils of U.P. are much deficient in nitrogen contents. This deficiency can be compensated either by the use of nitrogenous manures and fertilisers or to some extent by

\*Organic versus inorganic manures in Land improvement and crop production—Department of Agriculture, Madras Proc. Nat. Inst. Sci. Ind., 1953, 19, 97-108.

\*Relative merits of organic manures and inorganic fertilizers—H.D. Bhowmick and S. P. Raichaudhuri—Proc. Nat. Inst. Sci. Ind. 1953, 19, 35-43.

the recuperative processes of natural agencies (like fallowing) which fix atmospheric nitrogen by increasing biological activities. Thus various types of manures such as bulky and concentrated organic and the inorganic have been tried on sugarcane crop to study their effect on soil fertility with special emphasis on the yield and quality of the crop. Some of the results obtained are summarised below :—

### I. Green Manuring

(a) Effect of different portions of Sanai, *viz.*, roots, tops and the whole plant, when burried in the soil were studied. It was found that roots contained the highest percentage of dry matter and the lowest percentage of nitrogen. Maximum nitrogen per acre was turned in by the incorporation of whole Sanai followed by tops and roots, and the yield of sugarcane and the sugar mds. per acre were also found in the same order. Yield of cane was found proportional to the nitrogen per cent. and nitrate P.P.M. in the soil at planting time. The two peak periods in nitrate contents correspond with the two major sowing dates in the State, *i.e.* (*Rabi and Kharif*).

(b) Manurial value of different portions of Sanai when inverted in soil after 50, 60, 75 and 90 days of growth with and without stems alongwith the possibility of fibre extraction without lowering the manurial value was studied.

It was found that the highest total weight of green matter turned in per acre was contributed by stems, 75 days old Sanai added the maximum amount of nitrogen in soil and also gave the highest yield of cane and sugar per acre. Green manuring like other nitrogenous manures delayed maturity—75 days (tops and roots) gave the highest profits per acre when stem was used for fibre extraction.

This of great practical value to the cultivator as it is the cheapest method for enriching the soil with nitrogen and improving its tilth and humus contents.

(c) Efficiency of different leguminous plants, *viz.*, Dhaincha (*sesbania aculeata*), Sanai (*Contalaria Juncea*), guar (*Cyamopsis psoralioedes*), Lobia (*Vigna sp.*) as green manure for sugarcane and their effect on juice quality and chemical changes in the soil was compared. It was found that white lobia contained the highest percentage of nitrogen, Sanai gave the highest percentage of dry matter. Dhaincha and Sanai on an average gave highest percentage of nitrogen in soil both at planting time and for the average of the season. Maximum nitrate formation was observed in November. Yield of cane was generally proportional to the nitrogen per cent. in soil at planting time. Dhaincha gave higher percentage of nitrogen in soil but it led to comparatively low yield of cane. It seems, therefore, that the nitrogen in Dhaincha is not easily available to cane. Highest yield was given by lobia and Sanai followed by dhaincha and guar.

Lobi and Sanai are therefore the best and can be used with advantage by cultivators for green manuring.



## II. Molasses

Molasses was tried in doses of 90, 180 and 270 mds. per acre, alone and in combination with other manures like castor cake and ammonium sulphate of 60 lb. N per acre. There were ten treatments including the control. The following results were obtained :—

(i) Denitrification sets in after about a month of the application of molasses, and the low level of nitrogen continues for about four months, after which the nitrogen values in the molassed and unmolassed plots become more or less the same. Nitrate content in the molassed plots increases thereafter.

(ii) Application of 270 mds. molasses per acre considerably reduces the juice quality but gives the highest sugar and yield in mds. per acre.

(iii) Molasses when applied during the growth period appreciably reduced cane yield due to denitrification setting in. The highest yield was obtained when it was applied about 3 months before sowing cane.

(iv) Molasses soaked with bagasse did not give any increased yield over molasses alone.

(v) The yield of cane was proportional to the nitrogen per cent. in the soil at planting time and also to the average quantity of nitrogen for the whole season. This by-product of sugar industry can be very profitably utilised as a manure for sugarcane by factory owners and other who might get molasses at a cheap rate.

## III. Comparison of various Organic and Inorganic Manures

Various types of manures, e.g., nitrogenous fertilizers, oil cakes, bulky organic manures like farm yard manure, molasses, pressmud, urine earth and artificials were compared with the object to select the most economical manure for sugarcane. The data obtained with regard to cane yield and sugar per acre when the manures were applied at 100 lbs. nitrogen per acre showed that the manures were in the following order :—Molasses, inorganic manures, oil cakes, farm yard manure, pressmud, and farm compost.

Nitrogen of the inorganic manures becomes generally available within about a week, while of the oil cakes in about 3 weeks and of the other bulky organic manures in about two months.

With respect to C/N ratio and humus content, the manures were generally in the following descending order: Molasses, pressmud, farm compost, farm yard manure, ammonium sulphate and calcium cyanamide.

Further experimentation without molasses was continued with 120 lb. nitrogen per acre, both under cropped and fallow conditions. It was seen that on the whole there was an increase in the carbon content in the soil at harvest under both the conditions the bulky manures adding more carbon than the oil cakes. Nitrate contents were generally correlated with the yield of cane under different treatments. Farm yard manure and cattle urine earth in general showed as good juice quality as unmanured (control) while other nitrogenous treatments depressed juice quality. The different manurial treatments fall in the following descending order of merit

as regards both cane yield and sugar in mds. per acre: Ammonium sulphate, groundnut cake and castor cake, town compost and press-mud, urine earth, farm yard manure and control.

*IV. Effect of continuous application of chemical fertilizers on the yield of sugarcane and on the chemical composition of the soil and its recuperation by green manuring with sanai.*

A comprehensive experiment to ascertain the effect of nitrogen (sulphate of ammonia), phosphatic (Superphosphate) and potassic (Potassium sulphate) fertilizers on sugarcane was started in 1935-36 at Government Sugarcane Research Station, Shahjahanpur. The treatments consisted of all combinations of three levels of nitrogen (0 lb., 100 lb. and 200 lb. per acre), three levels of phosphate of potash (0 lb., 75 lb. and 150 lb. per acre), without the addition of organic manures such as farm yard manure or green manure etc. This experiment is being conducted in two fields, H. and H. and the sugarcane crop is sown therein in alternate years. The rotation followed is cane-fallow-cane. In both the experimental fields the cane yields show progressive deterioration after the first three or four crops, the fall being particularly marked in the plots manured with ammonium sulphate—Neither phosphate nor potash has shown any effect on cane yield, though there is a slight indication that the addition of superphosphate at the rate of 150 lb. P<sub>2</sub>O<sub>5</sub> per acre along with 200 lb. N as ammonium sulphate, arrests somewhat the average deterioration due to the continuous application of ammonium sulphate alone.

The bacteriological studies revealed that continuous application of concentrated nitrogenous fertilizers (sulphate of ammonia) decreased the total number of soil micro-organisms, *Azotobacter chroococcum* and hampers nitrogen fixation by creating unfavourable soil reactions. The steeper decline in cane yields from plots treated with sulphate of ammonia may be ascribed to markedly low bacterial activity in these soils. Application of phosphatic fertilizers creates favourable conditions for the growth of *Azotobacter* sp. and other soil micro-organisms.

It increases the nitrogen recuperative power of the soil by increased bacterial fixation of atmospheric nitrogen. Potassic fertilizer, on the other hand, depresses nitrogen fixing capacity and thus hinders soil recuperation. Hence it does not lead to increased yields. The *Azotobacter* plaque test was utilised for comparing the availability of various phosphatic fertilizers.

The chemical investigations showed that the continuous application of sulphate of ammonia has appreciably reduced the pH of plots and made the soil reaction acidic. Continued cropping with sugarcane has lowered the carbon contents and C/N ratio of all the plots. The status of Ca, Mg, total exchangeable bases, exchangeable Ca and Mg also has been reduced. It may, therefore, be concluded that the lower status of organic carbon, C/N ratio, Ca, Mg, total exchangeable bases, exchangeable Ca and Mg and pH are the reasons attributable for the deterioration of cane yields by ammonium sulphate manuring. The yield of cane and sugar per acre were, however, higher in N<sub>3</sub> (200 lb. N per acre) and N<sub>2</sub> (100 lb. N per acre) than in N<sub>1</sub> (no manure); whereas the available sugar per cent cane was higher in N<sub>1</sub> and N<sub>2</sub> than in N<sub>3</sub>.

To check further fall of yields in this experiment green manuring with sanai was introduced in the existing rotation, cane—fallow-cane, of the experimental fields since the year 1951. Detailed chemical analyses revealed that the green manuring has resulted in an overall increase in the fertility status of the fields.

*Future lines of work.*—In U.P. no response generally had been obtained by the application of both phosphatic and potassic fertilizers, but it is a well established fact that the soils are much deficient in nitrogen and organic matter contents. Hence proper combination of both organic and inorganic manures for application to U.P. soils is very necessary for replenishing and maintaining soil fertility. The doses of the inorganic manures like ammonium sulphate, ammonium nitrate, ammonium sulphate nitrate, etc., and oil cakes like castor cake and groundnut cake, applied in conjunction with bulky organic manures like sanai, farm yard manure and compost have to be ascertained with respect to maximum cane yield and best juice quality by actual field experimentation for different soil types and zones.

*Means of effective use of applied manures & fertilisers in paddy*  
by

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It is well known that the yield of transplanted paddy can be increased by various means important among which is through use of organic manures and fertilisers. It has, however, been found in the experimental work carried in West Bengal at Chinsurah that the paddy yield increased only to a limited extent and the limit was attained at fairly low levels of fertilisers application (30 lbs. of nitrogen per acre) (Table I).

TABLE I

\*1945-46 to 1952-55 (Ten years) Chinsurah Variety-Bhasamanik  
(Average of ten years.)

	Grain yield mds.	Straw yield mds.	Grain Straw Ratio
1. No manure . . . . .	22.34	36.13	1:1.61
2. 30 N (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> . . . . .	27.13	44.04	1:1.62
3. 60 lb. N „ . . . . .	27.18	52.43	1:1.93
4. 90 lb. N „ . . . . .	27.20	55.91	1:2.05
5. 120 lb. N „ . . . . .	25.08	57.55	1:2.29
6. F.Y.M. 100 mds . . . . .	26.33	42.27	1:1.60
7. F.Y.M. 100 mds. + 30 lb. N (Am. Sulphate). . . . .	28.00	46.60	1:1.66
8. F.Y.M. 100 mds. + 60 lb. N (Am. Sulphate) . . . . .	25.13	54.80	1:2.18
9. F.Y.M. 100 mds. + 90 lb. N (Am. Sulphate) . . . . .	23.85	58.14	1:2.43
10. F.Y.M. 100 mds. + 120 lb. N. (Am. Sulphate) . . . . .	20.98	59.16	1:2.82

\*Data supplied by Agricultural Chemist, Government of West Bengal.

Yield remained stationary or decreased with higher rates of application. Work in other parts of India also have indicated similar results except for the fact that the yield has been reported to have increased further, but only to a little extent when nitrogen is combined with phosphate.

P. K. De (1955) has shown that only 26.8 to 37.0 per cent. of applied nitrogen is utilised by the paddy crop and the balance is lost as nitrogen and in drainage water. Nearly 30 per cent. of applied nitrogen has not been accounted for.

TABLE II

*Nitrogen assimilated by the plant, and lost as gas and in the drainage water (As percentage of nitrogen added)*

Treatments	Burdwan soil (Pot experiment)			Chinsurah soil			
				Pot experi- ment		(Field experiment)	
	Crop.	Gas	Drain- age	Crop	Gas	Drain- age	Crop Gas
Oil cake . . . . .	26.8	23.8	24.7	34.3	19.6	16.7	.. ..
Am. Sulphate (Surface) . . . . .	27.7	27.6	15.4	34.9	24.4	10.4	39.8 23.5
Am. Sulphate (Placed) . . . . .	28.7	19.2	20.5	37.0	14.9	13.3	43.7 15.6

He has further shown that the loss of nitrogen gas is of higher order in uncropped lands as compared to the cropped lands.

TABLE III

*Nitrogen lost as gas, as percentage of nitrogen added—Chinsurah*

Treatment	Cropped	Uncropped
Oil cake . . . . .	19.6	26.6
Am. Sulphate (Surface) . . . . .	24.4	31.4

One exploratory and unreplicated trial was conducted in 1955-56 season at the West Bengal State Agricultural College Farm, Calcutta with transplanted aus and aman paddy. The treatments included three spacings that provided varying populations. The yield performances recorded varied considerably with the different populations and pattern of transplanting. The crop was manured with 20 lb. of nitrogen (Ammonium Sulphate) applied during puddling. The yield and other details of record are given in the following table (Table IV).

TABLE IV

	Sq. inch area per point	No. of points per acre	Age of seed- lings	Date of trans- plant- ing	Date of har- vest	Yield per acre Mds.	% on 10" x 10" plant- ing	Remarks
<i>Aus-Dharial</i>								
10" x 10"	100	62,726	36	26.7	22.9	24.06	100.0	2 transplants
15" x 3"	45	1,39,692	36	26.7	22.9	32.71	135.9	1 transplant
18" x 3"	54	1,16,160	36	26.7	22.9	27.06	112.5	1 transplant
<i>Aman-Badsalhog</i>								
10" x 10"	100	62,726	59	16.8	1.12	27.01	100.0	2 transplants
15" x 3"	45	1,39,692	59	16.8	1.12	32.20	119.2	1 transplant
18" x 3"	54	1,16,160	59	16.8	1.12	20.70*	76.63	1 transplant

\*Considerable lodging occurred in this treatment.

It would be seen that with aus, the yield has increased considerably in the continuous row planting than in the square planting method in spite of the fact that two plants were transplanted in the square planting system as against one plant, in the continuous row planting. With aman, the continuous planting gave less increased yield in the 15" x 3" treatment over the square planting system. The aman yield however was very much lowered in the 18" x 3" system. This crop suffered considerably from lodging. Increased population and points of transplanting per unit area definitely increased the yield. Tillering was more profuse in the square planting system but gave considerable number of non-effective tillers. In the continuous planting, tillering was more suppressed resulting in more number effective total tillers per unit area.

The increased yield besides being attributed to more effective tillers can also perhaps be attributed to more effective utilization of applied fertiliser and soil nutrient by arresting the losses that occurred in the square planting system. With aman, the results were similar with 15" x 3" series but when the spacing was increased to 18" x 3" considerable loss of yield occurred. Thus aman behaved somewhat differently as compared to aus paddy. More close planting with 12" x 3" spacing, etc., increase the yield.

It will also be worthwhile to investigate the possibilities of arresting the losses of nutrient that always occur in paddy through other means so that the applied manure and fertilizer is better utilised. We are told that the Japonica varieties utilize applied nutrients much more effectively than Indian varieties. In this connection encouraging the growth of blue-green-algae in the paddy field and other plants of shorter duration or growth that do not compete with paddy but only arrest the losses of nutrients temporarily and when ploughed under release the same for the paddy crop may be tried. Blue-green-algae in this respect, besides preventing losses and providing some organic matter to the soil, also may have the additional

advantage of providing with some additional nitrogen fixed from the air and releasing it for the benefit of the current paddy crop when ploughed under (De & Sulaiman—1950).

In the use of manures and fertilisers it is important to ascertain if full and effective use of the nutrients supplied is made by the crop.

Use of manures and fertilisers is only one of the numerous means for increasing and maintaining crop yield at high levels. Water supply, drainage, soil organic matter, soil type, physical condition of the soil, time and rate of seeding, spacing, growing adapted varieties are all factors that determine the crop producing capacity in any given region. The greatest benefit from use of manures and fertilisers result when the other factors are taken care of. In this respect much remains to be done in our country.

### References

1. De, P. K. & Sulaiman, M (1950). Soil Sci. 70, 137.
2. De, P. K. & Digar, S. (1954). J. Agri. Sci. 44, 124.

### *Fertilizer application of maize*

by

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The production of corn in the United States is roughly about three-fourth of the world's supply. India, on the other hand, grows 8.7 million acres producing only about 2.6 million tons. The yield per acre is about 664 lbs. only.

The improvement of corn through breeding and better cultural practices has engaged the attention of American growers since the discovery of the New World. An outstanding example of the crop improvement is the hybrid corn, which is the course of several years has replaced the open pollinated varieties on the major corn acreage in the corn belt and on about 25 per cent. of the U.S.A. corn acreage.

The greater vigour of the hybrids and their resistance to lodging, plant diseases and insect pests has increased the acre yield by 10 to 20 per cent. The tracts where it is grown on large scale have been greatly benefitted by hybrid corn as without increasing the cost of production the yields have been raised considerably. There is a tendency to concentrate its production on better lands of the country. In India the acreage of maize is mainly confined to the alluvial soils of Gangetic valley and the irrigated lands of the Punjab. The yield, under our condition, can be increased by adopting the following suggestions :—

1. Use of better seed. The area under hybrid corn should be increased as soon as possible.

2. Replenishing plant food in the soil which is being depleted by continuous cropping. Though increasing the genetic potentiality of maize seed has now focussed attention of the plant breeders in this country but information on its fertilization is meagre. At Pusa (Bihar), experiments were carried out from 1932-35 to compare the response of maize to 'No manure' and 8,000 lbs. per acre of Farm Yard Manure with and without 20, 40 and 25 lbs. of N, P. and K. Maximum response was obtained from the combination of N and P. A combination of N, P and K gave slightly lower yield. Response of F.Y.M. alone was next, in order. The difference between N alone and in combination with K was small. Similar was the case with P and K when applied singly, and the yields were much lower than from N alone. A combination of P and K, however, gave the lowest yields.

In U.P. the application of raw dung or compost at the rate of 60 lb. N gave slightly better yield than no manure. Similarly the mixture of town compost and ammonium sulphate at the rate of 30 lb. N gave significantly better yield than town compost or raw rubbish.

The experiments at I.A.R.I. conducted in 1952 and 1953 showed the application of ammonium sulphate at 20 lb. and 40 lb. N gave higher yield than plastered heap compost, over ground leaf compost or exposed pit compost.

Many modes of fertilizer application have been developed by workers in other countries but no systematic work on this line has so far been done with corn crop in India. In order to obtain an answer to this question field experiments are underway at the Indian Agricultural Research Institute, New Delhi. The results now discussed, relate to an experiment which was started in 1951 and carried out every year for four years. The authors, however, wish to emphasize at the outset that the system of fertilization discussed here applies primarily to the general farming areas in the north as exemplified by the condition prevailing in Delhi. For special conditions, properly adapted systems of fertilization need to be followed.

*Treatments.*—Five hundred pounds of NPK fertilizer mixture of the grade 1:2:1 was applied to an acre in the following manner. (1) Plough Sole (P). The fertilizer was placed on the bottom of the furrow, 2 to 2½ inches below the seed, with the help of funnel fitted up behind the plough. (2) Lap of furrow (K)—The mixture was applied by hand on both the 'laps' of the newly opened furrow at a distance of about an inch from the seed. (3) Broadcast (T)—In this treatment the fertilizer was applied on the surface and then mixed with the soil in the usual manner.

The above applications were given at the time of sowing. The crop was sown in lines with the break of monsoon every year.

*Results.*—The analysis of data is summarised in the following table:—

*Effect of different methods of application of fertilizers*

(Yield in maunds per acre.)

Treatments	1951	1952	1953	1954	Average
P . . . . .	20.85	9.67	14.14	11.91	14.14
K . . . . .	18.24	8.75	14.14	9.71	12.71
T . . . . .	15.67	9.34	14.78	10.19	12.49
"F" test . . . . .	Sig. 1%	Not Sig.	Not Sig.	Sig.	Sig. 1%
SEm ± . . . . .	0.61	0.53	0.34	at 1	0.18
C.D. at 1 % . . . . .	1.57	..	..	1.62	0.67
5 % . . . . .	2.06	..	..	1.22	0.50

The difference between the three methods of application of fertilizers are found to be significant at 1% level. The application according to plough sole (P) method gave the highest yields. The other two methods did not show much difference from each other. The good results obtained in case of plough sole placement may perhaps be due to the quick availability of the plant nutrients which reflected favourably on the grain yield. Based upon these results the recommendation about the application of fertilizers at plough sole appears to be reasonable.

*The role of organic manures and chemical fertilizers in crop production and maintenance of soil fertility with special reference to Madhya Pradesh*

by

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From the point of view of immediate increase in crop production and sustained higher yield by maintenance of soil fertility, the values of chemical fertilizers and organic manures are immense. From the evidence of vast amount of research work done on manuring of various crops in the various parts of the country it is observed that organic manures and commercial fertilizers are supplementary to each other and best go together rather than replace each other. Allan (1933) has shown better effects of fertilizers on Cotton after a basal dressing of organic manure and this has been further substantiated by later experiments. Panse (1945) has shown that effect of artificial nitrogenous fertilizers and organic manures is usually much more in fields of high than of low fertility. The organic manures are well known for their higher residual effect and maintenance of soil fertility which is a pre-requisite for a better effect of fertilizer.



Ekbote and Kalamkar (1953) have shown that for wheat, for immediate increase in production, chemical fertilizers are superior to organic manures which are useful for gradually building up of soil fertility. This was also indicated by Allan. They have further shown that for paddy under conditions of adequate soil moisture, superiority of organic manures both from a short and a long term policy is clear and recourse of fertilizer has to be taken to get immediate results to supplement the supplies of the former. Stewart (1947) summarising the results of various manurial experiments in India has stressed the importance of both organic manures and inorganic fertilizers and has pointed out that the effect of the latter may be enhanced if they are used to supplement basal dressing of bulky organic manures. On the other hand, he has also shown that the fertilizers can be used to produce humus as for instance, in the phosphatic manuring of legumes or in the manuring of green manure crops.

The foregoing has shown general principles underlying the use of organic manures and inorganic fertilizers. Now, with the introduction of Community Projects and National Extension Service blocks the extension workers need more specific recommendations to be passed on to the cultivators for each soil, climatic and crop zone.

Madhya Pradesh is divided into three crop zones, viz.

(1) *Paddy*.—With an acreage of 90 lacs in 9 districts, the soil being mostly of lateritic origin with an average annual rainfall of 50 to 60".

(2) *Cotton*.—40 lacs and Juar 50 lacs acres in 7 districts the soil being described as black cotton soil with an average rainfall of 36 to 45".

(3) *Wheat*.—With an area of about 30 lac acres in 6 districts, the soil being a heavy black with an average rainfall of 45 to 60".

The following gives an account of the manuring of the above important crop zones and tracts in zones for immediate crop production and maintenance of soil fertility.

### I. PADDY ZONES

*Paddy*.—The evidence on the manurial results obtained prior to 1930, reveal that both cattle-dung (6,000 lb. per acre) and green manure (Sann 8,000 lb. per acre) are very effective in bringing about significant increases in yield over no manure. The addition of phosphate (2 cwt. bone meal per acre) considerably raises their efficiency. Later experiments with town-compost have also shown the effectiveness of the bulky organic manures in raising the yield of paddy. Town-compost, when applied @ 60 lbs. N and 40 lbs. N per acre, increased the yield over control upto 67% and 48% respectively at Labhandi (Raipur).

Green manure, though the cheapest source of Nitrogen, is better suited to a transplanted crop of paddy. Its applicability is restricted to areas where irrigation before monsoon is an economic possibility

which renders its wide use unlikely. Recent trials with green manure conducted in biasi crop of paddy have put forth encouraging results. The green manure crop is sown broadcast along with the main crop of paddy and buried at the time of "biasi" (operation of light ploughing in the standing crop in presence of water about a month after sowing) putting no demand for irrigation before monsoon. With a suitable green manure crop, this practice stands every chance of being popular among cultivators very soon.

In places, close to forests where an abundant supply of green leaves is possible, green leaves can be used with advantage with this crop. Experiments conducted at Labhandi and other places have shown that application of three tons of Karanj (*Pongamia glabra*). Mahua (*Bassia latifolia*) Pipal (*Ficus religiosa*) leaves per acre resulted in an increased yield upto 65% over control.

Oil cakes have been found very effective in enhancing the yield of paddy 60 lb. N as oil cake raised the yield upto 88% over control. The high cost, its better utilization as a cattle feed and its non availability in the rice tract, have made, its use limited.

Fertilizer experiments have made it apparent that a combination of 20 lb. N + 20 lb. P<sub>2</sub>O<sub>5</sub> per acre is the best dose for paddy for medium soils. In very light (sandy) soils P<sub>2</sub>O<sub>5</sub> becomes the limiting factor. Nitrogen alone upto 40 lb. per acre had no response without P<sub>2</sub>O<sub>5</sub>, 20 lb. P<sub>2</sub>O<sub>5</sub> alone increased the yield significantly but a combination of both N and P enhanced the yield further upto 80% over control.

As regards different forms of inorganic nitrogen experimental results on cultivators fields reveal that no significant difference exist between the two forms of Nitrogen, urea and ammonium sulphate.

Placing the A/S 3" deep before transplantation, appears to be better than the broadcast application of the fertilizer at the surface.

Recent experiments at Labhandi and Sindewahi have indicated that further raising of the dose above 40 lb. N+40 lb. P<sub>2</sub>O<sub>5</sub> per acre, does not increase the yield further but cause the crop to lodge, earlier before maturity and thereby reduced the yield. Thus with the present cultural practices and varieties, doses higher than 40 lb. N+40 lb. P seem to be uneconomic.

A split application of the fertilizer 1/2 at the time of transplantation and half one month later, appears to be a better practice than the application of a single dose, at the time of transplanting in case of late riping varieties of paddy. In case of early ones a single dose application at the time of transplantation is advantageous.

Among the organic and inorganic forms of Nitrogen, the inorganic form is more effective than the organic one in raising the outturn. A combination of both organic and inorganic is not superior to the inorganic form alone. At Labhandi, 20 lb. N as Farm yard manure increased the yield to the same extent as was done, by a dose of 10 lb. N as ammonium sulphate of 5 lb. N as A/S+5 lb. N as Fym.

In another experiment conducted at Labhandi (Raipur) and Adhartal (Jabalpur) the residual as well as the direct effect of town compost at 40 lb. N was found to be the highest followed by Farm yard manure. Ammonium sulphate increased the yield to the same extent as town-compost but its residual effect was negative. This reveals the superiority of organic manures over the inorganic ones in maintaining the soil fertility over a longer span of time but this does not confirm the superiority of the inorganic fertilizers in effecting immediate increase in the outturns. However a long term trial, is necessary to stabilize the relative values.

## II. COTTON ZONE

1. *Cotton*.—The experimental results of the past 25 years carried out at Nagpur Farm reveal that this crop does not respond to the application of phosphate either alone or in combination with Nitrogen. 20 lb. N supplied through ammonium sulphate drilled with seed can be most profitably used as against any other fertilizer. This dose can however, be usefully increased to 30 lb. N per acre when the soil is heavy and rainfall is normal i.e. about 40" and well distributed. No residual effect of either N, P or this combination applied to crop of cotton, Groundnut and Tur was noticed on the following crop of cotton. The results of experiments on green manuring of cotton with sannhemp and urid (*Phaseolus radiatus*) grown between cotton rows with and without P.O. indicate the advantage of green manuring. It has also been observed to leave residual effect on the following crop of Juar but this residual effect was more perceptible in the year, when the direct effect of green manure was not marked in cotton. Similarly in the year when cotton showed good direct response of green manures no residual effect was noticed on the following crop of juar.

Basal dressings of bulky organic manures like F.Y.M. have been found to increase the effectiveness of inorganic fertilizers like A/S.

2. *Juar*.—Much work has not been done on the manuring of this crop. Evidence of the results shows that the crop responds to nitrogenous manuring and that dose of 15 lb. to 20 lb. N per acre through ammonium sulphate or through any other source is quite effective. This dose can be increased to even 30 lb. N per acre in years of normal rainfall. Application of phosphate is not responded to by the crop. There appears a great possibility of applying green manure to this crop with advantage as the crop is sown about a month later after the rains have set in. The green manure crop can be sown in lines with the first shower rain. Later, seed of juar can be drilled between the lines of the standing crop of green manure which can be buried later when the green manure crop attains sufficient height. In the alternative, if very early monsoon or showers are received the green manure crop can be sown broadcast and buried before the sowing of juar. This practice has given good results in Bombay Presidency and has also given good residual effect on the following cotton crop.

3. *Other Crops*.—Groundnut, Tur, Gram and Teorsa have shown no response to the application of either N or P at Nagpur Farm. Barseem (*Trifolium alexandrinum*).—This is the only crop which is

found to be the best utiliser of phosphate. A linear response to phosphate specially on a land unmanured for many years has been observed. Sulphur did not give any response in the same experiment.

### III. WHEAT ZONE

1. *Wheat*.—Experimental results have revealed the superiority of fertilizers over organic manures in immediate stepping up of the outturn. The increase in yield as a result of application of ammonium phosphate was upto 50% as against 9% with organic manurial treatment at Powerkhera and Adhartal Farms.

Among the fertilizers Niciphos has been found to be superior to ammonium sulphate.

With an effective dose of 15 lb. N per acre the increase in yield due to these fertilizers has been upto 46% and 21% respectively at Powerkhera. Urea has not proved a better substitute for ammonium sulphate as it is found to affect the germination of the crop adversely and consequently the stand of the crop which lowers the yield. Sodium nitrate has gone into disrepute because of its depressing residual effect. There is no response of this crop to P alone. On the other hand depressing effect of P has been observed on Nagpur Farm.

The method of placing the fertilizer by drilling with the seed is found to be superior to broadcast application of the fertilizer. Separate drilling of the seed and the fertilizer calls for extra labour. This has been overcome by a recent device which accomplishes both the operations simultaneously with one extra labourer. The drilling plough is made with two holes. One at the lower end and the other slightly above it. One tube is attached to each hole. The tube fixed to the lower hole is used for drilling the fertilizer while the other for seed. This method also avoids the usual checking of the tube while drilling seed and fertilizer together and thus ensures better and uniform stand.

Presoaking treatments given to seed with water and ammonium sulphate solution have not brought out any material gain. However, the water soaked seed appears to do better especially in dry seasons.

Groundnut cake has given good results but its applications with the seed causes patchy germination specially in dry years. The latter difficulty has been solved by applying cakes 3 to 4 weeks earlier at presowing cultivation.

Experimental results of Powerkhera conclusively show the beneficial residual effect of farm yard manure and the harmful effect of sodium nitrate over a long period of time of 18 years. The plots manured with ammonium sulphate were as bad as control. At Nagpur Farm too, no residual effect of N, P, or their combination, applied to crops of wheat, gram and Teora, was observed on the succeeding crop of wheat. This indicates the superiority of organic manures over inorganic in maintaining the soil fertility and the deleterious effect of fertilizers specially of  $\text{NaNO}_3$ .

Thus from the point of view of both effecting immediate increase in the crop yield and maintaining the soil fertility at a reasonably high level a combined use of organic manures with inorganic fertilizers seems to be a probable measure which requires confirmation after long term trials.

2. *Other crops (Gram, Masur).*—At Adhartal, both these crops have shown good response to the application of phosphate. Apart from the direct effect on these crops a good residual effect on the succeeding crop of wheat has also been observed.

*Valedictory remarks.*—The results of manurial trials are invariably found to alter with the soil type and climatic conditions. Hence, the findings of one place on a particular soil type and climatic conditions may not hold good for another, with changed conditions. This usually causes confusion in case of contradiction in results in the absence of the knowledge of the specific conditions. More stress should be laid on the study of the soil and climatic conditions to make the results more specific and comparable.

Manuring should not be considered separately but the whole cropping system with their economics need be studied. More experimentation is needed for manuring under irrigated conditions especially in view of the expanding irrigation facilities. Study of the effects of micronutrients on various crops also needs experimentation. For preventing of lodging in paddy resulting from a high dose of fertilizers, application of potassium chloride, sodium chloride and the practice of double transplantation require further investigation. Mostly the quantitative effect have been studied and qualitative effects have not been given due attention which aspect is also quite important and must be studied.

#### References:

1. Allon, R. G. (1933)—A consolidated record of the field experimental works carried out by the Department of Agriculture, in the Central Provinces between 1900 and 1930.
2. Stewart, A. B. (1946) Report on soil fertility investigations in India with special reference to manuring.
3. Panse V. G. (1944) Manuring of cotton in India included in technological possibilities of Agricultural Development in India by W. Burns, and revised edition of the above bulletin in 1953.
4. Proceeding of the Second meeting of the crop and soil wing of the Board of Agriculture and Animal Husbandry in India 1937.
5. Misra S. K. and Tiwari B. P. "Krishi Mahavidyalaya Jabalpur Patrika", 1956. Response of irrigated cotton varieties to Nitrogen and different spacings on the Black Cotton Soil.
6. Ekbote R. B. and Kalamkar R. J. Proceedings of the National Institute of Sciences of India Vol. XIX, No. 1, 1953. Manuring for land improvement and crop production.
7. Dave B. B. (1946) Manurial Requirements of Rice in the Central Provinces.
8. Unpublished official records and proceedings of the Research Committee meetings of M.P.

*Role of Organic Manures and Chemical Fertilizers in Crop Production and Maintenance of Soil Fertility*

by

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In primitive times when agriculture was started the cultivator realized before long that the productive capacity of the soil decreased by continued cultivation on the same field for any length of time, but as plenty of good land under natural vegetation was available, he cleaned another piece of land and practised shifting cultivation.

Since "Man is more gregarious than ants and beasts" the desire to live at one in small hamlets developed in him, but shifting cultivation was a great hindrance in setting down permanently in village, so something was to be done to maintain the productive capacity of the soil. This led to the use of manures for maintaining the fertility of the soil.

Thence forward till comparatively recent times only bulky organic manures were used. But when the area under cultivation considerably increased, with the increase of population throughout the world, the available quantity of bulky organic manure fell much too short of the requirements of agriculture. This led to the discovery and manufacture of synthetic manures that is fertilizers.

Thus it is quite clear that the role of manures and fertilizers in maintaining the fertility of the soil and in increasing the crop yields had been realised from the earliest times and now there is no need of substantiating this fact. What is really needed is to find the most beneficial and economic use of manures and fertilizers for increased agricultural production.

In recent times so much has been said and written on this subject that it is very difficult to avoid repetition or to add something quite new to it. However, an attempt is being made here in this paper to draw attention to some of the points that have not received due emphasis so far.

In order to get the full benefits from the limited quantities of manures and fertilizers that are within the reach of an average Indian farmer special emphasis should be laid on the following prerequisites:

1. The fields should be clean cultivated and properly levelled through contour bunding not exposed to soil erosion otherwise a good portion of manures will be taken up by weeds or lost through soil erosion.
2. The soil should have permanent water stable crumb structure. This will provide aeration to the roots and enable them to expand freely and to utilize sub-soil moisture in a large measure.
3. The timing of the application of the manures and fertilizers should be so planned that the plant nutrients are available to the plants when they are needed.
4. Great care should be taken that there is no moisture deficiency in the soils from the sowing time to the harvesting of crops, for which assured water supply must be available.

At the outset it must be fully realized that manuring for soils and manuring for crops are two distinct things; either of which can be overlooked in preparing a manurial schedule.

Among the manures and fertilizers that are in common use in India are bulky organic manures including green manuring and commercial fertilizer including trace elements.

*Bulky organic manures.*—They supply valuable organic matter to the soil and organic matter improves the soil tilth, increases its water holding capacity, improves aeration, regulates soil temperature and has a beneficial effect on soil micro-organisms. It has been estimated that a ton of farm yard manure, on the average, contains about 10 lb. of nitrogen, 5 lb. of phosphoric acid, 10 lb. of potash and sufficient quantities of other plant food elements. Further, certain organic constituents (hormones) are also present in it which are available in promoting and stimulating plant growth.

*Fertilizers.*—The principal substances required by plants in relatively large amounts are water, carbon dioxide, oxygen, and suitable compounds of nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur. Of these, nitrogen, potassium, phosphorus, and calcium are used in such large amounts that in many soils the available stock may become depleted, and returns to the land in the form of manures or fertilizers become essential, if soil fertility and crop yields are to be maintained. In considering the forms and amounts in which such additions or returns should be made to the soil, it is obviously important to bear in mind factors such as the functions of each nutrient in the life of the plant, its inter-relationship to other nutrients, the chemical composition and other properties of the manurial supplement, and the properties of the soil to which it is to be added. For instance, in the growth of the plant, nitrogen is concerned principally in the promotion of leaf growth and bulk, potassium with the efficiency of the leaf as an assimilator of carbon dioxide in the general photo synthetic reactions resulting in the formation of carbohydrates, phosphorus with root development of the plant, and so on. The question of ultimate balance of nutrient in the soil is thus a factor of prime importance. For instance, no addition of potash can be expected to be effective if nitrogen deficiency, such as is common in most Indian soils, is a limiting factor. The whole aim of manuring is to overcome shortages in the soil, and manuring can only become efficient when it is based on what is already present in the soil. The first step, therefore, in the determination of the manurial requirements of a crop is the determination of the manurial contents of the soil on which the crop is to be grown—"Amongst the trace elements known to be necessary for plant growth are iron, manganese, boron, copper, and possibly also zinc, cobalt and aluminium. In addition, many other elements are usually present in plants, e.g., compounds of sodium and other alkali metals, fluorine, chlorine, iodine, nickel, etc. With many of these trace element it is difficult to distinguish between those which are essential for the health of the plants and those which may be taken up adventitiously on which, as in the case of cobalt in various parts of the world, may be without apparent effect on the health of the plant but be necessary for the health of the animal consuming the plant."—Stewart.

The recent discovery that the plants take their nutrients not only from the roots but also from the leaves has placed special emphasis on the healthy developments and efficiency of leaves. For this it will be beneficial to spray the leaves with nitrogenous and potassic fertilizers.

The following fact should always be kept in mind when preparing any manurial schedule :—

Crops remove large quantities of food elements from the soil. A 2000 pound crop of rice removes about 30 pounds nitrogen 20 pounds phosphorus, 60 pounds potassium and 30 pounds calcium from one acre of land. In the same way a 1,400 pound crop of tobacco absorbs and removes about 87 pounds of nitrogen, 102 pounds of phosphorus, 61 pounds of potassium and 84 pounds of calcium per acre, while a ton of farm yard manure i.e. two cart-loads, contain about 10 pounds of nitrogen, 5 pounds of phosphoric acid, 10 pounds of potash.

The beneficial effects of green manuring are well known but it is necessary if some scientist had calculated as to how much of the principal substances required by the plants are supplied by turning down a green manure crop, in addition to supplying large quantities of organic material to the soil.

The fact is that if all the droppings of cattle, horses goats and sheep were collected and used only as manure, even this amount will fall much too short to manure all the cultivated area, hence there is no alternative but to supplement organic manures with fertilizers, in order to maintain and improve the fertility of soils.

Some responsible people contend that fertilizers when applied alone that is without organic manures cause damage to soils. Fertilizers are not responsible to any damage to the soils. It is due to the lack of organic matter in the soils, which is so essential for maintaining and improving the structure of the soil and for producing beneficial effects on the soil micro-organisms. The soils are bound to deteriorate in the absence of organic matter, whether fertilizers are applied or not.

There is another kind of organic manure of which I have no practical experience. It is sullage and sewage water. I have observed its remarkable effects on the improvement of soils, specially Usar lands and in increasing crop yields. Every effort should be made to utilize it wherever possible.

The use of tank-silt as manure which was most common some two generations before, has now been almost given up. I have found it very beneficial of Jowar (Sorghum) and paddy crops and also to fruit trees like citrus, guava and mango trees.

Thus we have to apply both bulky organic manures including oil-cakes and fertilizers also including trace elements to our soils if we wish to maintain and improve the productive capacity of our soils.



*Role of Organic Manures in Crop Production and Maintenance of Soil Fertility—Use of Sugarcane trash and paddy husk in the cultivation of sugarcane*

by

R. K. Tandon, Main Sugarcane Research Station, Shahjahanpur.

*Sugarcane Trash.*—For conserving soil fertility and getting good crops organic manures have been in use since long. Nature has been maintaining soil fertility or perhaps improving it, in its own way by providing cover to the soil. Dried leaves and twigs fall to the ground and almost cover the land below. They help in conserving soil moisture, add humus and get, decomposed adding plant nutrients to the soil.

Artificial covers or mulches on the fields have been used in agriculture in different parts of the world. A preliminary experiment conducted at the Sugarcane Research Station, Shahjahanpur has shown that covering the land in sugarcane fields with sugarcane trash (dried sugarcane leaves) about 2" to 4" thick, i.e. at the rate of about 25 to 30 cart loads of trash per acre, conserves soil moisture, keeps weeds suppressed in the fields and maintains soil fertility.

TABLE I

*Showing the average yield of sugarcane under different treatments*

Treatments	Average height of cane in ft. and inches	Average yield of cane per acre in mds.
1. Trash covering and no cultural operations	9'8"	984.5
2. Normal cultivation with hoeing and weedings.	9'6"	1001.9
3. Central (no cultural) operations and no covering of trash.	9'0"	800.5

As seen from the above, the treated plots wherein trash was spread and no cultural operations were undertaken gave an yield comparable and almost equivalent to that obtained from normally cultivated plots where proper hoeings and weedings were carried out. The average height of plants as well, in the trash covered plots was comparable to that in the normal cultivated plots. Number of weed plants was also less in the trash covered plots and the population of *Cyperus* sp. in them was about 49 per cent. less as compared to the control plots where no cultural operations were undertaken and trash was not spread.

The aforesaid practice in addition to conserving soil moisture and eliminating competition from weeds without the aid of cultural operations has the added advantage of minimising the cost of production due to the curtailment of cultural operations. The damage to the soil by rain drops may also be avoided and this practice may check soil erosion.

It is sometimes apprehended that the trash may serve as a protective cover for some of the insect pests. Bose (1954) has on the other hand reported lesser incidence of top borer, stem borer, root borers, etc. in the plots covered with trash as compared to the control plots where no trash covering was provided. Nevertheless this aspect has to be studied thoroughly. Care may be taken not to use trash from red rot infested fields.

The problem of manuring millions of acres of arable land in India warrants serious efforts to explore all possible sources of materials that are known to improve soil fertility. Paddy husk obtainable in huge quantities has not been utilised as manure, because of its extremely silicious nature which renders its decomposition very difficult. With a view to utilising this by-product of rice mills a preliminary experiment was laid out at Sugarcane Research Station, Shahjahanpur in 1954-55. There were in all the following 5 treatments.

- (1) Control.
- (2) Sanai green manuring + 30 lb. N/acre as  $(\text{NH}_4)_2\text{SO}_4$  + 32 lb. N as groundnut cake.
- (3) Paddy husk @ 40 lb. N/acre + Groundnut cake @ 40 lb. N/acre +  $(\text{NH}_4)_2\text{SO}_4$  @ 40 lb. N/acre.
- (4) Paddy husk @ 40 lbs. N/acre (before sowing Sanai) + Sanai as green manure.
- (5) Sanai green manure + Paddy husk @ 40 lb. N/acre (composted with Sanai) + 32 lb. N/acre as  $(\text{NH}_4)_2\text{SO}_4$ .

NOTE.—Paddy husk contained 0.3 per cent. nitrogen. Ammonium sulphate was applied as top dressing with the break of monsoon.

Analysis of sanai at the turning in, in September indicated that on an average the crop to which no paddy husk was added, was capable of supplying 1,100 lb. N per acre. On the other hand where paddy husk was applied to the field @ 40 lb. N per acre prior to the Nitrogen @ 88.88 lb. per acre.

Average yield of sugarcane in mds. per acre under different treatments has been shown in the table below.

Treatment	Average per acre
1. Control	493 mds.
2. Sanai green manuring 53 lb. N/acre as $(\text{NH}_4)_2\text{SO}_4$ 32 lb. N/acre as groundnut cake	742 mds.
3. Paddy husk @ 40 lb. N/acre + 40 lb. N/acre as $(\text{NH}_4)_2\text{SO}_4$ + 40 lb. N/acre as groundnut	775 mds.
4. Paddy husk @ 40 lb./acre + Sanai green manuring	818 mds.
5. Sanai green + Paddy husk @ 40 lb. N/acre composted + 32 lb. N/acre as $(\text{NH}_4)_2\text{SO}_4$	697 mds.

The experiment is being repeated to obtain the confirmation and to understand the manner in which the addition of paddy husk has proved to be beneficial to the green manure crop and eventually to the succeeding crop of sugarcane.

I thank Shri H. H. P. Singh and Shri P. S. Mathur for supplying the data for this note.

Bose, B. D.—Artificial mulching as an aid to increase Sugarcane Production Proc. Sec. Bie. Conf. Sug. Res. Dev. Wor. Jullundur 1954.

*Role of Organic Manures and Chemical Fertilisers in Crop Production and Maintenance of Soil Fertility*

by

Dr. A. Mariakulandai, M.Sc., Ph.D., Government Agricultural Chemist, Coimbatore

In the past Kolingi, Daincha, Sunnhemp and Pillepesara were recommended as green manure plants and recently *sesbania speciosa* has been recommended as green manure for paddy crop. There is a large volume of data on the yield of these green manure crops and their influence on the yield of the paddy crop in the Agricultural Research Stations of the State. But very little is known of the actual chemical and biochemical changes which this mode of manuring paddy induces in the soil. Hence a stage has now been reached when the valuable data accumulated in the form of yield results have to be correlated with more specific and scientific data so that it will be possible to state as to what particular biochemical or chemical set up in the Soil leads to maximum yields and how best this optimum chemical and/or biochemical condition in the soil, can be achieved through judicious green manuring supplemented with inorganic nutrients and the particular green manure plant which would best suit a given condition.

(a) *Decomposition of Plant Material.*—The biochemical decomposition of plant residues in the soil is not understood very clearly because of the lack of suitable methods of analysis and on account of complications arising out of the synthesis of microbial protoplasm and the excretory products of microbes both of which cannot be differentiated from the plant residues. Even more than Carbo-hydrates the protein portion presents great difficulties and its transformation during the rotting process is not at all known to any extent of accuracy.

But what is well understood is that for the decomposition of the Carbo-hydrate of the plant by micro-organism, nitrogen is necessary. When the plant residues contain only small quantities of nitrogen (such as in materials like straw containing 1.2% nitrogen with a wide C:N ratio) the micro-organisms take up the extra nitrogen required for them from the soil and to that extent the soil nitrogen becomes immobilised and is temporarily unavailable to the crop. But if the plant material added to the soil contains more than the requirements of the soil micro-organism (1.8 per cent. Nitrogen) the excess nitrogen is mineralised as ammonia or nitrate for the use of the Crop. The Nitrogen composition of the green manure for immobilisation and Mineralisation, are based on data obtained under a variety of conditions elsewhere. The nitrogen level for such mineralisation under swamp paddy conditions of Madras is not yet worked out.

Thus the rotting of nitrogen poor material in soil will lower the content of mineral nitrogen while rotting of nitrogen rich material will increase it. This probably accounts for the lowered yield of paddy crops when very high doses of green manure crops have been turned in without adequate nitrogenous supplement. For a given carbon and nitrogen content in the decomposing material therefore the amount of soil nitrogen locked up during decomposition increases with the speed of decomposition of carbohydrates present in the rotting material. Hence in green manuring it is of paramount importance to know the critical nitrogen level.

(b) *The Agronomic Practices and the C/N ratio.*—The practice now obtaining in the matter of green manuring varies in that in some places, the green manure seeds are sown in January itself during the time of the harvest of the paddy crop and the crop is allowed to fully mature up to July before it is turned in. The yields are quite high if summer showers are good. Some ryots wait for the summer showers in March-April for the sowing of the green manure crop and turn it in July, while very many sow early in June when water is first received in the channel and plough in the immature crop in July or August. Thus broadly there are the following stages of green manure crop which are ploughed in (three.)

1. Green-Manure grown—January to July (6 months crop).
2. Green-Manure grown—April to July (4 months).
3. Green-Manure grown—June to July (2 months crop).

These three stages of maturity of the green manure crop naturally will have a different C/N ratio. The first being wide, the second intermediate and the third narrow C:N ratio. The ryot by empirical means adopts a dosage in relation to his yield of paddy based on past experience and in very many cases he has no idea as to what is the optimum dosage of green manure he has to add nor an idea as to the amount of nitrogen he is incorporating. The Agricultural Research Stations adopt 5,000 to 7,000 lb. of mature green manure. It is now therefore necessary to study what is the optimum C/N ratio under the different practices and stages in which the green manure is ploughed in.

(c) *Nitrogen as a major nutrient.*—As already indicated briefly the ratio between the Carbon and nitrogen of the material used is of great importance in the decomposition because, the nitrogen mineralised from the organic sources maximum, intermediate or narrow depending upon the C/N ratio. Earlier researchers like Harrison and Aiyer at Coimbatore had believed that green manuring did not yield any nitrogenous nutrient to the plant but only helped to aerate the soil under water-logged conditions. Subsequent findings by Lord et al (1932) show green manuring as having a dual function of making nitrogen available to plants as well as of increasing the supply of oxygen by promoting algal growth. Recent findings in the Chemistry Section (unpublished data) indicate that green manures give significantly better yields than the no manure but not as effective as ammonium sulphate on the same nitrogen level. This aspect of green manuring as a supplier of nitrogen under optimal C/N ratio is still to be elucidated and needs systematic study.

(d) *Fixation of Nitrogen.*—Further, from the bacteriological aspect, a great deal has been written about the nitrogen fixed by legumes. No clear information of the quantities of nitrogen so fixed by the various green manure crops and the conditions favourable for maximising such fixation are available. Various soil conditions as well as differences in the composition of the nitrogenous and the accompanying non-nitrogenous organic substances lead to the development of distinctive and different micro-flora capable of decomposing the plant materials. The carbon nitrogen metabolism of these micro-organisms is different and this leads therefore to difference in the amounts of ammonia liberated in the free state. The optimum conditions and the variations under a given set of conditions, root nodulation, fixation of nitrogen etc., have to be studied from the fundamental and applied aspects of Bacteriology.

(e) *Phosphorus as a factor.*—Current research on soil-plant relationship has brought out the importance of organic phosphorus in plant nutrition. Black and Goring (1955) have pointed out that the content of organic phosphorus in soils is correlated positively with the content of organic carbon and nitrogen. Thompson, Black and Zoellner (1954) have shown that organic phosphorus mineralisation is correlated positively with organic nitrogen mineralisation. Hence the two major nutrients, nitrogen and phosphorus are inter-related in mineralisation, and consequently in availability; and it would be necessary to establish the optimum relationship of carbon, nitrogen and phosphorus in the green manuring of paddy to get maximum benefits.

The inorganic fertilisers containing high amounts of nitrogen and phosphoric acids have been found in numerous experiments to be very useful in supplying the immediate requirement of the crop and for stepping up production.

A judicious combination of inorganic and organic manures is better than either of these applied singly. For, the inorganic fertilisers will supply the immediate needs of plant nutrition of the crops, while, the organic manures will have to be mineralised before they become gradually available to crops. Much work remains to be tackled to settle the best combination of organic and inorganic manures for the different crops and under the different soil climate zones.

### PAPERS ON SUBJECT No. 3

#### *Notes on the utility of rapid soil tests for evaluating the Soil productivity and use of Fertilisers*

by

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Judicious use of fertilisers is one of the important steps towards increasing the production of crops. Government of India realising the importance of fertilisers in our agricultural economy is making great efforts to increase the production of fertilisers and to popularise their use. And farmers are now becoming more and more fertiliser conscious. The fertiliser practices now followed are based on fertiliser recommendations given out from field experimental stations and the farmers' past experience. Because of considerable variation in soil and cultural practices from place to place the field experiments carried out at few experimental stations will only give a general recommendation for the tract. In order to get the maximum benefit from the use of fertilisers and prevent their wastage it is necessary to apply fertilisers based on soil tests carried out at large number of places where the fertilisers are required to be used. For this purpose the soil tests have to be rapid, so that a large number of tests can be carried out in a short time. The rapid soil tests for evaluating the need for application of fertilisers is a new branch of study, which is attracting the attention of Agronomists, Soil Scientists and progressive farmers in different parts of the World. The research on this highly useful subject is still, however, in the formative stage and the methods have not been thoroughly worked out to suit varying conditions.

In soil tests one wants to know two things about the soil :—

1. Which element or elements are deficient in the soil that limit the crop production.
2. What is the adequate amount that is required to be added to get an economic increase in the yield.

To get answers to these questions various methods have been evolved from time to time and some of the important ones are described below :—

(i) *Chemical analysis of the Soil.*—One of the major objectives in soil analysis is to measure the available forms of nutrients and correlate them with crop growth and response to fertiliser. The establishment of correlation is pre-requisite for any successful method of soil analysis for different nutrients. Rapid chemical tests have been described by Peech (1948) and Miles and Reed (1948) in *Diagnostic Techniques for soils and crops* (published by American Potash Inst.) Chakravarti (1955) has worked out rapid chemical tests to determine the nutrient status of some of the West Bengal soils. So it is necessary to study the different methods and work out the rapid tests to suit different conditions.

(ii) *Biological Tests.*—Chemical analysis of the soil has its own limitations and for many elements it is difficult to determine the available portion. As the plant is a better indicator of the nutrient status in the soil, various methods have been worked out to test the soil by growing plants. Biological methods to test the soil are used in conjunction with or when it is not possible to get response correlation with soil tests. Some of the methods are described below :—

(a) *Mitscherlich Pot Method.*—This method is essentially a fertiliser test in pots in which the soil requirement for N, P and K are determined simultaneously. The percentage ratio of the yield from the unfertilised soil to the maximum yield obtained from complete fertiliser treatment is found, then the plant nutrient reserve in the unfertilised soil can be read in pounds per acre from the table prepared on the assumption of constant effect factor for each nutrient. On the basis of the amounts of plant nutrients thus found, the yield tables can be used further to calculate the percentage increase in yield corresponding to a given addition of plant nutrients and this serves as basis for calculating the profit that can be expected from the fertilisers.

(b) *Lettuce Pot Culture.*—This method have been evolved by Jenny (1944) modifying the Mitscherlich Method. This method consists of growing leaf lettuce in pots. Lettuce is selected because it has a short growing season and relatively free from pests and diseases.

Plants are grown in pots with varying fertiliser treatment. The plants are then harvested, dried and weighed. The relative percentage weights obtained, comparing treatments with corresponding full treatment are used to estimate nutrient deficiencies. A tentative scale of deficiencies is then prepared, depending upon the trends indicated by additional data obtained with field experiments. The method is described in detail by Vandecareye (1948) in *Diagnostic Technique for soils and crops* (Published by American Potash Inst.).

(c) *Sunflower Pot culture Test.*—The principle of the method consists of vigorous extraction of nutrients by passive plant growth on a small quantity of soil. Sunflower is a vigorous growing plant. The visible differences in growth of sunflower plant and difference in weight of dry matter as affected by fertiliser treatments is noted and deficiency levels recognised.

(d) *Neubauer Seedling Method.*—This technique is based on the principle of intensive uptake of plant nutrients by a large number of seedlings grown on a small quantity of soil. The plant nutrients removed by seedlings is quantitatively determined by chemical analysis. In this technique as developed by Neubauer and Schneider (1923), 100 rye seedlings are grown in 100 gms. of soil mixed with nutrient free quartz sand. The seedlings are removed 15 days after sowing, and analysed. It is a useful test, although originally designed for P, K, but now with modification, it can be used for wide range of nutrients.

(e) *Plant Tissue Tests.*—Plant tissue tests have been worked out by Wallace (1951) for various nutrient elements and for different crops. The tissue tests with certain standards fixed will enable to

determine the deficiency levels from the plants growing in the field. The tests can be used as a guide for subsequent fertiliser programme. The tests can also be used for correcting the deficiency levels in the standing crop. The tissue test methods have been further elaborated by Clement (1951) and *crop log technique* has been developed to aid application of fertilisers to standing crop as per its nutrient status.

(f) *Visual method of diagnosis of nutrient deficiencies in the plants.*—In this method deficiencies are recognised by specific symptoms. The deficiency symptoms are mainly exhibited on the foliage of the plants, when a nutrient element is insufficient for healthy growth. Before the method can be used, the special symptoms for each deficiency element and for each kind of plant must be developed in sand culture and plated in colour. The colour plates are then used for diagnostic purposes. This method has its limitations, but however, the advantage of this method is that, it is rapid.

(g) *Bioassay Method.*—In this method certain micro-organisms are used to test the available nutrients in the soil. This method is particularly useful in determining the minor elements deficiencies which otherwise by chemical analysis are very difficult to determine. The test organism like *Aspergillus niger* is commonly used for determining the deficiencies of zinc, copper and Molybdenum. The mycelium developed in a flask where a weighed quantity of soil is put with different levels of the element to be studied, is observed, weighed and analysed to determine deficiency levels.

*Recommendation.*—Various methods of testing the soil have been evolved to suit different conditions and requirements. However, the methods are mainly tools in the hands of Agronomist and they have to be used with thorough understanding of soil-plant relationships and cultural practices followed in the tract. In India where the land holdings are small and where cultural practices vary considerably from place to place, the development of rapid tests to aid fertiliser recommendation is an urgent need, so that there is no unnecessary drain on the meagre pockets of our farmers. To work out the rapid tests and apply them for fertiliser recommendations it is suggested that a chain of soil and plant laboratories be opened all over the country situated in different tracts, representing different soil types and cropping practices. This organisation can conduct a large number of scattered field trials and carry out regular soil and plant tests and evolve suitable method of advisory work. The staff of each such laboratory can be as follows :—

1. Agronomist.
2. Plant Chemist
3. Soil Chemist.
4. Junior Agronomists (Field Officers).
5. Laboratory Assistant.

The laboratories can be well equipped and situated at a central place where electricity is available.



Benefit derived from such an organisation will be :—

1. Increase in the production of crops.
2. Prevention of the wastage of fertilisers.
3. Cutting down the cost of production of crops.
4. Advice to Government as regards the fertiliser needs of the Country.

*References:*

- (1) Chakravarti, S. N. (1955)—Nutrient Status of some West Bengal Soils as determined by rapid chemical methods.—Indian Soc. Soil Sci. 83:86.
- (2) Clements, H. F. (1951)—Environmental influences on the growth of sugarcane 'Mineral Nutrition of Plants'.—Wisconsin Univ. Press, 451:469.
- (3) Jenny, H. (1944)—Nutrient level determination by green house and field methods of studying fertilizer needs. Unpublished work referred by Vandecaveye (1948).
- (4) Miles, I. E. and Reed, J. F. (1948)—Operation of State Soil Testing Service Laboratory. Diagnostic Techniques for Soils and Crops (American Potash Inst.) 87:103.
- (5) Neubauner, H. and Schnicider. W. (1923)—in German referred by Vandecaveye 1948.
- (6) Peech, M. (1948)—'Chemical Methods for assessing soil fertility'—Diagnostic Techniques for Soil and Crops (American Potash Inst.) 1:52.
- (7) Vandecaveye, S. C. (1948)—Biological Methods of determining nutrients in soil—Diagnostic Techniques for soils and crops (American Potash Inst.) 199:230.
- (8) Wallace, T. (1951)—The Diagnose of Mineral Deficiencies in plants. H. M. St. office.

*Use of Rapid soil tests for assessing soil fertility and determination of fertilizer seeds*

by

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**Introduction**

Rapid chemical tests for the determination of fertilizer and lime needs of soil have gained wide spread application in advisory work in many other countries during the past decade. The objective of such chemical tests is obviously to know to what extent crops will respond to fertilizer when applied and at the same time telling whether such an application will be economically feasible.

Soil tests can be used to show the amount of available supply of major plant nutrients like phosphorus, potassium and Nitrogen present in a particular soil; but in no case it is known how to measure the exact quantity of available supply. For this reason empirical tests have been developed. Since soils vary widely, a soil test that gives good results in one area may give poor results in another. It thus becomes necessary to try out each test in the soil area of which it is to be used. If, therefore, these empirical tests are to be of value, the results obtained must be correlated with the available supply of the nutrients in the field. Information of this kind is usually obtained from field experiments which when correctly planned and carried through give the increase in crop yield per unit weight of fertilizer under the given conditions. Only by comparing the soil tests value with the results obtained from fertilizer experiments in the field, the accuracy of a particular test can be determined.

Field experiments to that extent answer one important question, but such experiments are of long duration tedious and by no means easy to carry out on all types of soils occurring in our country. Therefore it is only natural that new and easier methods have been sought. Among these methods chemical analysis of soil samples are by far the most common and cheap. By analyses of soils an attempt is made to find some sort of a figure supposed to express the soil ability to furnish crops with necessary quantities of mineral nutrients during the growth period particularly such nutrients containing nitrogen, potash and phosphorus. If however, one can standardize the tests on the basis of field experiments recognize its limitation and does not use it as the sole guide in determining the fertility of the soil, soil tests can be a valuable aid in diagnosing the fertility status of a soil.

### **Soil fertility and nutrient balance in soil**

Soil fertility refers to the nutrient status within the soil. It includes quantity, availability and rates between different nutrients. A fertile soil can be defined as that soil showing or capable of supporting a well balanced and adequate supply of soil nutrients in available form to meet the requirement of the growing plant during different stages of growth. The question of nutrient balance in the soil is of great importance if the application of fertilizers to be placed upon a scientific basis. If the content of a nutrient in the soil is originally low so that its concentration in the leaf is near the minimum required for normal growth, the addition of other nutrients to the sort in large amounts may cause the content in the leaves of the elements originally present in small amounts to fall below the critical minimum and deficiency symptoms of this element may be induced as a result of upset of proper balances. Whereas if the mineral concentration within the plant is above the critical level throughout the entire period of growth, most likely plants will not respond to new additions of nutrients. Normal growth of plants require merely a balance between nutrients whereas maximum growth requires a proper balance together with optimum concentration. Soil tests can be made useful to give the above needed information only when their relative utility is established by adequate correlations with crop responses for different soils and crops. Therefore, systematic examination in regard to their nutrient status is the most useful tool in

determining on a large scale the needs of phosphate and potash in soils in each region and soil analysis will turn out to be valuable means to the farmer.

### Procedure

In a soil test programme, a summary of soil testing data on a state or district or on a type of farming or village basis shows general fertility level. Such a summary is of value to local agricultural workers and extension worker as a broad basis for estimating fertilizer needs in a district or in a group of villages. Similarly such a summary aids research workers in orienting certain of their research investigation.

In such a programme invariably the test results for phosphorus and potassium are rated as VL (very low) L (low) M (Medium) H (High) and VH (very high). A reading of L or VL means that soil does not contain enough of a plant element for maximum production with average fertiliser. At the M and H levels sufficient plant nutrients should be applied to equal the expected crop removal and other losses. With a VH level in soil somewhat less than normal fertilization can be applied resulting in utilisation of the soil reserves. The organic reported in terms of per cent or organic carbon and the acidity reported in terms of pH.

Interpreting the results of soils and making fertilizer recommendation of various crops is one of the most important steps in the soil testing procedure.

### Soil Test results

**Nitrogen.**—Nitrogen is one of the most commonly deficient elements in our soil. Soil organic matter contains about 5 % N each per cent. of the organic matter fraction then represents 20,000 lbs. of O.M. or 1,000 lbs. N in the surface 6" depth i.e. 20,00,000 lbs. of soil. But from the practical experience laboratory method for determination of available nitrogen in soils must, in some way or another, express the rate of ammonia and nitrate formation. The method that is being used to assess the nitrogen supplying power of soils are those of involving the estimation of available Nitrogen after incubation at optimum moisture and temperature. The work done on paddy and wheat indicates that alkaline permanganate method is rapid and promises good correlation with crop responses (S. P. Raychaudhuri, B. V. Subbiah and M. P. Sinha, 1955).

### Potassium

Like nitrogen, the element potassium is absolutely necessary for the growth of all crops. But the potassium deficiency in our soil is yet not very apparent. The form in which potassium occurs in soils include soluble exchangeable, primary minerals and secondary clay minerals. It seems therefore very reasonable to determine soil content of exchangeable K and take this as an expression for its content of "available potash". Among several methods which have come into use for the estimation of available potassium (1) 1% cit. acid (2) Normal ammonium acetate (3) Morgan's universal extractant (4) dilute acids are found useful. The amount of potassium extracted by

above tests may be determined by a turbidimetric method or with a flame photometer. But a number of factors are involved in making sound potassium fertilizer recommendations from the soil test. All these must be considered in the interpretation of the potassium test.

### **Phosphorus**

Amongst several procedures for the estimations of phosphate (1) Olsen's method using 0.5 mol. sodium bicarbonate as the extracting agent. (2) Bray's methods using ammonium fluoride and the strengths of hydrochloric acid (3) Troug's procedure using N/500 sulphuric acid are promising. The reliability of various phosphorus extractants for determining the phosphorus needs of Indian soils is being investigated. Trials with various phosphorus extracting solutions have shown that Olsen's method and Bray's method are found to give good correlation with crops response on wheat and paddy on Indian Soils.

### **Organic carbon**

As the estimation of total nitrogen by K method is very time consuming, organic carbon is usually estimated to assess the carbon and nitrogen status of soils.

### **Soil reaction pH**

This test is valuable if the acidity or alkalinity of soil has been correlated through field investigations.

### **Soil Test Summary**

A soil test summary furnishes specific information that can be used to assess the fertilizer needs of an area. Such summaries when prepared from year to year will be important guides in assessing the fertilizer changes taking place from year to year. The soil tests summaries are prepared in such way that the table shows the percentage of samples of low content of both potassium and phosphorus as well as percentage of samples of high content of the nutrients. These tables are very useful in determining the ratio of fertilizers needed. This information is particularly important for the fertilizer distribution in different parts of the country.

### **Soil test and increased use of fertilizers**

When fertilizer recommendations are made to the farmers on the basis of the soil tests, the increased use of fertilizers can result only to the extent to which the soil test recommendations are effectively put into practice by the farmers.

Thus the problem of the fertilizer industry as well as the soil scientist is how to make the farmers uniformly make use of the soil testing facilities and actually apply the recommendations. If soil testing service comes into extensive use and if the recommendations are followed, the fertilizer industry will have to expand extensively.

With the increased production of fertilisers expected to be produced in several factories under the Second Five Year Plan, there is the need to carry the advantages of sound fertilizer use practices to each and every farmer in the country.

*Utility of rapid soil tests for evaluating soil and productivity and the use of fertilisers*

Department of Agriculture, Andhra, Bapatla

Rapid chemical tests in one form or other are used in many countries as an aid in furnishing advice to farmers in regard to fertilizer use and soil management. In carrying out these tests, use is made of mildly acid or alkaline solutions, often heavily buffered, to extract the various readily available plant nutrients. The rapid chemical tests on soils are usually made for determining deficiencies in Nitrogen, Phosphorus and Potassium.

The extractant to be used varies with the soil type and has therefore, to be determined for the tests to be satisfactory. Studies are in progress at the Chemistry Laboratories of the Agricultural College, Bapatla, to determine a suitable method for assessing the readily available Phosphoric acid in soils.

*Plant Tissue Tests as a Mean to Determine Soil Deficiency in Nutrients*

by

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*I. Introduction*

Malnutrition of plants manifests itself in various forms. This malnutrition is an indication that plant nutrients, essential for plants, are not being supplied by the soil to the extent they are required for development and growth. Obviously an unbalance of nutrition is thus recorded. Every essential element is required for some functional activity or the other. Some are essential in the synthesis of protoplasm, some for translocation functions, some for transformation of simpler compounds to complex ones and *vice versa* and so on. All these functional activities result in addition of organic substrate and, therefore, in production of dry matter. Deficiency means, set back to these activities.

Side by side with the development of the methods of soil testing for determination of the nutrient status of soil for maintaining plant growth at normal level in any agro-climate, methods of testing the nutrient status of the cell sap in tissues have also been standardised. When the plants are well nourished the excess of nutrients are stored in their tissues and are utilized as growth proceeds. Chemical tissue test show deficiency when tests indicate negative results. According to Hoffer and Krantz (1951). "These chemical tests are invaluable in the field when other complicating factors due to climate, diseases or pests are involved. The tests can be used at any time during the growing season." This, however, is not true of rapid soil tests. Initially the soil may show excess of potassium. Luxury consumption may take place in the early stages and availability may decrease when it is most needed for crop growth. Similarly initially the soil tests may indicate high nitrogen but some of it may leach

down or pass out of soil by erosive processes or excessive weed competition. In the same way phosphorus may be initially available because it was present in the organic form, later on may become unavailable because of chemical fixation. Under all these circumstances chemical tissue tests provide a 'firmer basis for planning changes in the soil management and fertilizer programme.'

## 2. Storage of nutrients in the plant

(a) *Nitrogen*.—The nitrogen from the soil is absorbed generally as  $\text{NO}_3$  or  $\text{NH}_4$  ions. According to Conrad (1934) less energy is required to incorporate the nitrogen of  $\text{NH}_4$  ions into proteins than from  $\text{NO}_3$  ions. Normally  $\text{NH}_4$  ions are more readily absorbed from the alkaline soil solution and  $\text{NH}_4$  ions from acid soil solution. When excess of ammonical, nitrate or organic Nitrogen is applied to the plants it is absorbed and translocated to the growing points. These  $\text{NH}_4$  ions and organic nitrogenous compounds are either synthesised into proteins or are oxidised into nitrates and stored in tissues for future use. It is the nitrate status which is determined by chemical tests.

(b) *Phosphorus*.—A large part of phosphorus in plants is soluble in water. In alfalfa, cabbage, turnips respectively 75, 61 and 80% of the total has been found to be in water soluble form. Most of the Phosphorus is stored in protein form in seeds and fruits until then it exists in plant tissues in water soluble state. The amount present depends upon the availability in the soil. Excess not utilized for plant growth, is stored in the tissues. Major portion of it is stored in the stem and the least quantity in the leaves (Hortwell-1917). In the stem higher percentage of phosphorus is associated with regions of rapid growth. It tends to equalise when plants are phosphorus starved (Mac Gillivray-1927). Matter (1929) found the presence of phosphorus in plant tissue sap was in proportion to the amount present in the soil and confirmed subsequently by various workers (Miller-1938).

(c) *Potassium*.—The growing points are especially rich in potassium. It is usually withdrawn from old tissues into freshly developed ones Latshaw and Miller (1924) found 45% of K in leaves, 32% in stems; 14% in grain, 5% and 4% in roots of a corn plant. Hartt (1934) observed potassium migrating out from dying leaves of sugarcane to living ones. Potassium in the soil is absorbed as  $\text{K}_2\text{O}$  ion. Petrie (1934) is of the opinion that potassium occurs entirely in the ionic form in the cell sap and cytoplasm. It is readily soluble in water (Janssen & Bartholomew-1922) and can be readily extracted with cold water (Weaver-1911 & Kostytschew and Eliasberg-1920). The amount absorbed from the soil by plants is directly related to the relative availability there, when excess is available luxury consumption occurs (Johnston & Hoagland-1929; Wallace-1931 and Lart-1934).

## 3. Selected tissues for tests

The temporary storage organs are usually the tissues which contain excess of these nutrients. In most plants belonging to Gramineae family the tissue commonly employed for test is the mid-rib of the petiole. Hoffer and Krantz (1953) have employed base of stalk of young corn plant for nitrate, phosphate and potassium test, when the corn is tasselling the tissue of stem below tassel is used for tests.

For grain Crops also they found the same tissue tests to answer the purpose. Krantz & Raheja (unpublished) found that mid-rib of central 3 leaves of Sorghum and paddy gave very accurate tests of deficiency of the three elements. The petiole of the leaves of cotton gave similar results. The use of these tissues avoids the employment of such tissues which usually have excessive accumulation of nitrates, potassium and phosphate.

#### 4. Chemical tissue tests

(a) *Tests for nitrate.*—The most common field test used for studying the relative abundance of nitrates in plant tissues is the diphenylamine test. The solution consists of 1% diphenylamine in concentrated sulphuric acid. It is qualitative test reagent. On the selected tissue 2-3 drops of the solution are dropped. A dark-blue colour indicates abundance of nitrates, a pale-blue indicates adequate quantity and no colour suggests deficiency of nitrates.

But the more accurate test is the Bray's modified test described in "Diagnostic Techniques for soils and crops". The reagents consist of the following:—

*Reagent I.*—BaSo. (100 gms.) + Powdered Zn (1gm) + MnSO<sub>4</sub> (10 gm). This powder mixture is thoroughly ground and well mixed.

*Reagent II.*—10% acetic acid made nitrate free by addition of a little powdered zinc.

*Reagent III.*—To 50 ml. of reagent II is added approx: 0.25 gm. of mixture equal parts by weight of alphanaphylamine and sulfanilic acid.

For comparison nitrate solutions in 10% acetic acid are prepared. The standard solution is 20 P.P.M./N.

Finely cut plant tissue material, 1/4 tea spoonful is placed in a test tube. To this is added 1/4 tea spoonful of reagent I and 10 ml. of reagent II. This is shaken for one minute. To this is added 6 drops of reagent III. This is again shaken and allowed to settle for observing colour development against the standard solution of nitrate in 10% acetic acid.

Both these tests have been found to detect nitrate nutrient deficiency in maize, wheat, oats, barley, rye, rice and Sorghum & cotton. The diphenylamine test is applied in the field for rapid testing of nitrate deficiency in the crop while material is brought from the field for test of nitrate deficiency when Bray's modified test is put into service. The colour variations in both cases indicate sufficiency or deficiency of the nutrient.

(b) *Test for Phosphate.*—Purdue plant tissue test has been found quite serviceable for testing deficiency of phosphate in various crops. Two reagents required are as follows:—

*Reagent I.*—It consists of 4 gm. of molybdate in 500 c.c. of distilled water. To this is added 63 c.c. of HCl (Conc.) and 437 c.c. of distilled water. While these are being added the ammonium molybdate solution is constantly stirred.

**Reagent II.**—Dry stannous chloride or stannous oxalate. Young plant tissue is cut and a tea spoonful of it is placed in a vial. To this is added 10 c.c. of reagent I. After shaking it thoroughly for 60 seconds reagent II, equal in volume to a mustard seed is added to the solution. This is again shaken for a little while.

A Dark-blue solution indicates abundant supply of inorganic phosphate; a medium-dark blue indicates adequate supply; and a light-blue, greenish or yellowish green colour exhibits deficiency of phosphate. This test has been found to work on maize, small grains including rice, cotton and Sorghum.

(c) *Test for potassium.*—For testing potassium deficiency Purdue plant tissue test has been quite high efficiency. The reagents are as follows :—

**Reagent I.**—Sodium cobaltinitrite—5 gms. and sodium nitrite—30 gms., are dissolved in about 50—70 c.c. of water. To the solution 5 c.c. of glacial acetic acid is added and to volume of solution is made upto 100 c.c. This solution stands over for several days. 5 c.c. of this solution is added to 15% solution of sodium cobaltinitrite. The pH of this solution is adjusted to pH5 with acetic acid.

**Reagent II.**—Ethyl alcohol (95%).—For carrying out the test cut material,  $\frac{1}{2}$  tea spoonful, is placed in a glass vial. To the vial 10 c.c. of Reagent No. I is added and shaken for one minute. Then 5 c.c. of Reagent No. II is added and mixed thoroughly. The vial lies for 3 minutes.

The brownish-yellow turbid solution colour indicates high concentration of potassium, yellow turbid solution indicates moderate quantity and no colour acute deficiency of phosphate.

Purdue University supplied colour charts for Phosphorus test and potassium test. Comparison of colour with these colour scheme charts provides fairly accurate idea of the excess or deficiency of these nutrients.

### 5. Necessary precautions

According to Hoffer and Krantz (1953), "It is imperative to use all possible tests for nutrient elements correctly to diagnose deficiency symptoms. For example, the very high phosphate tests may be misleading when nitrates and/or potassium are deficient in the plants used. Medium tests for nitrates, phosphates and potash indicate adequate amount in the plant at the time of testing. They are particularly important when the ears (of corn) are maturing, in order to ascertain whether all of the plant nutrient were adequately supplied in the fertilizers applied to the crop."

This is very solutary precaution and its disregard will not give correct idea of deficiency of nutrients. The balance of nutrients in the plant system is a factor of high importance for normal development and growth of plants.



## BIBLIOGRAPHY

- Conrad, J. P. (1934) . . . . . Physiological acidity and alkalinity inorganic nitrogenous compounds in solution cultures.  
*J. Am. Soc. Agronomy* 26 : 364-72.
- Hart, C. E. (1934) . . . . . Some effects of potassium upon the growth of sugarcane & upon the absorption and migration of ash constituents, *Plant Physiol.* 9 : 399-457.
- Hart C. E. (1934) . . . . . Some effects of potassium upon the amounts of protein and amino forms of nitrogen, sugars and enzyme activity of sugarcane, *Plant Physiol.* 9 : 452-490.
- Hartwell, B. L. (1927) . . . . . Relative crop response to potash,  
*J. Am. Soc. Agron.* 19 : 479-82.
- Hoffer, G. N. and Krantz, B. A. (1951) . . . . . Deficiency Symptoms of corn and small grain, Chapter III "Hunger Signs of Crops", Washington, D.C.
- Janssev, G. and Bartholomew, R. P. (1929) . . . . . The translocation of potassium in tomato plants and its relation to their Carbohydrate and nitrogen distribution,  
*J. Agr. Res.* 38 : 447-65.
- Kostytschew, S. and Eliasberg, P. (1920). . . . . Über die Form der Kalium Verbindungen in lebenden Pflanzen gewebe, *Z. Physiol. Chemistry* 111 : 22-235.
- Krantz, B. A. and Raheja, P. C. (1953) . . . . . Estimation of nitrogen deficiency by Bray's modified method in Sorghum, rice and cotton (unpublished).
- Latschaw, W. L. and Miller, C. E. (1924) . . . . . Elemental composition of Corn plant,  
*J. Agr. Res.* 27 : 845-4.
- Mather, T. H. (1929) . . . . . The effect of fertilizers upon the forms of phosphorus and the amount of phosphorus, nitrogen C sillile in Lays, *Soil. Agri.* 10 : 35-63.
- Johnson, F. S. and Hoagland, D. R. (1929). . . . . Minimum potassium level required by tomato plants grown in water cultures, *Soil Sci.* 27 : 89-109.
- Miller, C. E. (1938) . . . . . "Plant Physiology" Mc Graw Hill Book Company N.Y.
- Mc. Gilliusiay, J. H. : (1927) . . . . . Effect of phosphorus on the composition of the tomato plant, *J. Agr. Res.* 34:97-129
- Petric, A. H. K. (1939) . . . . . The drift contents of potassium & calcium with age of plants, *Australian, J. Exp. Biol Med. Sci.* 22 : 99-110.
- Wallag, T. (1931) . . . . . Chemical investigations relating to potassium deficiency of fruit trees, *J. Pom. & Hort. Sci.* 9 : 11-2.
- Wcevers, T. (1911) . . . . . Untersuchungen über die Lokalisation and Funktion des Kaliums in der Pflanze, *Rec. Trav. Bot. Néerland.* 8 : 289-332.

*Utility of Rapid Soil Tests for evaluating soil productivity and the use of fertilizers*

by

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Evaluation of fertilizer needs of a soil and the type and quantity of fertilizer required for profitable yield of crops is indispensable to economic fertilizer usage. The most reliable method for the evaluation of fertilizer requirement of a soil is by the actual field experimentation method where varying quantities of fertilizers are applied on the field, and the responsiveness is measured by the growth and yield of crops. This method, however, is slow and time consuming and offers data only on specific crops and soils on which such tests are carried out. The alternative method for this purpose would then be the estimation of available nutrients in the soil from which deficiencies of available plant food together with the quantities required for making good these deficiencies could be worked out. During recent years, therefore, soil testing in the laboratory has become very popular all throughout the world and almost everywhere there is a keen desire with farmers to know the plant food requirements of their soil through such techniques. In western countries these methods have been found to be satisfactory and the values obtained from the modern methods of testing have been reported to bear significant correlations with the actual responses from field experiments.

During the last two decades Rapid Soil Tests have become very popular with farmers and extension workers in Western countries, more so in U.S.A., for evaluating the nutritional deficiencies of their soils. Elements, both major as well as secondary plant food, in soils are estimated by a large number of different but fundamentally similar rapid methods. In all these methods use has been made of a variety of extracting solutions which on simple shaking extract the plant food either partially or completely. One or two drops of the extract are used for colour development with specific chemical reagents. These methods, though highly acclaimed by a large section of soil workers in U.S.A. have failed to receive universal recognition because of their limited applicability on soil conditions other than those on which they have been worked out. Even if some data on nutrient contents of soils tested through rapid methods are obtained they have to be supported through actual responses obtained on the field by application of requisite doses of fertilizers. This aspect of investigation has not been satisfactorily worked out and the evaluation of fertilizer need of soils had been more of an arbitrary nature. Even where correlations have been worked out with actual field response it cannot be said with certainty that results obtained under one set of conditions will also hold good under completely different soil conditions. But Rapid Soil Testing has served useful purpose in humid and acidic soils where chief soil requirements are lime and phosphorus which can be easily measured through rapid and reliable estimation of soil reaction and some of the known methods of determination of available phosphoric acid in soil. A number of other plant nutrient contents could be easily and approximately estimated in the acid or neutral soils. In spite of this applicability the U.S.

Department of Agriculture in one of its recent publication has reported that quick soil tests are easy to make but difficult to interpret. Even the Soil Survey Manual does not recommend quick tests for available or soluble plant nutrients in soils. Only particular ones could be useful if well standardised by field plot tests. Soil conditions in Uttar Pradesh, on the other hand, are of an absolutely different nature since, whereas, soil acidity and soil phosphorus are the two chief problems needing soil testing in U.S.A.; soil nitrogen, salt and alkalinity and soil phosphorus are the problematic soil characters requiring testing in our soils. These soil factors cannot be easily and correctly estimated with the known rapid methods under our conditions and the results obtained with the existing methods bear no correlation either with the crop yields or with values obtained through orthodox methods. Evidently, there is need to evolve our own methods for soil testing to suit our conditions.

Systematic investigations of a preliminary nature were undertaken few years back in the U.P. Agricultural Chemistry Section to study the applicability of some of the more important rapid chemical methods on U.P. soils and it was found that these methods could be useful under certain limitations in the estimation of available calcium, organic matter, pH and to certain extent base exchange capacity. None of these estimations are useful for evaluation of fertilizer needs of the soils. The American technique in respect of testing for important plant food requirements viz., nitrogen phosphorus and potash etc. was found to be unsatisfactory.

It would thus be evident that Rapid Soil Testing, though extremely popular in Western countries, has not made much headway under our conditions where what to say of rapid testing on the field even orthodox soil testing in the laboratory is at a preliminary stage. The main reason for this shortcoming is the absence of suitable rapid methods of estimations of plant food requirement in relation to actual crop responses applicable to the soil conditions of Uttar Pradesh. Systematic investigations are necessary before technique can be evolved which can be used with advantage in determining crop productivity and fertilizer use.

*Note on utility of rapid soil and plant tissue tests for evaluating soil productivity and use of fertilisers*

by

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Those responsible for the development of methods for the physical and chemical examination of soils were quick to realise the limited scope of application of the methods already in vogue. Most of the nutrients analysed for, could not be directly correlated with soil fertility or the suitability of soils for agricultural operations. Moreover, these methods were very tedious, time consuming and expensive. They do not also furnish ready information about soil condition for immediate application in deciding manurial and agricultural practices. Rapid soil and tissue tests, however, have overcome these limitations to a considerable extent and have facilitated the rapid examination of a large number of soil and plant tissue samples in a

very short time and at a low cost. It is to be admitted that rapid tests are not very accurate; but in the hands of an experienced scientist they form a valuable tool in detecting nutrient deficiency fairly accurately.

These tests have been extensively employed in America which could be rightly described as their place of origin. In India comprehensive trials for assessing the suitability and reliability of rapid soil and tissue tests have not been conducted on a large scale till recently. However of late much useful data has been accumulated in the various States. In Madras State work along these lines was started at the beginning of the last year. The Purdue and Morgan Systems of rapid tests were examined first for their reliability and scope of application by using very dilute solutions of salts containing N. P. and K.

Pot-culture studies were conducted with soil samples collected from the Old permanent manurial plots, Coimbatore representing control, N. P. K. NPK and Cattle manure, raising paddy as the experimental crop. Similarly another series of pot culture experiments were performed on soils taken from permanent Manurial experimental plots at the Agricultural Research Station, Aduthurai, (control N.P.K., PK, Ca and NPK, Ca) and from plots belonging to a farmer in Aduthurai (representing fertilise or poor soils) and another from the lands of a farmer in Tanjore. The paddy crop samples were tested for Nitrate, Phosphorus and Potassium by the Purdue method and for Nitrate N, Ammonical N, Phosphorus and Potash by the Morgan method at about 20 days intervals during the crop growth.

Growth observations were recorded along with the analytical work in these tests. At harvest, the yield of grain and straw was determined. Results of rapid tests indicated that there was a general relationship between the nitrite-Nitrogen, Ammonium Nitrogen and Phosphorus of the plant tissue and soil samples as indicated by the rapid tests, and the growth features as well as the yield of paddy. Recently the rapid tests were employed for investigating the decline of mandarin oranges in the Wynad area. Soil from orange orchard and leaf tissue from affected trees were examined by rapid tests. Results indicated that phosphorus deficiency might account for the deterioration in the condition of the trees.

As the use of rapid soil and tissue has been adopted in these laboratories only very recently, definite conclusion about their utility cannot be arrived at the present juncture. Further work involving the simultaneous examination of a large number of soil and plant tissue samples by rapid and ordinary methods of analysis will supply information for correctly assessing the utility and reliability of these methods.

*Utility of rapid soil tests for evaluating soil productivity and the use of fertilisers*

by

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Right from the beginning soil has been the basis of all human prosperity. The cycle of life starts from the Soil and goes back to it. It is the soil which gives everything to this world and takes back

some of them to keep up its balance. Our forefathers called it 'mother earth' because the present world is the result of her creation.

Agriculture the main stay of India is directly related with soil and its prosperity is entirely dependent on the condition of the soil. Being situated in the tropics the organic matter gets burnt and the matter binding the soil particles is least. Through the intensive type of cultivation which is more prevalent in this country, the soil gets exhausted of its nutrients soon. It is necessary to replenish it in a suitable manner. Soil studies had been recognised as an essential aspect of agricultural research.

The Indian farmers although illiterate have completely realised the value of soil from time immemorial and even now we can notice that some of the cultural practices brought down from generation to generation are meant to keep up the quality of the soil. Application of green manure, cattle manure including sheep penning and using tank silt not only keep up the basic elements in the soil but helps to increase the mechanical texture in addition providing a residual effect.

The Agricultural Chemistry section of the State Departments of Agriculture has made a valuable contribution in the study of the soil formation and classification and has brought out soil surveys.

The soil analysis mainly consists of finding out the chemical composition, mechanical texture, exchangeable basis, clay minerals and silica sesquioxide ratio.

The soil surveys should provide all the data on soil quality, how much plant food it contains, whether the amounts are adequate or whether manuring is necessary, the drainage facilities available in the tract and the susceptibility to soil erosion.

There are two kinds of surveys of which one is routine and another special. Routine surveys are made once in a number of years on a large area. It will be worthwhile to reduce the time interval between two consecutive routine surveys. Just like population census is necessary in the economic point of view of a country the soil survey is essential to increase the Agricultural production in accordance with the rise in population.

Special surveys are conducted on newly opened irrigation projects or on other occasions like the cyclone affected areas etc. This is of great importance as it acts as a guidance for the farmers who face a new situation. Unfortunately at present although such surveys are conducted in a few places the results are not carried properly to the practical farmers. The efficiency in the dissemination of the survey and results should be increased and simplified so that an average farmer will be able to understand just by seeing a few charts or pictures. The proper application of the results of these soil analysis have not been made so far. A soil may contain a high percentage of Potash or Phosphorus but if it is not in a soluble form ready to be absorbed by plants such soils have to be given the plant food in a soluble form through a fertilizer. A genetic analysis of soils relating to its origin—how the soil was formed from its parent

rock, where it was formed—how it moved down into the plants—how it got deteriorated in cultivations and what is needed. Based on this the correct method of fertilising it ameliorating it by addition of organic matter and leaves etc. can be worked and adopted. There are various widespread farmlands in Madras State where specialised farming is carried out. The Tanjore delta the granery of South India, cultivates paddy, Koilpatti area deals with the cultivation in black cotton soil and Coimbatore has got a characteristic garden cultivation. These are typical areas where the soil is almost uniform and the crops grown and the climatic conditions are the same. Special surveys are being conducted which can be advantageously summed up as leading to recommendations for a manurial policy to be followed by these different areas.

Apart from this the State Government with the help of the Central Government may make a thorough survey of the whole state and divide it into different zones according to the similarities found in a particular area. Soil maps showing in detail the variation in the cultivate soil of the farmsteads may be prepared. Government can subsidise and do this work which will be of great use to the farmer as individual and to the nation as a whole. According to the classification a definite manurial policy can be advised to the farmers, of a particular zone or area. In U.S.A. some states do this kind of work and they find it very effective. The ultimate aim should be that every piece of farmland should come under the survey and classified accordingly. Farmers want to get the soil surveyed and tested but they are not in a position to get them since the cost or the financial aspect acts as a bottle neck.

The Agricultural institutions of the different states are in a position to get the soil tested and analysed. But there is so much of formalities and correspondance that a farmer would prefer to go without them. Further only analysis data are communicated to the farmer and not advice thereon—asking them to use such and such manure and quantities thereof in such and such relation of crops etc.—There is great need in this country for more laboratories and farmers should be given all facilities to get the soil analysed at the shortest time and at the lowest cost.

It is gratifying to note that Dr. Panjabrao S. Deshmukh, Union Minister for Agriculture, has recently announced that the Government of India were setting up 24 soil testing laboratories throughout India. This establishment comes under the Technical Co-operation Mission Project on Soil fertility and fertiliser use and is estimated to cost about Rs. 28 lakhs. These soil testing laboratories are really going to be a boon to the farmers and there is every hope that farmers will get the soil analysed with the least trouble.

The regular laboratory examination consists of seven parts—

1. The mechanical composition gives an idea about the ratio between coarse and soft fractions.

2. Single value constants. This consists of hygroscopic co-efficient, maximum moisture holding capacity pore space and the absolute specific gravity of a soil. There is close correlation between these and mechanical composition.

3. Total soluble salts. It is estimated that the toxic limits of different salts are as follows:

0.10% Sodium carbonate.

0.25% Sodium Chloride.

0.75% Sodium sulphate.

4. Exchangeable bases gives the total exchange capacity of the soil.

5. Degree of alkalization.

The yield falls down with the rise in alkalization.

6. pH reaction indicates the nature of soil reactions acid, neutral or alkaline. Lime status rises the pH value of the soil and keep the degree of alkalization.

7. Other estimates including N, P K value.

A survey and analysis of soils in a cyclone affected area will be helpful in the reclamation of lands. Proper recommendation may be given regarding suitable varieties of crop, fertilizer treatment and use of bulky organic manure.

There are also special studies carried on in the following subjects:

1. Soil moisture and dry farming practices.

2. Soil erosion and its control.

3. Alkali lands and their reclamation.

4. Soil organic matter and its decomposition.

5. Soil conditions as affected by cropping, cultural and manurial treatments; and

6. Fundamental studies on soil.

It has been found that the soil in Madras State is generally deficient in humus and nitrogen. There is a deficiency of phosphoric acid in intensely cropped areas.

The soil testing unit requires a well equipped laboratory with the proper technical persons. The regular laboratory analysis takes a few days.

Quick soil testing kits are spreading fast in U.S.A. Very simple methods and analysis according to change in colour on chemically coated papers or reaction of plant tissue to certain chemicals makes a farmer do the job himself in no time. They may not be very accurate. But they are very helpful in deciding how much fertilizer or lime to apply and for avoiding the unnecessary expense of using nutrient elements where it is plainly evident that they are present in available form in adequate amount. You can tell by simple tests if your growing crops are hungry. How you can head of trouble

and lowered yields by giving them plant food before the brown leaf symptom of starvation tells you it is too late. The simple test kit costs about Rs. 18. You can tell if your crop needs nitrogen or Phosphate, if your garden vegetables have plenty of all the three major plant nutrients. There are also filter paper tests to find out if the plant received these in adequate quantities. Such soil testing kits may be imported first and then we ourselves can make it, in this country with the help of those foreign manufacturers. Quite a few farmers are really interested to keep one kit in their farm and Government may take necessary steps to get them. At least the extension Officers can be provided with these—to facilitate them examining the soils of farmsteads in which they are working.

In some foreign countries soil tests are often supplemented by tests of the tissues of the growing crop. Tissue tests give an indication of the capacity of the soil to supply the crop with nitrogen and mineral nutrients and an indication of the extent to which the applied fertilizers have been delivered up to the crop. With the proposed soil testing laboratories throughout India and its further expansion gives us full scope for 'tissue tests' of different crops. But this can only supplement the data obtained through soil test. In addition to these soil studies of crops have to be made to recommend particular crops to particular soil conditions. Also the quantity of water required to produce 1 lb. or a unit weight of plant material has to be worked out so that the correct quantity of water may be given to the plants.

With all these plans for expanding the facilities to analyse soil it is a very important factor that the overall efficiency of the Government laboratories should be increased and farmers should find it as an attraction to approach the concerned officials and get the analysis and proper recommendations. This is a practical point of view as the present situation is very commendable and it is our duty to face the exact situation and take necessary remedy.

The soil survey and analysis gives an idea about the soil requirements and how far we can grow the crop in a better way. Soil can be replenished with organic and inorganic manures.

The requirements of the soil in Madras State in regard to manurial experiments are in the following order—

1. Organic matter.
2. Nitrogen.
3. Phosphoric acid.

Through the extensive soil surveys the State Department of Agriculture has found out that the most successful manures have been green manures in rice lands, cakes and ammonium sulphate in Sugarcane lands and cattle manure for all garden and dry crops.

Organic matter is essential for the soil. Cattle manure conserves fertility better than artificials and produces seeds of higher cropping and nutritive value. Residual effects of cattle manure last much longer. So to maintain good yields organic matter has to be kept continuously supplied to the soil.



Artificial fertilisers have to be used in conjunction with organic manures. Ammonium sulphate and superphosphate have proved beneficial for almost all crops. Super is generally unable to act well alone and requires supplementing with organic manures. Correct fertiliser mixtures containing the plant N, P & K in both organic and inorganic forms have to be worked out and given to ryots so that the harmful effects of prolonged use of single fertilisers is avoided. The farmer should be considerably educated in the correct use of fertilisers. Studies to find out the periods of maximum intake of nitrogen, phosphate and potash by the plant have to be conducted so that the correct time of application of fertilisers can be determined. You will realise the ineffective use of fertilisers when they are applied at a time when the off take by the plant is low. In areas where single fertilisers are under prolonged use the value of the soil has gone more on the acid side. This has tended to alter the pH value of the Sap of plants growing on it—also to the acid side. This is slightly aggravated by the farmer not using soil ameliorants or correctives. As a result we find fungus diseases that thrive on acid Sap of plants or insects (not seen in previous Years) occurring on a large scale in such tracts. Studies—correlating insect incidence to pH value of plant sap—may seem essential at this juncture.

It is doubtful whether we can maintain good yield for a long time with artificials alone. The indications are that the yield will go down by their continuous use while the soil also will be adversely affected. Our best course therefore will be to use artificials only on basal doses of cattle manure or other bulky organic manures.

The value of green leaves, waste straw, night soil, slaughter house wastes, and farm wastes has to be utilised to the best advantage.

Even before the second world war chemical fertilisers were being used in India, but at that time only plantation crop used them.

Production of phosphatic fertilisers had started through private sector during the war. In November 1951 the Sindri factory started producing nitrogenous fertilisers.

The use of nitrogenous fertilisers is mainly in the form of ammonium sulphate. Urea and ammonium sulphate nitrate are more concentrated artificials, but they are economical in the cost of production, transport and handling. Ammonium sulphate nitrate contains 26% of nitrogen, 1/4 as nitrate nitrogen and 3/4 as Ammonical nitrogen. Just like ammonium sulphate this has got good keeping quality and produces equally good effect on crops. It is advantageous in a way that it produces slightly less acidity than ammonium sulphate.

Urea contains 44—46% nitrogen—Few days after the application it changes into ammonia and behaves more or less like ammonium

sulphate. It produces acidity lesser than ammonium sulphate. It is likely to be leached out from the soil and it should not be applied when the soil contains free water. It absorbs moisture and thus presents a problem for storage in humid areas.

Large scale and continuous application of nitrogenous fertiliser and highly intensive cultivation which is being practised in most of the areas depletes the soil of its phosphates and unless their supply is concurrently replenished the soil will suffer serious damage and will get exhausted soon.

Some private companies have begun to supply mixed fertilisers for different crops like paddy, sugarcane, tobacco, chillies etc. This is a common practise in U.S.A. and the mixture contains carriers of nitrogen, phosphoric acid and potash. A 6-8-6" fertiliser contains an amount of total nitrogen as would be equivalent to 6% of nitrogen, an amount of 'available' phosphorus equivalent to 8% phosphoric acid and an amount of 'available' potassium equivalent to 6% of potash.

Higher analysis mixed fertilisers are also available in U.S.A. They are in concentrated form and it reduces cost of transportation. Mixed fertilisers can be popularised in India and necessary publicity may be given in this direction. Companies will readily come forward to supply such fertilisers. The Department of Agriculture should work in collaboration with fertiliser dealers and put on the market, the correct fertiliser mixtures at the cheapest rates.

In 1950 the Government of Madras passed a legislation 'Madras Manure mixtures quality and price control Order' which was controlled by 'Fertilisers Advisory Committee' and the Director of Agriculture. The Inspector of Fertilisers appointed under this scheme obtained samples and analysed the fertilisers to check with the guarantees given by the firm. It should be continued and the Government should always keep an eye on the quality specifications of the product. A comprehensive legislation act is needed.

A glance at the figures relating to the production and consumption of chemical fertilizers in various countries of the world is enough to show that acre yields of crops run somewhat parallel to the consumption of fertilisers. So increased and judicious use of artificials have to be made to step up production. However to secure the best results artificials should be used in conjunction with organic manures. Sufficient guaranties of organic matter that are taken out of the soil should be returned to it for balancing the same.

PAPERS ON SUBJECT NO. 4

*A review of methods of reclamation of saline soils in West Bengal*  
by

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The State of West Bengal has got about 21,18,200 acres of saline tract. This area has been formed by the deposition of silt brought down by the rivers. With the formation of this land gradually Mangrove forests first came into existence. Out of this saline area 19,76,960 acres are in the district of 24-Parganas and 1,41,240 acres in the district of Midnapore. In the district of 24-Parganas 9,34,400 acres have been deforested and of this 7,04,000 acres are being cultivated. The remaining 2,30,400 acres remain practically sub-merged due to tidal action. In Midnapore, district almost the entire saline area is now under cultivation.

Cultivation in these saline tracts is carried out after reclaiming the area with embankments to prevent ingress of salt water, and by gradually lowering of the salt content in the soil. The embankments are constructed on both banks of rivers and channels in the tidal zone. This prevents the tide water to get in through the spring tides. During rains these areas get a precipitation of over 60 inches. This dilutes the salt present in the soil and during ebb tide the rain water containing salt is surplussed out into tidal channels through opening of sluice gates. The area where embankments have been constructed become fit for rice cultivation in about three or four years according to above method of reclamation. As the humidity in this area is high the efflorescence of salt during winter months is not very high.

The saline areas which are now under cultivation in this State were thus reclaimed in the above manner. If the reclamation work had been taken up in a planned manner and only on lands which have become raised sufficiently above the spring tide level, management of these areas could have been better controlled.

In course of time as the progress of leaching proceeds the salt gets washed and the soil assumes the following characters :

1. *Acid soils*.—Where the organic acids due to decomposition of imbedded organic dead matters are produced and convert the soil into acid soils.
2. *Sodium soils*.—Where organic matter in the sub soil is low. The entire soil after being leached gets deflocculated and stops the pores. In these soils growing of high land crops is difficult, but transplanted rice can grow well.
3. *Calcium soils*.—In areas where the parent alluvium is rich in calcium carbonate. As the salt gets leached, the calcium enters the exchange complex slowly converting it into good soil where high land crops can be grown fairly well.

For soil amendments in these areas, experiments have been carried out so far with Gypsum in the first two groups of soils. In the acid soils the Gypsum produces H<sub>2</sub>S in the first year due to anaerobic condition, and this creates toxic condition for plant growth.

In second type of soil it was found that application of 4 tons of Gypsum per acre releases too much of sodium sulphate and as a result the beneficial effect is not perceptible for the first two years. The possibilities of Gypsum as a soil amendment on sodium soil is however still under investigation.

Suitable afforestation methods have not led to much improvement in these areas. Reserve forest stands over an area of 1,629 sq. miles. The forest is of shrubby nature, producing mainly fire wood. No good timber has so far been produced in these areas.

The problem of reclamation of saline areas in India has so far received very scanty attention from scientific point of view. The reclamation of such areas that has been carried out so far, has been done purely by common sense methods. If a proper scientific approach is made it might be possible to reclaim vast areas in the country for production of food and other products to develop our natural resources. The Netherlands is the only country in the world that has waged a perpetual fight with salt water throughout its history, and has reclaimed land from sea bed. Many of their methods are worth emulating in this country. Nature has bestowed us with a benevolent climate under which we can grow crops all round the year. If we could solve only the problem of salt in the soil, vast areas could be added to productive use.

#### *Reclamation of Saline and Alkali soils under marine influence*

by

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New Delhi—12

*Introduction.*—One of the important problems of Indian Agriculture is that presented by what are commonly called saline and alkali soils. The origin of the salts in soils may be traced to the composition of soil forming materials or salts from the ancient seas. The three chief factors responsible for excess salts in cultivated soils are an arid to semi arid climate, poor drainage leading to temporary excess of water and bad irrigation. The adverse effects of excess soluble salts on the properties of soils are brought about in two principal ways: (1) by increasing the salt content of the soil solution and (2) by increasing the degree of saturation of soil colloid with absorbed or exchangeable sodium. The former are usually designated as saline soils while the latter are called alkali soils. In the evolution of saline and alkali soils several phases are recognised by considering the salt and lime content of the soils. Thus, under the soil order 'Sodium soils' Sigmond (1932) included five main types *viz.*, saline soils; salty-alkali soils; leached alkali soils; degraded alkali soils and regraded salty alkali soils. The problems connected with the reclamation of saline and alkali soils resolve into an understanding of the type of soil and changing the course of soil evolution and soil dynamics into the required channel.

*Distribution of saline and alkali soils.*—Saline and alkali soils are extensively distributed in India and they are not limited to a single soil or climatic zone. These soils occur principally in the following areas :—

- (1) Through out the Indus Valley.
- (2) Valleys and basins of Western India.
- (3) The Ganges Valley west of about 80°E longitude.
- (4) The up-lands of the Deccan plateau, especially the Tapti, Godavari and Bhima rivers.
- (5) The saline marshes of the sea coast and the deltas of the Ganges, Cauvery and Mahanadi.
- (6) The coastal soil flats particularly along the Saurashtra coast and the Rann of Kutch.

The Indian Agricultural Research Institute, during the years 1947-55 conducted extensive soil and land utilisation surveys in the Rann of Kutch. The Rann of Kutch covers about 8,000 sq. miles and out of this nearly 1,900 sq. miles in the Great and Little Rann of Kutch are inundated by river waters. Satyanarayana (1951-54) reported the general nature of the saline soils of Rann of Kutch and their better utilisation. Under a scheme financed by the Ministry of Food and Agriculture, on the basis of field and laboratory studies, a reclamation and development plan was drawn up for the Little Rann of Kutch (Satyanarayana, 1955). In the present note some aspects of the reclamation of soils under marine influence with particular reference to Rann of Kutch are presented.

*Nature of soils of Little Rann of Kutch.*—The alluvial soils of Little Rann are usually grey and black coloured silty loams and clays. The permeability or normal internal drainage of the soils is good. In the sub-soils blue or green coloured horizons occur at depths varying from 4 ft. to 7 ft. indicating a general high water table influence under the existing conditions. However, the presence of red and brown mottlings in layers above the blue or grey horizons indicates some amount of aeration. The soils contain from 2 to 10 per cent. soluble salts and a major portion of this is present as sodium chloride with lesser amounts of sulphates.

Calcium carbonate, which varies from 1 to 8 per cent., occurs through out the soil profile and some times is also found to accumulate in the lower horizons. One striking feature of these soils is the high percentage of solid gypsum which they contain.

*Reclamation of saline and alkali soils.*—All marine sediments have been at one time or other charged with soluble salts. Upon leaching, the same general type of changes will take place with marine sediments as with non-marine soils of the same kind and salt concentration. Laboratory experiments showed that the Kutch soils do not develop unfavourable reaction and physical condition on desalinisation. As a result of the surveys it was concluded that 3 lack acres of land could be reclaimed easily and further 3 to 4 lac acres by adopting special measures.

*Need for Research.*—Raychaudhuri and Dutta Biswas (1954) reviewed the work on saline and alkali soils of India and the ameliorative measures applied for successful crop growth. The work on reclamation of saline and alkali soils in this country is limited to isolated and small areas with varying degrees of success. In the three states, Punjab, Uttar Pradesh and Bombay—Deccan alone it is estimated that the introduction of canal irrigation brought about an increase in unproductive areas amounting to about 5,000 sq. miles due to the accumulation of soluble salts in the surface soils resulting in crop failures. There are vast areas of potential agricultural value under marine and non-marine influence the reclamation and better utilisation of which is essential.

Small scale experiments and laboratory studies, however, promising be, their application to large areas and under field conditions require great care. Reclamation of land is neither easy nor are the results achieved quickly. Reclamation work demands the co-operation of soil scientists, agriculturists and engineers to study the basic principles and to work out techniques suitable for the varying soil and climatic conditions of the tracts. The permanence of any reclamation work obviously depends upon the care exercised after a piece of land is reclaimed.

In Holland soils below sea level have been reclaimed but in this country we do now have experience of such large scale undertakings. It is high time that the salinity research is centralised and the several aspects are investigated. A centralised body or Research Institute should be made, responsible for research and the execution of large scale reclamation of all the saline tracts in the country. The programme of the Salinity Research Institute may have to be broad based and comprehensive to cover the subjects (1) Soils (2) Agronomy and (3) Engineering. The soils section may give special emphasis to the physical and physico-chemical properties of soils which govern the water and salt movement, drainage and development of proper structure. On the Agronomy side the tolerance limits of crop plants to salts during the growth period have to be worked out. Similarly the Engineering aspects of bunding, construction of drains and methods of lowering water table need to be investigated.

The Institute, in co-operation with the Universities may train youngmen in soil physics with special reference to salinity problems. The Institute may thus supply the much needed technical men to handle reclamation projects.

#### *References:*

1. Raychaudhuri, S. P. & Datta Biswas, N. R. (1954)—Trans. 5th Internat. Cong. Soil Sci. 1 : p. 1919.
2. Sigmond, A. A. J. de (1932)—Imp. Bur. Soil Sci. Tech. Commun. No. 23.
3. Satyanarayana, K. V. S. (1951)—Indian Soc. Soil Sci. Bull. No. 6 p. 125.
4. Satyanarayana, K. V. S. (1954)—Nat. Inst. Sci. India Bull. 3 p. 89.
5. Satyanarayana, K. V. S. (1955)—Final Report of Soil and Land Utilisation Survey of Little Rann of Kutch.

*Principles and Methods of Reclamation of saline and Alkaline soils with special reference to agronomic practices soil amendments and afforestation*

by

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Kelley (1951) points out that the results of many of the earlier experiments on reclamation were only temporary due to the inadequacy of consideration given to soil drainage in them. Great vigilance specially as regards the quantity and quality of irrigation water, the irrigation practices and the drainage conditions including the flow of water through the soil is necessary to make the results last longer. The question therefore naturally arises whether the prevention of alkali troubles would not be better in the long run than their remedy. It has been estimated that the introduction of irrigation through the canal system in this country has brought about an increase in the unproductive saline and alkali soils to about 3.2 million acres (Raychaudhuri and Biswas, 1954) presumably out of 20-25 million acres under canal irrigation existing at the start of the first Five Year Plan. The magnitude that this problem is likely to assume in future can be judged from the expectation of the Planning Commission of doubling this area under canal irrigation by 1965.

Excessive or too little irrigation out of proportion to the consumptive use and leaching requirements (which can now be estimated for any given soil and crop and for meeting which, automatic control of the distribution system is used in Algeria), seepage losses from the canals and the laterals which can also be reduced by lining the canals (with buried asphalt membrane as is done by the U. S. Bureau of reclamation or with concrete as in the Coachella Valley, California), the non-uniform application of the irrigation water due to defective levelling of the fields and, the failure to employ simple agronomic practices are usually responsible for the bad effects associated with the increase in irrigation facilities. This can be controlled more easily at the time of planning the irrigation projects than afterwards. The U. S. salinity Laboratory points out the advantages in balancing the irrigation requirements taken from two sources, the one by pumping ground water locally from wells and the other from canals so as to ensure a favourable drainage of the irrigated soils. Since both electric power which can also be used for pumping and water for the canals are expected to be available from the river valley projects of this country, this combination can easily be tried in this country. Apart from the need to prevent usar formation, the provision of proper drainage is important and necessary from the public health point of view and would justify the expenses involved. Although the method of pumping the ground-water is much superior, the drainage in any area, where artesian conditions do not occur, can be ensured also by tile or open drains. The drains should generally be oriented perpendicular to the direction of the ground water flow and wherever possible should connect with gravel or sand deposits with a gravel pack used as a filter around the tiles. This requires a knowledge of sub-soil stratigraphy obtainable from soil logs made at the time of digging the wells in the locality and requires the preservation and collecting all such information. In the Ground Valley Colorado, U.S.A.,

it was shown that a few well-placed drains, cutting across the impermeable layers and intercepting sand and gravel deposits were found to be more effective than a large number of them dug parallel to these deposits at regular intervals.

Russel (1950) estimates that since 3 to 4 acre feet of water may either be evaporated or transpired a year leaving behind  $\frac{1}{2}$  to 4 tons of very soluble salts in the surface soil, these will produce either due to the aridity of climate or due to impeded drainage 0.06 to 0.2 percent of soluble salts in the absence of a rainwash or leaching to the extent of 10"—15" in the cooler months. Thus the accumulation during even one year under those circumstances is enough to make the soil unfit for many crops. The existence of impeded drainage is indicated either by the presence of ponded water or marshes or by the growth of hydrophytic plants or from the shallow depth to water table. The climate, the quality and quantity of the irrigation water, the nature of the soil the crops and the cropping systems determine the drainage requirements for any locality and must be met not only for preventing the formation of saline and alkali soils but also their reclamation even to a greater measure.

The reclamation of any affected area involves the following processes:—

(1) Cutting off the source of salts by embankments in case it is due to flow of tidal water from the sea in the coastal areas or by wind break if it is wind borne from the sea as is likely in Gujrat or the Rann of Cutch, or by relief drains in the case of seepage from canals, rivers or ground water mounds as was found to be the case in the Pusa farm in Bihar; (2) the use of water of as low a salt content as possible consistent with keeping the soil aggregated in order to dissolve the salts present in the soil; (3) flushing the accumulation of salts from the surface into the ground water by ensuring adequate internal drainage so as to keep the water table well below 6—8 ft. (4) replacement of exchangeable sodium by calcium by the use of suitable soil amendment, stabilisation and deepening of this exchange; and (5) the establishment of a suitable crop on the land by adopting necessary agronomic practices. The feasibility of reclamation in any area largely depends on the cost of carrying the irrigation water as will be the case in a desert and on the cost of keeping adequate drainage as will be the case if the impervious sub soil layer is very thick and also to some extent on the cost of the soil amendment, where necessary. The importance of the seepage mentioned above can be judged from the fact, that apart from the deltaic areas of the Ganges, the Mahanadi, the Krishna and the Coastal belts in the Rann of Kutch, Saurashtra and Ramnad where the source of trouble is the present sea and the areas in Rajasthan and West Pakistan where past sea are responsible for the salt lakes and rock salt deposits, important patches lie on the alluvial soils between the Jumna and the Gomti in the Ganges Valley to the west of 80° long, and also some extent between the Gomti and the Gogra in U. P. on the one hand and the river Gogra and the Kosi on the other in Bihar, between the Sulley and the Jumna in the Punjab and Delhi States and on the medium black soils between the tributaries of the Krishna in the Andhra State, between the Godavari, the Bhima and the Tapti in the Deccan and between the R. Sabarmati and the Mani in Gujarat, while Madhya Pradesh is relatively free from this trouble.



Usually soils are classified into saline, saline-alkali and alkali groups on the bases of their soluble salt content and tentatively on the sodium saturation per cent of the exchangeable complex in the soil. More work on the role of exchangeable potassium and exchangeable Magnesium in alkali formation is yet necessary to make this more precise. Somewhat similar classification into 3 groups was made of the U. P. soils by Mukherjee and Agarwal (1946). Besides classifying the saline soils according to the associated zonal types, Kovda (1937) classified them according to the kinds of salts prevailing in them. Talati (1941) used a simplification of these into four classes based on the pH and presence and kinds of salts in the Deccan. The classification of the Punjab soils by Puri, Taylor and Ashgar (1937) into 5 classes is very useful from the practical agronomic point of view. Basu and Tagare (1943) emphasise the importance of recognising and differentiating these soils on the thickness of the impervious layer, which is useful both from the pedological and practical point of view. Basu (1950) classified the soils according to the causes of formation into seven groups, which will be helpful in devising measures to prevent recurrence of the trouble. If such classes are again subdivided according to the method of U. S. salinity Laboratory into (1) Soils containing alkaline earth carbonate (2) Soils containing no alkaline earth carbonate but with pH = 7.5 or higher and (3) Soils containing no alkaline earth carbonates and pH less than 7.5, they would prove of great value in choosing the methods of their reclamation.

After barricading the inflow of salts and providing for adequate drainage as mentioned earlier, the right quantity and quality of water for leaching the soil has to be chosen. As shown by the ratio law and the inverse ratio law of cation exchange, higher sodium to calcium ratios in the irrigation water can be tolerated in water of low than high salinities and more in montmorillonitic soils than in Kaolinitic types. This aspect of the question of the quality of irrigation water suitable for the different regions needs greater study in India. Water of sufficient salinity or the presence of the required amount of salts in case rain water is to be used, just to flocculate the soil during leaching should be used as there is the danger of increasing the impermeability of the soil during reclamation.

The permeability of the soil can also be sometimes increased by very deep ploughing as shown by Kovda (1941). This can also be achieved by periodic drying of the soil between the leaching operation (Reitmer and Associates, 1948; and Bower et al (1951) and by the establishment by agronomic practices of crops. Ponding an appreciable depth of water on the soil surface by means of dikes or ridges or contour checks was found to be vastly superior to surface flushing in U. S. A. Such more mechanical methods of reclamation should be sufficient if the soil is not saline and contains enough of soluble calcium salts or when the salinity is merely due to the aridity of the climate. Mechanical methods were found to be successful at Harij in the Bombay State and in some places in the Krishna Valley. At the former, drainage spacing of 100' to 150' was found to be more successful than the chemical methods.

The next step is the use of a suitable soil amendment wherever necessary. In alkali soils containing alkaline earth carbonates, limestone is of no use while it will be very useful for alkali soils of pH less

than 7.5. Acids or acid forming amendments on the other hand have the reverse effects, and must be used along with lime stone on acid soils. For this reason ammonium sulphate was found by Mehring (1935) to be more useful than nitrate on calcareous saline soils. Besides their effect on the structure of the soil, the benefits of establishing crops and grasses like lucerne during reclamation is due to the increased amount of carbon-dioxide and carbonic acid produced in the soil. F.Y. M.; composts and green manures, molasses etc. also help in a similar way. But their effect in the absence of calcium carbonate cannot be much. Any of the soluble salts of calcium like gypsum, lime-sulphur and sometimes calcium chloride besides the acids and acid formers like sulphuric acid, sulphur (or lime sulphur) can be used on alkali soils containing alkaline earth carbonates. Gypsum, sulphur and lime stone are usually applied broad-cast and incorporated into the soil by means of a disk or plough, while thorough incorporation and keeping the soil just moist for some weeks for the oxidation to be completed in the case of sulphur is necessary before the leaching operation can be commenced. In the case of gypsum however, the soil could be leached both before and immediately after its addition and in between successive additions depending on the permeability relationships. The amount of gypsum required for the reclamation can be calculated from the amount of exchangeable sodium in the soil but further work is necessary to make this calculation very precise. The efficiency of replacement of exchangeable sodium by calcium depends on factors like the replacement energy of these cations from the clay phase, the exchangeable sodium percent itself and the total cation concentration of the soil solution.

In Dharwar, for soils with thick impervious subsoil layers, mixtures of  $\frac{1}{2}$  ton per acre of sulphur + 2 tons/acre of F. Y. M. were found to be efficient while sulphur (2 cwts/acre-every alternate year) and the use of suitable agronomic practices were suitable for the Karl soils of Nargundi. In Unao, 3 tons of gypsum were needed for the refractory types of soils. At Cawnpore, gypsum + Cake or gypsum + senai tops were found successful. 10-15 tons of molasses used were successful for the soils of Allahabad and Cawnpore. The use of molasses was not considered to be economical on the Bari soils of Punjab while soluble salts of Calcium followed by F.Y.M. were used on the Kalar soils deficient in exchangeable calcium in that state.

The success in reclamation by mere agronomic practices of establishing a crop cover largely depends on the presence of calcium reserves in the soil and on the condition that the soluble calcium requirement of the soil to reduce its exchangeable sodium to safe limits is not more than what can be produced by the carbon-dioxide pressure in the soil air. At least the loss of nutrients especially of ammonium during leaching should be made good by fertilisation and manuring. One useful line of investigation is to test different species and involve varieties that can thrive under the moisture stresses obtainable in the different regions of the country having saline soils and to withstand the high exchangeable sodium and water logging conditions of the alkali soils. M. C. George and Wharton (1936) and Heald and Coworkers (1950) have shown that growing plants on the sides of ridges and irrigating the furrows in the early stages will remove the salts into ridges away from the root zone enabling the plant to establish itself even where water is not enough to flush out the salts from the entire

soil. Once the plants are established, they can be encouraged to root deeply by being given heavy irrigations at as long intervals as possible consistent with keeping them maintained. The cool months having low transpiration and evaporation losses would be economical to start the leaching.

In the types of soils with only the A horizon impervious in the Deccan, Basu and Tagare (1943) find suitable crop rotation itself sufficient. Kenphad wheat, Yadhar cotton, M-35-1 Jowar with higher seed rate and wider spacing along with contour listing were found suitable for the Karl soils of Nargund after treatment with 2 cwts. of sulphur every alternate year. Green manures like sunhemp, hongay and Morgosa at Baber and Lantana and Euphorbes at Irwin canal appeared to help reclamation of the soils in Mysore state. Wherever thick impervious sub-soil strata occur and where wind borne salts are of consequence, afforestation may be of special advantage.

#### References:

1. Kelley, W. P. (1951) "Alkali soils, their formation properties and reclamation". Reinhold Public, crop Newyork P-157.
2. Raychaudhuri, S. P. and Datta Biswas, N. R. (1954) Trans. 5th Int. Congr. Soil Sci. Vol. 191.
3. Second Five Year Plan—A draft outline, Planning Commission, Government of India (1956).
4. Russel, E. W. (1950) "Soil conditions and Plant growth" p-555. Longman's green and Co., Lond.
5. Mukherjee and Agarwal (1946) Ind. J. Agri. Sci. 16, 263.
6. Kovda (1937) quoted by Joffe "Pedology" 1949, P-538.
7. Talati, R. P. (1941) Ind. J. Agri. Sci. 4, 958.
8. Puri, Tayler and Ashger (1937) Punjab Irrig. Res. Inst. Res. Pul. 4, Vol. 9 (1937).
9. Basu and Tagare (1943) Ind. J. Agri. Sci. 13, 157.
10. Basu (1950) Tras IV Inst. Congr. Soil Sci. 3, P-169.
11. Reitmier, Christiansen, Moore and Aldrich (1948). U.S.A. Dept. of Agri., Tech. Bull, 937.
12. Bower, et. al (1951) reg. Agri ; Ext. St. Tech. Bull. 22.
13. Mehring (1935) Landw—Jahrb. 79, 481. quoted by Russel (4) P-481.
14. Mc. George and Wharton (1936) Arobons Agri. Expt. St. Bull 152.
15. Heald, Moddie and Leawer (1950) Wash Agri. Expt. St. Bull 519.

*A review of methods of Reclamation of Saline and Alkaline soils with special reference to*

- (a) agronomic practices,
- (b) soil amendments and
- (c) afforestation.

by

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Saline and alkaline soils are regarded as a class of problem soils everywhere in the world and require special remedial measures and management practices. A vast tract of such lands in Punjab State (at a moderate estimate of more than 10 lakh acres) is lying waste and barren. This figure for India as a whole can easily be put over 30 lakh acres. Moreover, this trouble is likely to aggravate further due to increased irrigational facilities in the country.

This loss of land in this way cannot be afforded and therefore, there is always need of continued research on this problem to find out suitable methods for the reclamation and the measures to prevent normal soils from becoming infested with this trouble.

The problem of salinity and alkalinity is an old one and much technical information on this subject is available. The various principles have been fairly formulated but these findings can be successfully applied only if problem of the area to be reclaimed is properly understood. It is then that an economical method for its reclamation can be worked out. This note deals with the work done on this problem in the Punjab and the future line of work.

The kaller or User lands can be divided in the following two groups :

- (1) Saline soils.
- (2) Alkaline soils.

1. *Saline soils.*—To begin with the trouble starts with the accumulation of soluble salts like carbonates, bicarbonates, chlorides and sulphates of calcium, magnesium, sodium and potassium carried from salt bearing surface or added by ground water or irrigation water rich in salts. This accumulation of salts occurs especially in areas with arid climate and poor drainage or permeability and high water table. This excess of salts although keep the soil infavourable structure due to flocculation phenomenon but this results in the decreased uptake of water by the plants resulting in water starvation and death. Such salted soils are known in the Punjab as “kallar”, “thur”, “reh” etc.

2. *Alkaline soils.*—When these salts react with the soil acidoid it results in the replacement of divalent bases like calcium and magnesium by sodium. Such soils have high pH value are impervious, sticky and hard or in other words these have got defective structure as well as high alkalinity. Therefore, the failure of crops on such soils can be attributed to the following three causes:—

- (i) Defective or unfavourable structure.

- (ii) High alkalinity which may be toxic to plants as such or high alkalinity may indirectly render the important nutrient like phosphorus and nitrogen unavailable. Such soils are known as Rakkar in Punjab.

Thus the problem of salinity and alkalinity reduces itself to removal of salts in case of saline soils and improvement of structure and supply of nutrients in the alkaline soils.

#### METHODS OF RECLAMATION

(a) *Reclamation of saline soils.*—In the Punjab attempts to reclaim saline soils were made as early as 1916. The methods then used were as follows:—

- (i) Washing down of salts.
- (ii) Washing out of salts.
- (iii) Scraping of salts.
- (iv) Growing of salt resistant crops.

(i) *Washing down of salts.*—The work was started at Narwala in Lyallpur district where attempt was made to reclaim the soil by washing down of salts by applying heavy irrigations. The land was highly infested with salts and when the salts were washed down in the sub-soil, the land began to support a normal crop. On the basis of good results obtained this method was recommended for the reclamation of such soils in the State.

(ii) *Washing out of salts.*—In the above method huge amount of irrigation water was required to leach down the salts therefore, attempts were made to dissolve the salts in water and wash them out into a deep pit or into waste land or thrown into some natural drain.

This work was started at Lyallpur in 1927 and was found that this method was practicable for the reclamation of soils in which the salts had accumulated on the surface.

(iii) *Scraping of salts.*—At Parinjripur in Montgomery district in 1924-26 trials were made to reclaim the saline soil by scraping the salt from infested surface layer. The soil was removed by means of Karah (Scraper). The method could not find favour because it was practically impossible to dispose off large amounts of scraping. However, this method was recommended when the salts were found in patches.

(iv) *Growing of salt tolerant crops.*—Sugarbeet and salt bushes were tried in the salt infested areas. Sugarbeet did well on such soils and reduced the percentage of salts in the soil. However, this practice could not find favour because the use of sugarbeet crop could not be made.

Growing of salt bushes (*Portulaca Oleracea*) was the common practice which was followed by cultivators. Salt bush was used for the preparation of Sajji a product rich in washing soda.

## AMENDMENTS

The reclamation of such land on the small scale when salt concentration was not very high was carried out by the addition of organic matter as farm yard manure, green manuring etc. Therefore, it was recommended by the Department of Agriculture that along with the above agronomic practices farm yard manure may be applied to reclaim such soils.

## AFFORESTATION

Kikar (*Acacia arabica*) trees were found quite effective in the reduction of salt content from saline soils. At Agricultural College and Research Institute, Lyallpur (now in Pakistan Punjab) kikar trees were grown in kallar effected land, square No. 2 and it was found out that this method reduced the salt content considerably. It has also been experienced that on such soils trees like Jand and bushes like Karir flourish. However, this process of reclamation is slow, tedious and time consuming.

(b) *Reclamation of alkaline soils.*—In about 1920 it was found that there was a large tract of land commanded by lower bari doab canal which contained considerable amount of carbonate salts. Attempts were made to leach down these salts but as the soil was impervious to water it was not found possible to wash down the salts. As the salts were mixed up with the soil scraping could also be of no use.

Attempts made to reclaim such soils could not succeed. It was later found (1926-27) that these soils contained high amount of exchangeable sodium. Therefore attempts were made to replace exchangeable sodium by the application of gypsum and calcium chloride. Later on it was found that calcium carbonate present in the soil could be made use of for the replacement of exchangeable sodium by calcium when salts from such soils were removed by flooding and washing and the soil was irrigated with canal water, its structure improved and the yields of crops increased. This process could be accelerated by growing of rice and berseem, the later crop being used as green manure. Therefore, the methods evolved in the Punjab for such soils are:

- (i) Amendments like calcium chloride, gypsum and press mud.
- (ii) Agronomic practice i.e., rice, berseem rotation.

*Gypsum.*—Gypsum or calcium sulphate being a cheap product and also being fairly soluble in water can be used with great advantage. The work conducted in the Punjab from 1928-32 by Singh and Nijhawan (1932) showed that this salt could be used for the reclamation of such soils.

The actual procedure consists in flooding the land to remove salts if present. When the soil comes in Wattar condition gypsum in a well powdered form may be applied and land ploughed up to mix up gypsum with the soil and the field watered copiously afterwards. This process is continued for 4-6 months. The amount of gypsum to be applied depends upon the degree of alkalinity and nature of soil but 2 tons of gypsum per acre was found quite sufficient to reclaim,

known as "Bara" containing 80 to 90% of exchangeable sodium. Prior to the sowing of crop application of farm yard manure at the rate of 15 tons per acre was found advantageous. The results of experiments are given below in table I.

TABLE I

Results of reclamation of alkaline soils by the application of calcium salts

	Yield of wheat in maunds per acre.								
	Control leached plot.		Calcium chloride 2 tons p.a.		Gypsum 2 tons p.a.				
	M	S	M	S	M	S	M	S	
<i>Suank:</i>									
1927-28 1st year	Grain	0	0	0	0	0	15	0	8
	Straw	0	0	0	0	13	15	7	12
1928-29 2nd year	Grain	0	0	0	0	1	32	0	11
	Straw	0	0	0	0	19	18	19	29
<i>Wheat:</i>									
1929-30 3rd year	Grain	0	0	0	0	3	20	2	30
	Straw	0	0	0	0	8	20	5	0
1930-31 4th year	Grain	0	0	0	0	4	17	3	10
	Straw	0	0	0	0	9	13	5	3
1931-32 5th year	Grain	0	16	0	34	13	39	9	14
	Straw	1	24	2	6	24	1	16	6
Applied F.Y.M. at 15 tons p.a. 1932-33									
6th year	Grain	5	0	8	10	17	20	21	0
	Straw	8	20	14	30	26	20	31	20

Further work on the problem carried out by Singh and Nijhawan (1936) showed that it was not necessary to completely replace sodium by calcium but when exchangeable calcium was only 55-70% of the total exchangeable bases the soil began to support a normal crop and at this concentration of exchangeable calcium there was a sudden increase in the rate of percolation of water indicating thereby that structure of soil has improved. Therefore, rate of percolation can be used

as a method for the determination of dose of calcium salts required for the reclamation of such soils. The rate of percolation of water obtained are given below:—

TABLE II

S.No.	Exchangeable calcium as Ca percentage on air dry soil.	Maximum water holding capacity (moisture as percentage on oven dried soil)	Rate of percolation (time required for 100 c.c. of water to pass through).	
			Hrs.	Mts.
1	0.0432	28.91	27	55
2	0.0524	31.88	27	32
3	0.0720	32.44	25	36
4	0.0992	33.11	24	12
5	0.1008	34.02	24	3
6	0.1104	34.9	7	41
7	0.1120	34.88	4	5
8	0.1184	35.05	2	39
9	0.1304	35.53	2	19
10	0.1334	36.26	1	54
11	0.1352	38.47	1	5
12	0.1824	44.26	0	26

*Press mud.*—It was considered uptill recently that pressmud from carbonation factories cannot be made use of and therefore, this product has been going waste. But now it has been shown that pressmud can be successfully utilized for the reclamation of alkaline soils where rice berseem is being used as a method of reclamation. Pressmud besides containing about 70% calcium carbonate also contains 4 to 5% nitrogen, 1.25% P<sub>2</sub>O<sub>5</sub> and 8 to 9 percent organic matter. The results of experiments conducted are given below in Table III.

TABLE III

S. No.	Treatments	Grain yields in maunds per acre.	
		Paddy	
		Kachwa	Tarn Taran.
1	Control . . . . .	4.0	6.9
2	Gypsum at 2 tons per acre . . . . .	5.5	13.3
3	Pressmud at 2 tons per acre . . . . .	6.0	10.6



These results point out that pressmud is as effective as gypsum in reclamation of soil by rice cultivation if not superior.

(ii) *Agronomic practice*.—Usefulness of rice berseem rotation to reclaim alkaline soils were found as back as 1934-35. This rotation was found to be economical and best suited for soils containing sufficient amount of calcium carbonate. This practice can be used with advantage for the reclamation of saline or saline-cum-alkaline soils. The results of the experiments conducted are given below in table IV.

TABLE IV

*Yield results of rice grown for reclamation of Bara or Rakkar soils*

Year	Crop	Yield in maunds per acre	
		Grain (unhusked)	Straw
1933-34	Rice	2.35	8.2
1934-35	Rice	7.83	18.72
1935-36	Rice	19.75	43.12

It may be seen that the yield of rice could be increased about 8 fold in the 3rd year after which period the land became suitable for growing of other crops.

Further work carried out at Kala Shah Kaku showed that green manuring with 'Dhaincha' considerably increased the yield of paddy crop used for reclamation. The reclamation could be accelerated if gypsum was applied to the soil before putting in Dhaincha.

Now-a-days work in the Punjab is being carried out to find out how far the three limiting factors in crop production in alkaline soils viz., defective structure, deficiency of nutrients and high alkalinity contribute towards the decrease in yield. Preliminary work done is being reported under the following two heads:—

- (i) Relative effect of defective structure and deficiency in plant nutrients.
- (ii) High alkalinity.

(i) *Relative effect of defective structure and deficiency in plant nutrients*.—Due to defective structure and excess of salts the availability and supply of nutrients is greatly decreased. Due to defective structure and its attendant effects on soil physical condition, the air and water relationship of such soils are greatly impaired. Therefore, nitrification and other biological phenomenon do not take place properly. Due to high alkalinity organic matter is highly dispersed and is easily leached. Thus these soils are low both in total and available nitrogen. High alkalinity also renders the soil phosphorus unavailable to plants. Thus these soils suffer from the supply of proper amounts of two essential and major plant nutrients i.e., nitrogen and

phosphorus. This had been amply proved from the results of experiments conducted with gypsum and pressmud when applied alone and in combination with nitrogen and phosphorus.

The application of nitrogen and phosphorus to the paddy crop grown for reclamation greatly increased the yield. The increase was higher as compared to gypsum treated plots. When the fertilizer was applied in addition to gypsum treatment, there was further increase in yield but increase in yield does not justify the application of gypsum. Results from these experiments are given below in tables V and VI.

TABLE V

*Effect of application of nitrogen and phosphorus to alkaline soils*

	Yield in maunds p.a. of paddy	
	Grain (un-husked)	Straw
1. Control . . . . .	2.25	3.15
2. Ammonium sulphate 25 lbs. nitrogen p.a. . . . .	6.75	7.95
3. Ammonium phosphate 25 lbs. nitrogen + 31.25 phosphorus per acre . . . . .	9.15	12.30

TABLE VI

*Effect of application of nitrogen and phosphorus alone and in combination with gypsum*

	Crop yields of paddy in maunds per acre	
	Grain	Straw
<i>Tarn Taran:</i>		
1. Control . . . . .	6.9	13.8
2. Ammonium sulphate + superphosphate (25 lbs. P + 50 lbs. nitrogen) . . . . .	11.3	18.3
3. Gypsum 2 tons per acre . . . . .	11.3	20.3
<i>Karnal:</i>		
1. Control . . . . .	4.0	..
2. Gypsum . . . . .	5.5	..
3. Ammonium sulphate + superphosphate . . . . .	7.0	..

From the data so far obtained it is quite clear that application of fertilizers to alkaline soils increased the yield and the increase in yield can cover the cost of fertilizer. The fertilizer not only affect the rice crop but increase the yield of berseem following it. It was

found out that the increase of green fodder of berseem was 324 maunds per acre. It has been further shown that when nutrients are supplied the addition of gypsum becomes unnecessary. This was indicated by Singh and Nijhawan (1942) while working on those soils. The recent work has proved it further that supply of nutrients definitely increases yield of paddy thus accelerating the process of reclamation. The dose recommended for Punjab is 50 lbs. nitrogen plus 25 lbs. phosphorus.

(ii) *High alkalinity*.—No detailed work has been done as to how far alkalinity itself decreases the yield. The preliminary work showed that when kribium was added to soils high in pH, it improved the structure of soil but did not decrease alkalinity. On such soils it was possible to grow crops like maize and cowpeas etc. When fertilizers were added to it, it further improved the stand of crop thereby indicating that high alkalinity itself was not much responsible for decreasing the yield but it indirectly lowered the yield by decreasing the supply of nitrogen and phosphorus to the plants.

No one method can be recommended for every type of saline and alkaline soils. Rice-berseem method can be used for both alkaline and saline soils provided soil contains calcium carbonate, water table is not high and sufficient water is available for growing of rice and berseem which requires large amount of irrigation water. However, berseem can be replaced by gram or dhaincha as green manure crops. When alkalinity is very high it may not be possible to grow any crop in such soils and in such cases the first step will be to somewhat lower the alkalinity by the use of gypsum or any other soluble salt of calcium. The application of such salts may also be necessary for the areas where calcium carbonate is absent or sufficient irrigation water is not available for growing of rice. However, saline soils may be reclaimed by following any one of the simple agronomic practice enumerated above.

*Future line of work*.—(1) So far no method exists for calculating the quantity of calcium salts required for reclamation. This will depend on the amount of exchangeable sodium which can be tolerated by different crops and the strength with which sodium is held on the exchange complex. Preliminary work carried out in Punjab shows that higher percentage of exchangeable sodium can be tolerated than suggested by workers in U.S.D.A.

2. It is still to be investigated how far each of the three limiting factors, defective structure, high alkalinity and non-availability of nutrients contributes towards the failure of crops. Work done in these laboratories show that nutrients are by far the most important factors which effect the crop yields.

3. The most problematic kallar soils are those that are formed due to high water table. For the reclamation of such soils precise information is required on the movement of salts and the amount of irrigation to be applied. It is highly essential to add as much water which may be sufficient to keep the salts below the root zone without raising the water table. In such cases the use of practices like mulching, suitable rotation of crops and growing of crops by the side of ridges may be helpful in getting increased yields.

However, the permanent remedy in such cases lies in the lowering of the water table which may be attained by the use of drains open or files of installation of tube-wells to pump out the sub soil water. How these measure can be successfully adopted in different areas will have to be worked out.

*References:*

1. Singh, D and Nijhawan, S. D. (1932). A study of the physico-chemical changes accompanying the process of reclamation in alkali sons. Ind. J. Agri. Sci. Vol. II. 1—18.
2. Singh, D and Nijhawan, S. D. (1936). A preliminary study of the effect of certain actions saturating the soil exchange complex on its physico-chemical properties and their relation to the plant growth. Ind. J. Agri. Sci. Vol. VI.
3. Singh, D. and Nijhawan, S. D. (1943). Availability of phosphorus in alkaline and calcareous soils. Ind. J. Agri Sci. Vol. 13.

*Note on the reclamation of Saline and Alkaline Soils in the Deccan Canal area with special reference to (1) Agronomic practices (2) Soil amendments*

by

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The problem of saline and alkaline soils in the Deccan Canal area in the Bombay State is very important and deserves foremost consideration, in view of the large area to the extent of 82,000 acres which have gone out of cultivation either due to salinity or alkalinity. This feature, if allowed to increase unchecked would undoubtedly present a gloomy future especially under the increasing pressure on land. The results of work done in the Deccan Canal tract on this aspect are presented in this note.

(1) *Present position*

*Survey and classification.*—Plans for reclamation of any area should be based on the thorough study of the soils regarding their morphology and chemistry. With this object in view a large number of profiles were examined in the saline and alkaline areas and as a result of this detailed study they were grouped under.

I. Alkaline soils—(a) Soils on flat topography with subsoil water table below 10 to 15 with 'B' horizon compact and impervious.

(b) Soils occurring in lowlying situation—Alkalization on the surface inspite of fairly porous subsoil.

II. Saline soils—Soils with surface incrustation formed as a result of nearness of sub soil water table.

The undesirable characteristics of these soils are mainly the high saturation of clay complex by sodium, high soil pH and free salt content. A rapid survey of the sugarcane areas revealed the limiting levels with respects to these chemical properties as under:—

	Just cho- pan	Moderately cho- pan	Highly chopan
Sodium Saturation	5 to 10%	10 to 15%	above 15%

  

	Good	Fair	Poor	Bad
Total Salts	Below 0.2%	0.2 to 0.5%	0.5 to 1.0%	above 1.0%

  

	Good	Medium	Bad
Soil Reaction	Below 8.5	8.5 to 9.0	Above 9.0

### (2) Studies on alkaline soils

The experiments were conducted on typical soils on the following lines viz., (1) agronomical methods dealing with the cultural operations and various other factors of cane growing, (2) chemical methods. In addition, series of permanent plots with (i) irrigation and manure, (ii) cropping, (iii) Rotational crops have been established and they are yielding results of very practical utility in trying out various methods for improvements of these soils. The important findings of these series are as under:—

*Irrigation and manuring.*—Increasing doses of water have effected progressive increases in Ex. Ca. The reduction of sodium has taken place in a number of treatments but in the case of manured plots the changes are appreciable. Farm Yard Manure has found to be the best in reducing the sodium. As regards the soil reaction higher doses of irrigation have appreciably lower pH. Sulphate of amonia has also helped to reduce pH.

*Cropping and fallowing.*—Under this series there are 5 different fallows having different combinations like cultivated manured, uncultivated, irrigated, etc., and 3 systems of cropping with cane with and without manures. The cropping has helped reduction in pH, total salts and sodium saturation, where as fallowing has definite adverse effects.

*Rotational cropping.*—Some of the common rotational crops with sugarcane were tried regarding their suitability in the improvement of these soils. These were Rabi, jowar, wheat, berseem, shevri, cotton, tobacco, dhaincha, rice. Considerable improvement of these soils was observed by way of increase in Ca/Na ratio in the case of rice, berseem, dhaincha and cotton. *The order of superiority was berseem, rice, dhaincha, cotton.* Growing of Lucerne and shevri in summer

months helped in lowering sodium salts. Crops like dhaincha, shevri because of their deep root system have helped in opening of the sub-soil especially where the 'B' horizon is compact.

*Soil amendments.*—The following amendments were tried:—

1. Gypsum.
2. Sulphur.
3. F. Y. M. singly and in combination.

The dose of sulphur was  $\frac{1}{2}$  ton and that of Gypsum was 1 ton per acre. Highest beneficial effects were seen in the case of sulphur+F.Y.M. Molasses (10 tons per acre) also proved as efficient material for reclamation next to sulphur+F.Y.M. treatment.

*Effect of Krilium.*—The alkaline soils due to the presence of sodium in the clay complex get dispersed necessitating the building up of soil structure. Krilium, a synthetic product claimed to be 500 times more efficient in improving the physical condition of the soil as compared to ordinary organic matter was tried to examine the possibility of using this material in improving the chopan soil. Effect of Krilium at the rate of 2,000 lbs. per acre on the physical and chemical properties was studied as compared to compost to the extent of 160 tons per acre, i.e., 200 times Krilium application. The results show that the application of Krilium has a very good effect on soil aggregation. In the Krilium treated plot the percentage of soil aggregates of 1 m.m. or bigger size was 50.5 against 12.4 in compost treated plots. Krilium has however no effect on the soluble salt content, exchangeable sodium and calcium of the soil. The good effect of aggregation by application of Krilium may be taken advantage of in a scheme of soil reclamation when the soil gets dispersed. The experiments with agricultural waste products like paddy husk, groundnut hulls, safflower hulls for improvement of alkali soil are proposed to be tried.

### (3) *Studies on Saline and water logged soils*

The problem of improvement of water logged and saline soils was undertaken at sub-station at Hol on Nira Left Bank Canal where considerable area has gone out of cultivation due to water logging. The water table of the area chosen for the experiment was found to be at 2½' below the surface and the salt content varied from 1.1 to 2.4%.

*Drainage.*—Where large areas of land are under irrigation at least part of the area must be drained to keep the level of subsoil water at least below certain level. Drainage on large scale is costly and is not advisable unless otherwise forced by (1) nature of topography, (2) very high water table with highly saline subsoil water.

The pot culture experiments at Padegaon have shown that the water table at 4' does not act as a limiting factor for growing of many of the crops. Besides according to the survey report of the sugarcane areas, areas with 4½' and below hydroisobath lines are found not to be liable for salt efflorescence. The important problem was thus to reduce the salt concentration of the soil as well as of the subsoil water.

*Agronomical methods.*—A number of crops were therefore tried to find out their suitability for saline soils. Among the crops tried dhaincha, cane, onion, paddy, safflower Garlic and wheat were found useful both from the point of view of reduction of salt content and also higher tolerance. Various cultural operations were also tried and the following were found most beneficial (1) Deep ploughing and frequent interculturing; (2) Growing of Adsali crop as this crop makes sufficient growth to cover the surface during summer months; (3) Close planting to minimise the area exposed to surface evaporation; (4) Heavy irrigation by following serpentine methods to wash of accumulated salts; (5) Application of large quantities of bulky manures to build up the structure of the soil. Different rotations were also tried. (1) Four crop rotations—Cane-cotton-paddy-dhaincha; (2) Three crop rotations—Cane-wheat-shevri or, cane-onion-wheat; (3) Two crop rotations cane paddy. The data showed that four crop rotations and three crop rotations are well suited and out of the two-three crop rotation system showed better performance. The two crop rotations however showed definite harmful effects. The growing of crops like dhanicha shevri have helped to reduce the salt content of subsoil water.

#### (4) *Utility of soil classification maps*

The soil survey and soil mapping of the entire sugarcane areas was undertaken by the soil survey section at Padegaon in the year 1948 and the work has now been completed for the entire area. The soil profiles were examined at every 1320' apart and chemical analysis of these soils is also available. The levels of sodium saturation, total soluble salts, soil reaction etc. are shown in the form of maps. These maps will serve as basic maps and can be made use of wherever necessary with further collection of some data, in—

1. Keeping a watch against further deterioration of these soils.
2. Delineating areas suitable for varied intensities of irrigation.
3. Planning drainage works.
4. Preparing outlines of proposed procedure for reclamation.

#### (5) *Plan for future*

*Recommendation.*—In order to plan the permanent productive agriculture it is desirable that the whole problem of canal irrigation and cropping be reviewed taking into consideration soil classification reports of the Padegaon Research Station and various other data collected by other research institutions to fix up (1) the acreage under irrigation on each distributory, (2) distribution in relation to potential production, (3) suitability of the area towards varied intensities of irrigation, (4) cropping plan depending upon the pattern of soil type, (5) out lines of procedure for reclamation of saline and alkaline soils and so on.

As the reclamation of saline soils depends largely on movement of water, wider region round and above it (apart from the area to be reclaimed) should be considered as a unit. Again as it entails heavy investment and co-operation by a number of cultivators—small and big some sort of organizational set up will have to be thought of as is being done in other countries like U.S.S.R. and U.S.A.

**Reference:**

1. Rege and Basu (1948) Sugarcane Research in Bombay Deccan (1932—44).
2. Lad, Raghvan, Patel (1956) Proc. of International Society of Sugarcane Technology.
3. Basu and Tagare (1943) Indian Jou, of Agri. Sci. Vol. XIII Part II.
4. Mirajkar and Patel (1955) Proc. of Decc. Sug. Tech. Assoc. Pages 82—87.
5. Rege and Patwardhan (1951) Proc. of Dec. Sug. Tech. Assoc. Pages—101—110.

*A review of methods of reclamation of saline and alkaline soils with special reference to soil amendments*

by

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*1. Introductory*

It stands to reason that the progressive amelioration of saline and alkali soil, as the result of reclamation of such land should normally be accompanied by amendment of certain characteristics of those deteriorated soil. Systematic studies were made some years back of progressive changes in some of the physico-chemical soil characteristics resulting from the application of the soil reclamation technique developed by the Punjab Irrigation Department (1), (2), (4), (6), (7). The salient features of amendments of certain soil characteristics brought about by reclaiming deteriorated land by that technique are presented briefly in this paper.

*2. Genesis of Land Deterioration*

The soils of the arid and semi-arid regions are generally characterized by the presence of soluble salts, mainly of sodium and/or an alkaline reaction (8). Under adverse conditions, the soluble salts contained in the soil crust tend to move upwards and as the result of evaporation accumulate in the top portion of the profile of even at the soil surface. That process of accumulation of salt in the top soil, if allowed to continue uninterrupted, culminates in such land becoming completely saline. Saline land deteriorates further into alkali land by the process of sodiumization, i.e., replacement of calcium in the soil exchange complex by sodium, the latter made available by the preponderating sodium salts, the change being brought about as below:



The longer the lands in arid and semi-arid regions are subjected to conditions favouring the development of salinity and/or alkalinity, the more advanced is the stage of deterioration of the soil.



Whereas under the ancient system of agriculture in India there had been very little increase in the amount of soluble salts at the surface, with the construction of large modern canals and the applications of unnecessarily large quantities of irrigation water, the increase in alkali had been very rapid.

Numerous plausible explanations regarding the genesis of soil deterioration in arid and semi-arid regions have been advanced by various workers. Irrigation is confined to arid and semi-arid regions. Also the rise of water table after the introduction is generally inevitable. The rise of water table and the appearance of salts at the soil surface have, therefore, been assumed to be associated phenomena, the former being regarded as the cause of the latter. An examination of a large number of soil profile samples from land both from the canal irrigated areas and unirrigated areas, brought out the fact that the presence of soluble salts in the soil profile was not restricted to the former areas but occurred in the latter as well. There was, however, one interesting difference. Whereas, in irrigated areas the salt was accumulated conspicuously in the form of a definite zone, in unirrigated areas it was, more or less, evenly distributed throughout the soil crust. (9) (10).

The present position of our knowledge about the salinization of land based on the Punjab experience may be summed up by stating that the pre-requisites for soil deterioration to proceed in any arid and semi-arid region are:—

- (a) The presence of salts in the soil crust.
- (b) Formation of a zone of salt accumulation with the introduction of irrigation and its position in the soil crust as a result of the intensity of irrigation applied and other factors operating.

Before the commencement of canal irrigation, salts are more or less evenly distributed throughout the soil crust. With the introduction of irrigation the salts accumulate in the form of solution at some depth below the surface forming a zone of accumulation, and the position of the latter in the soil crust depends on the intensity of irrigation and the use made of irrigation water. Under canal irrigation, due to larger quantities of water, the connection between the surface soil and the zone of salt accumulation in the soil crust is usually established which helps in the movement of moisture and salts in the crust. Under well irrigation, however, such a contact is not established and, therefore, little fluctuation of salt ensures. That points to the greater precautions necessary to avoid salinization of land under canal irrigation than under well irrigation.

Rainfall is another factor determining the position of the zone of salt accumulation in the profile, with a good rainfall that zone tends to depress to lower depths than when the rainfall is low. (9) (10).

### **3. *Technique of Reclaiming Deteriorated Land Practised by the Irrigation Department***

On account of the menace of water logging and land deterioration which was brought to the forefront as the result of introduction of irrigation in the Punjab, the soil reclamation technique developed

by the land Reclamation Department of the Punjab had been employed successfully over a number of years for reclaiming deteriorated land in that and other States. (8). Briefly it consists of leaching deteriorated land with water to reduce the excessive concentration of soluble salts followed by cropping of rice.

The crop rotation generally advocated is rice followed by berseem or senji, then sugarcane followed by wheat or cotton. With adoption of gram in place of berseem and senji the difficulty of the rabi water supply for the growth of the leguminous crop can be overcome. The leguminous crop, introduced in the crop rotation, helps to re-establish the soil nitrogen balance which otherwise gets depleted due to the prevalence of anaerobic soil conditions.

The amelioration of deteriorated land, as the result of reclamation operations, is usually assessed in terms of the decrease in the soluble salt content and pH, a reduction of the former to below 0.24 and of the latter to 8.5 being usually aimed at. Such areas, which are only mildly saline and in which the alkalization of land has not proceeded very far (pH between 8.5 and 9.0), may require only one rice crop followed by proper crop rotation to reclaim them. For those areas, where the salt content is still higher and alkalization somewhat more advanced (pH between 9.0 to 9.5) two rice crops may be necessary. Such lands, where alkalization has advanced still further (pH higher than 9.5), are more difficult and expensive to reclaim; the reclamation being a long-drawn affair in their case. The *Sathra* variety of rice is particularly advantageous as a reclamation crop on account of its being more suitable for early transplanting, requiring less irrigation and being able to withstand relatively high salt content in soil, achieving early maturity, etc.

For leaching and for growth of the first rice crop an irrigation depth of 5 to 5.5 ft. of water during the crop has been found ample and an area of about 50 acres of *thar* land can be put under reclamation with one cusec of water. The use of *Sathar* variety of rice enables two rice crops to be grown on the same water supply. If area once reclaimed is put to planned cropping subsequently, it stays good.

If deterioration of land due to the upward movement of salts is to be avoided then it is essential that in the development stages of an irrigation project the amount of water applied should be sufficient to ensure that the sodium salts are washed below a minimum depth of 6 ft. from the surface. In fact the salts should be washed below the normal root zone of the crop and for that purpose washing of salts below a depth of 10 ft. from the surface should be aimed at. In order to secure this result, rice should be the initial crop in any irrigation project. To determine whether the results desired have been achieved an analysis of soil profile samples is essential. The prevention of soil deterioration or the actual reclamation of such deteriorated land in those regions by, say, a judicious use of irrigation water coupled with adequate crop rotation, etc. therefore, naturally assume considerable importance.

In terms of productivity rating of land, the deteriorated land of the Punjab has a conspicuously low rating than normal land. (3).

#### 4. *Physico-Chemical Changes in Soil as the Result of Application of the Punjab Technique of Soil Reclamation*

The soil sampling in the experimental fields was done first prior to the commencement of the reclamation programme and subsequently on the completion of each reclamation cycle. One reclamation cycle comprises leaching of the soil with water and cropping of rice followed by cultivation of some nitrogenous or other crop till the time for the next leaching operation. Soil samples were collected at these sites to a depth of 5 to 6 ft., the top one or two feet having been sampled at every 6 in. and the remaining depth at every foot. The soil samples were later analysed in the Laboratory. The salient features of the various studies are described below:—

(a) *Soluble Salt Content of Soils.*—The heavy application of irrigation water tends to eliminate the excessive salts from the top soil. There either occurs a decrease in the soluble salt content of soil up to the depth sampled after the completion of reclamation cycle or, as recorded in a few cases, a decrease in the top few feet of the profile with an accumulation in its lower portion. Further leaching as part of the second reclamation cycle tends to reduce the salt content of these soils further. (7).

The soluble salts mainly comprise the chlorides and sulphates of sodium. A comparison of the extent of removal of these two salts from soils at various sites, as the result of leaching, reveals the interesting difference that chlorides get removed at a relatively quicker rate than the sulphates.

(b) *Soil pH.*—In general, whereas there is a tendency of pH of soils to decrease as the result of reclamation operations, there are cases where, on the contrary, an increase in pH is manifested either throughout the depth or in its top or bottom portion. An increase of soil pH may result from the removal of excessive soluble salts, as the latter when present exert a buffering effect. The decrease of soil pH is rather a slow process depending as it does on the relative ease of removal of sodium in the soil exchange complex. The cropping of rice helps in this phenomenon due to the root system of this crop evolving carbon dioxide which forms with sodium in soil exchange complex sodium bicarbonate which latter gets removed by leaching into the drainage normally provided for the purpose and render soil progressively permeable.

(c) *Exchangeable Base Content of Soils.*—With regard to exchangeable calcium content of soils, it is shown that as the result of one reclamation cycle there occurs, at a majority of sites, an increase in the exchangeable calcium content either throughout the depth or in the lower portion of the profile. (7). In the latter case there occur a slight decrease in the top few feet. In a few cases, the exchangeable calcium content actually decreases after one reclamation cycle. After the second reclamation cycle, however, there occurs a slight decrease of the exchangeable calcium content of soils in the top 2 to 3 ft. with an accumulation at lower depths of the profile at a majority of sites.

Sodium is the predominant base in the exchange complex of alkali soil and is mainly responsible for its undesirable agronomic features. A consideration of the results of the monovalent exchangeable bases

(NaK) of soils of the experimental sites reveals that there is a tendency for them to decrease especially in the top portion of the soil profile as the result of one reclamation cycle. With the continuation of reclamation operations, however, an increase in the NaK content in the top portion of the profile occurs at a majority of sites. (2) (7).

(d) *Calcium Carbonate Content of Soils.*—The processes of leaching of soil and rice cropping tend to reduce markedly the calcium carbonate content of soil. An indirect advantage of this carbonate removal from soils is the reduction in its cementing effect and thereby contributing to an improvement in the soil tilth. Moreover, the calcium thus released in the process tends to replace sodium from the soil exchange complex. The depletion of calcium carbonate content of soils as the result of reclamation operations is, therefore on the whole an ameliorative feature. (2) (7).

The soils of arid and semi-arid regions generally contain a fair content of calcium carbonate which manifests itself at places in nodular form and at times even as consolidated compact mass. This natural form of impure limestone a sort of subsoil tufa is familiarly known as 'kankar' and is generally met with at varying depths of the soil crust, at times right at the soil surface. The kankar nodules are generally classified as fine, pea, medium and big according to their relative sizes.

Kankar generally occurs in tracts subject to alternate drying and wetting cycles, a condition normally prevalent in tropical and sub-tropical regions and its formation in the subsoil is attributed, amongst other causes not yet fully explored, to seasonal fluctuation of the sub-soil water rich in bicarbonate content. The conspicuously high content of manganese in the kankar nodule and in the soil of kankar bearing strata pointed to the possibility of manganese in some form serving as a sort of nucleus for its formation and subsequent development in size.

The qualitative aspect of the genesis of kankar strata in the soil as effected by cropping or maintaining fallow conditions on land for a period of five years at one of the Reclamation Farm was investigated. (1).

It was shown that while a programme of planned cropping on land bearing kankar tended to decrease the kankar bearing strata quite appreciably, leaving such land continuously fallow, on the other hand, resulted in its overall increased development. The formation or deformation of kankar bearing strata had been particularly observed in the top 3 ft. and at depth of the profile below 9 ft. in the various plots.

(e) *Available Phosphate Content of Soils.*—There seems to be quite a conspicuous difference between the available phosphate content of the top and bottom portions of soil profiles at a majority of the sites, the content of the top portion being more than that of the bottom portion. At most of these sites the phosphate content of soils increases throughout the profile depth, particularly in the top portion, as the result of one reclamation cycle. In a few cases, however, there is an increase in the top 2 or 3 ft. with a decrease in the lower portion of the soil profile. As the result of the second reclamation cycle the

available phosphate content decreases in the top few feet and increases at lower depths at the majority of sites. It is not unlikely that the carbon dioxide evolved by the root system of rice crops tends to remove the available phosphate content from soil in the root zone. (2) (7).

(f) *Manganese Content of Soil.*—Out of the trace elements usually associated with deteriorated soils, manganese content of such soils is particularly conspicuous. The presence of manganese in soils in an excessive amount is known to be toxic to plant life. The manganese content of soils in the Punjab has been shown previously to have a significant and negative correlation with the yield of wheat but not so with the yield of rice. Alkali soils of the Punjab have also been shown to contain relatively greater manganese content than normal soils of this region. (5). The toxic effect of manganese is enhanced by more of it coming in solution under alkali soil conditions. It has been brought out in the present study that, in general, a fair amount of manganese (as high as 4 mill equivalents) is present initially, but its content decreases either throughout the depth or at least in the top few feet as the result of reclamation cycles. (2) (7).

(g) *Dispersion Coefficient and Soil Structure.*—The dispersion coefficient (i.e. ratio between clay percentage on autodisintegration to the total clay content of soils) is practically negligible in the initial soil samples due to the presence of high soluble salt content which causes complete flocculation of clay in these samples. After two reclamation cycles, however, a conspicuous increase in the values of the co-efficient seems to occur at all sites due to the removal of excessive salts by leaching. The deflocculation of soils, indicated by the increased dispersion co-efficient, is not altogether a happy feature. Soils with pH higher than 10 usually manifest an almost complete auto-dispersion due to their attaining a deflocculated state on wetting, and the latter tends to inhibit movement of moisture and air through such soils. However, with decreased pH which gradually results from the application of reclamation techniques and increased organic matter content due to cropping, the soil tilth may be expected to improve appreciably. (2) (7).

(h) *Soil Fertility.*—The fertility of soils can seldom be attributed to one simple cause and normally results from the combined effect of several factors. Increased soil fertility is known to be associated with increased bacterial activity. It can be expected that such changes in soils as implement the activity of soil bacteria, would also tend to enhance soil fertility. The progressive variation in the conductivity of soil suspension as the result of keeping the latter has been suggested to be an index of the bacterial activity of any soil. For instance, it has been shown by some soil workers that whereas the electrical conductivity of the professedly fertile soil manifests a progressive change with time, that of infertile soil show little such change. This is attributable to the activity of soil bacteria in the former and their relative inactivity in the latter. A study was made as to how far the changes recorded in the conductivities of soil suspensions reflected the state of soil amelioration of deteriorated soils brought about as the result of the application of the reclamation technique. (2) (4).

It is shown that whereas the soils in their initial deteriorated state manifest little change in their conductivities the same after reclamation show a continuous increase with time on keeping thus showing that apart from the other changes brought about in the soil, there is a distinct revival of bacterial activity as the result of reclamation operation.

(i) *Gypsum Content of Soils.*—That gypsum has a beneficial effect on certain types of soil and crops has been known for a long time. Gypsum has a marked effect on leguminous and such other crops, which particularly depend upon calcium. Gypsum is known to have another use in that it minimizes preventable losses of nitrogen from volatile nitrogenous manures by chemically combining with ammonia to form non-volatile compounds. Gypsum is the only practicable material that can be employed to restore the workability of a soil rendered heavy by preponderance of sodium in the exchange complex. For soils with too much sodium in the exchange complex it is advisable that the leaching water is supplemented with gypsum or sulphur. Due to the relative insolubility of gypsum and reversibility of the chemical reaction, however, large quantities of gypsum may generally be required.

The gypsum inherently formed in soils should, therefore, be expected to play a beneficial role in the amelioration of alkali soils. It has been shown that the presence of gypsum is mostly restricted to soils having pH up to 9.0, soils with high pH having been shown to contain little gypsum. High gypsum content is, again associated with high salt content of soil, particularly sodium sulphate. As the result of reclamation operations gypsum gets washed to lower depths. Both calcium carbonate and exchangeable calcium appear to be responsible for the formation of gypsum in soils. A comparison of the results of gypsum content before and after the application of soil reclamation technique shows that as the result of reclamation operations gypsum gets removed from the top to lower depths along the soil profile. (2) (6). A recouplement of gypsum thus lost during the process of reclamation by surface application or along with irrigation water would be beneficial to cropping on the reclaimed land.

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#### References:

- (1) Hoon, R. C. (1942). The physico-chemical changes in deteriorated soils as the result of soil reclamation operations 1. The deformation of Kankar Cen. Board of Irrig. Jour. India, Vol. VI No. 1. page 50—53.
- (2) Hoon, R. C. (1951). Irrigation & Soil Reclamation in arid and semi-arid regions—a study of the physico-chemical aspect of soil behaviour. First Congress International Commission on Irrigation & Drainage. Question 2R2.

- (3) Hoon, R. C. (1955). "Productivity Rating of Land" paper presented at the 25th annual meeting of the Research Committee of Central Board of Irrig. & Power.
- (4) Hoon, R. C. & Ganga Singh Ahluwalia (1953) "Productivity Rating of Land" paper presented at the 25th annual meeting of the Research Committee of Central Board of Irrig. & Power— V: Soil fertility in relation to the salt content of soils. Irrig. & Power Jour. Vol. X No. 4 pp. 38—42.
- (5) Hoon, R. C. and Dhawan, C. L. (1943) The occurrence and significance of trace elements in relation to soil deterioration I Manganese. Ind. Jour. Agri. Sci. XVI, pp. 601—608.
- (6) Hoon, R. C., Jain, L. C. & Bhatnagar, B. B. (1950) The physico-chemical changes in deteriorated soils as the result of soil reclamation operations I. The occurrence of gypsum in soils Cent. Board Irrig. Jour. Vol. VII No. 1 pp. 14—22.
- (7) Hoon, R. C. & Ratan Lal Dewan (1949) The physico-chemical changes in deteriorated soils as the result of soil reclamation operations II Cent. Board Irrig. Journal Vol. VI No. 3.
- (8) Mehta, M. L. (1940) The formation and the reclamation of thur lands in the Punjab. Force. Punjab Engg. Congress paper No. 235.
- (9) Taylor, E. M. (1940) Some aspects of the physics of water-table rise and salt movement in the soil under irrigated conditions. Proc. Ind. Acad. Sci. India Vol. XI, pp. 451—466.
- (10) Taylor E. M. & Mehta M. L. (1941) Some irrig. problems in the Punj. Ind. Jour. Agri. Sc. Vol. II part 2.

*A review of methods of reclamation of saline and alkaline soils with special reference to (a) Agronomic practices (b) Soil amendments  
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The principles underlying the methods of reclamation of the alkaline soils, are the removal of the salts by washing out with water, good drainage and the use of certain soil correctives, the method to be applied depending on the type of salts present. For the alkalinity development by neutral salts like chlorides and sulphates, more leaching out of salts may be sufficient, provided the supply and drainage of water are good. For the type of salts like the carbonates and bicarbonates of sodium, which have effected changes in the clay, mere washing is not sufficient. In such cases, correctives like sulphur and gypsum have to be used. Recently molasses has been used for the purpose. The effect of these agents is to liberate acids by chemical and biological oxidation, sulphur producing sulphuric acid and molasses organic acids, which react on the carbonates and bicarbonates and by forming sulphates and organic acid salts of sodium, thereby effecting change in the clay complex. The sodium clays are changed into calcium, clays, which will improve permeability and other soil conditions.

Gypsum and sulphur have been tried with success in various parts of the world and in experiments carried out at Mettu Maradur in Trichy District, but the effect of molasses has not been studied in enough detail to warrant its being recommended with confidence.

In addition to the chemical treatment the ploughing in of large quantities of organic matter, such as cattle manure or green manure leaf is always effective and probably is the cheapest method of reclaiming alkaline soils. It has also been found that the presence of organic matter in the soil assists the plant to resist the toxic effect of the salts present. Incorporation of about 5,000 lbs. of paddy straw is practiced by the ryots of coastal Andhra for the removal of salinity.

The quantities of the agents to be applied depend on the quantities of salts present in the soil, and before undertaking reclamation, it is desirable that the soil be analysed. Such an analysis will indicate the types of treatment, and the quantities of ameliorants to be used.

*Method of reclamation of saline and alkaline soils with special references to afforestation*

by

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Alkaline soils are usually found in arid climates. The occurrence of an impervious stratum in the subsoil and a high water table which may also develop as a consequence of the above, are the chief factors responsible for the formation of alkali soils in a climate where the precipitation is less than the evaporation. A high water table is conducive to the formation of alkali soils in arid climates because in such regions the ground water usually contains much more dissolved salts than in humid regions and the precipitation is insufficient to leach away the soluble salts which rise into the upper layers of the soils by capillary action during the dry periods of intensive evaporation. Since a high water-level may also be caused by excessive irrigation or seepage from canals, many irrigated areas in which a high watertable has been formed in this manner also suffer from alkalinity.

If the level of the water table is brought down by some means the upward movement of ground water is retarded, the accumulated salts are leached out or the harmful salts especially Sodium Carbonate are changed to less harmful ones by soil treatment then the alkaline or saline soils can be reclaimed and rendered fit for growing crops.

A tree plantation helps in reclaiming alkaline soils by pushing down the water table on account of accelerated moisture losses. More directly, the shade of trees retards evaporation of soil moisture and thus tends to reverse the upward creep of groundwater, its loss by evaporation and the consequent deposition of salts in the upper layers.

As a rule leaching or chemical treatment of the soil is ruled out in forestry practice on account of its great cost but in order to initially establish or forest crop, it may be necessary to apply some cheap treatment or adopt special techniques of soil preparation. Since most saline and alkaline soils also contain limestone



nodules or pans at no great depth from the surface, it is difficult to raise trees unless the impervious concretionary layer or pan is perforated.

Once a plantation has been formed the soil conditions improve gradually because of the lowering of the local watertable, reduced upward movement of water, deposition of salts in the upper layers and incorporation of humus in the topsoil. Tree roots also penetrate the soil and even the concretionary layers if they are not too thick. This improves the internal drainage and accelerates the leaching down of injurious salts.

Although some small scale trials on the application of soil conditioners like molasses, gypsum etc. have been carried out, by and large these methods are too costly to be adopted in regular forestry practice. The only practicable solution is to choose suitable species which are tolerant of alkaline or saline conditions and to plant them at a wide spacing in deep pits, breaking any superficial kankar pans that may be encountered. It has been found that the chances of success are very much greater if the pits are filled with non-alkaline soil at the time of planting. The better soil ensures a suitable medium for initial growth during the establishment period.

2'x2' to 4'x4' deep-pits filled with non-alkaline soils have been tried in U.P. and Madhya Bharat with fair results. Although the soils were heavily impregnated with salts (PH usually 10 or over), it has been possible to create an open park-like forest by planting large basketed plants of hardy species like *propois juliflora*, *Azadirachta indica*, *Acacia Arabica*, *Albizzia Spp*, *Utea Monosperma*, *Pongamia pinnata*, etc. before the planting pits are prepared it is desirable to leach the top soil by flooding if irrigation is available or by trapping the rain water by a system of bunds.

#### *Techniques for the reclamation of saline and alkali soils*

by

Dr. R. R. Agarwal, Agricultural Chemist to Govt., U.P., Kanpur

Reclamation techniques for different categories of saline and alkali soils differ widely and involve amongst other practices lowering of water table, leaching down the salts, mechanical shattering of hard clay pan in the subsoil, providing adequate drainage, use of calcareous amendments to replace sodium of the exchange complex and finally growing salt or alkali tolerant crops. Suitable practices for different categories of saline and alkali soils found in the state are outlined below.

*Saline Soils.*—Saline soils are the mildest type of sodiumised soils and can in general be turned into normal soil through the use of agronomic practices only. The most important pre-requisite for the reclamation of this category of soil is to lower the water table permanently to depths 5 to 6 feet below the surface, even during monsoon months. This should be followed by leaching with good quality irrigation water. The former objective is achieved by providing a net work of deep cuts (drains) in the area in direction

perpendicular to the slope of the land such that surplus water could be drained out. Unless the water table is very high usually two to three leachings with good quality water suffices to remove all harmful soluble salts. In more degraded cases where permeability is initially impaired or becomes bad during the leaching operations a light dressing of gypsum not exceeding one ton to an acre considerably improves the nature of the soil. Growing of salt tolerant crops such as paddy, barley, sugarcane and castor proves highly beneficial.

*Saline-alkali soils.*—Reclamation of this type of soils necessitates the use of both agronomic practices as well as soil amendments. These practices are separately described below :

(a) *Agronomic Methods.*—In these soils the problem is two fold; firstly the high salt content and secondly poor internal drainage caused by the presence of hard clay pan and the highly dispersed sodium clay. For such soils mechanical shattering of the pan, through the use of massive single tyne rippers attached to heavy tractors helps to restore water infiltration. Subsequently leaching with water, addition of plentiful supplies of organic matter and growing paddy crop during the first monsoon considerably lowers the salt contents. Use of this method on larger areas on a pilot experimental project at Usar Reclamation Farm, Chakeri (Kanpur) has shown extremely encouraging results and an area which once used to be denuded of all vegetation is now growing normal crops. The soil has become productive and attained the characteristics of normal soil in as much as the soil alkalinity and the salt contents have both gone down considerably. This process necessarily involves launching of large scale reclamation work and is suitable only as a co-operative project subsidised at Governmental level.

(b) *Chemical amendment method.*—Techniques of reclamation of such soils on smaller holdings would involve an application of requisite quantity of gypsum in pre-monsoon period. The field is ploughed deep and after partially levelling is treated with finely pulverised gypsum preferably to the extent of theoretical requirement of this amendment. In absence of absolute theoretical values an economical dose of about 3 tons of 85 per cent. gypsum per acre yields very satisfactory results. The field is bunded properly and flooded with good quality irrigated water. After few days the standing water is flushed out into the drains and carried out from the area. *Dhaincha* (*Sesbania aculeata*) crop is sown into the field to use it as a green manure. Flooding and flushing operations are continued while *dhaincha* grows into the field. Six week old crop *dhaincha* is turned into the soil and paddy transplanted into the field. Where transplanting is not possible broadcast method of sowing paddy may have to be adopted. During the growth of paddy crop plentiful supplies of water should be maintained into the field and flushing continued. Usually four flushings are essential to remove the salts present in the soil as well as the bye products of the exchange reaction. In order to ensure reclamation operations successfully it is most essential to maintain plentiful supplies of water, and grow only salt tolerant crop in the early years of reclamation. Necessarily the reclamation operations should be started in *kharif* and the first crop limited to paddy after *dhaincha* green

manuring. In *rabi* barley or oat crop can be recommended to the advantage of the cultivator. Wheat crop should only be taken when the soils have been greatly reclaimed. Small scale experiments conducted on these lines by the Soil Survey Organisation on cultivators holdings have shown manifold increase in crop yield even when supplies of water and satisfactory drainage system could not be arranged. The initial increase in the yield of paddy crop obtained during the first year of reclamation has been well maintained by the soil and succeeding *rabi* crop *viz.*, Barley crop, also showed similar trends.

*Alkali Soils.*—Methods of reclamation of alkali soils are more or less similar to the methods given for saline-alkali soils with the difference that alkali soils being very strongly alkalized and having a hard *kankar* pan do not respond only to mechanical shattering and necessarily required calcareous or some other acidifying amendment for changing the nature of the soil and partially reclaiming it. Highly degraded soils of this category should either be left out completely or taken up for afforestation purposes. This practice has yet to establish its large scale economical use because many trees used for afforestation purposes may not stand the alkali toxicity and the extremely poor physical condition of such soils.

*Crop rotation with particular reference to paddy in Madras State*  
by

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Crop rotation has many advantages, the chief of which is an improvement of the Physico Chemical conditions of the soil, especially so in wet lands where the conditions change during the period of rice culture when the whole field is maintained in wet condition. The culture of other crops in alternation with rice, when it is possible to do so with profit, should strengthen the rice industry, apart from its effects in improving the soil. The kind and nature of cultivation, of the crops coming in rotation, will depend upon the season of rice cultivation, conditions of soil and facilities for irrigation. In the dry lands dependent solely on rains, the rice is grown during the rainy season and the land remains fallow for the rest of the year. The crops that come in rotation with paddy in dry lands and the wetlands are different. In wet lands since most of the area is made up of heavy clayey soil, crops which would normally come up well in such soils, can only be rotated.

Almost all the rice cultivation in Madras State is confined to the two monsoon periods *i.e.*, June to January. The crop either gets the benefit of the rains directly as in the West Coast districts or gets its water supply from rivers which depend upon the monsoon for their freshes as in Tiruchirapalli, Tanjore etc. In places where water facilities extend beyond February a hot weather crop of rice may also be grown between February and May. No regular rotations exist in areas where rice is cultivated under swamp conditions and the bulk of the area is cropped year after year with only rice. However, there is a practice in some areas of taking a catch crop of sunnhemp (*Crotalaria juncea*) or Pillipesara (*Phaseolus trilobus*) or pulses like greengram or blackgram by sowing the seeds in the

standing rice crop just before its harvest. These catch crops are able to grow with the residual moisture in the fields that had been under water for nearly six months. In certain favoured localities, where the land is rich and well-drained with abundant water facilities, sugarcane, banana, betelvine or turmeric are rotated with rice once in three or four years. In areas where the water supply is not sufficient for taking a rice crop, millets like sorghum, bajra or ragi or oilseed crops like Gingelly, groundnut or cotton are grown between February and September. Rainfed crops of Sorghum, groundnut or Gingelly are rotated with dry paddy.

The various rotations adopted in different rice tracts of this state are as follows :—

In Chinglepūt in wetlands there is practically no rotation. Wherever rice is grown under well irrigation, a crop of ragi or gingelly is grown in the hot weather. This is practised in every district where rice is grown as a garden crop as in North Arcot, Salem, South Arcot Madurai and Ramnad, the crops grown in rotation are several and varied. In parts of North and South Arcot Districts, Sugarcane is grown in extensive areas in wetlands in rotation with paddy.

In parts of Tiruchirapalli district where water supply is available almost throughout the year, bananas and sugarcane are grown in rotation with rice in wetlands. In Tanjore district there is practically no rotation, the land remaining fallow from February to June. In some places green or blackgram is sown before the harvest of rice crop. In limited areas green manure crops are also raised. Recently it has been established that the most economic utilisation of the rice fallows is to grow a short term cotton crop which comes in rotation with paddy. This method of cultivating cotton in rice fallows is becoming increasingly popular. In the single crop lands in Tirunelveli district, field beans or cholam (*Sorghum* sp.) is grown in the early kar season. In the double crop lands after the harvest of Pishanam (winter) paddy, a crop of Senna (gingelly) or pulses like green gram or blackgram is grown. In Coimbatore mostly a single crop of paddy is raised. Whenever facilities exist Banana or Sugarcane is rotated with rice. After the harvest of paddy, the fallows are being, of late utilised for growing groundnut or cotton in certain areas leguminous crops and green manures are also grown.

In Malabar, in the Palliyals (single crop lands) horsegram is grown in rotation with paddy. It is always precarious and even if no grain is obtained, it is ploughed in as green manure for the following paddy crop. In the Modan lands where rice is grown as a dry crop, a regular rotation is practised. The dry rice occupies the land from April to September after which gingelly, blackgram or sweet potato is grown. In some areas, ginger and tapioca are also grown in rotation with rice. Cotton (Sea Island) is also cultivated in the Modan lands in rotation with paddy, with success. In South Kanara horsegram or other pulses like greengram is commonly grown after rice in both single and double crop lands.

The order of succession of the crops is diverse and variable in different localities and the crops involved mainly depend upon the nature of cultivation of rice *i.e.* dry or wet. The availability of water for irrigation and the seasons of cultivation also determine to some extent, the crops that come in alternation with paddy. Apart from these, the regional peculiarities of soils and climate, market demands as well as domestic needs of the cultivator are also responsible for the varied nature of the crops that are grown in rotation with rice.

Of the various rotations described above, growing leguminous crops after rice as practised in many tracts is beneficial and the soil is enriched by the fixation of atmospheric nitrogen by the nodule bacteria and it is regarded as improving the soil for the succeeding rice crop. This fact has been recognised in other rice growing countries also. If pulses like green and blackgram or groundnut are grown, the haulm can be ploughed in as green manure after picking the pods. Cotton cultivation in rice fallows is widely advocated in recent years in Madras State as it is most economical. Further there is no deleterious effect on the succeeding crop of paddy. Growing such exhaustive crops like tubercrops, bananas and sugarcane will no doubt deplete the soil of its nutrients and the paddy that follows will suffer to some extent, unless adequately manured.

Thus the rotation of crops should be such as it would be beneficial for the crops involved and at the same time economical. Considering this, it is necessary that legumes should form a crop in the rotation and preferably it should precede a paddy crop. Cultivation of cotton in rice fallows is also recommended as it is the most profitable method of utilisation of the fallow period of rice soils.

### *Agronomic Practices*

by

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The agronomic practices deal with the application of economic dosages of manures to get maximum returns in the form of yields of crops. Nitrogen, phosphorus and potash are the three major requirements of crops and these are applied in various forms to the several cultivated crops. The availability of these nutrients is controlled by weather conditions to a great extent. Rainfall is an important factor which controls the availability of these nutrients to the crops. Rainfall, in addition to supplying moisture to the soil. Data are available to prove that combined nitrogen to the tune of 4 to 5 lbs. per acre can be had from an annual rainfall of 30 inches. In Ceylon, a quantity of 13 lbs. of combined nitrogen per acre is stated to be received mainly from an annual rainfall of 100 inches. In the agronomic experiments conducted in India this factor is not generally taken into consideration. A genuine need, therefore, exists to conduct systematic experiments and collect data on the availability of combined nitrogen in all the Agricultural Research Stations. To being with, rainwater can be collected for every rainy day at four major Agricultural Research Stations, namely, Coimbatore, Aduthurai, Pattambi and Koilpatti. The samples collected may be analysed on the same day at these four Stations. These stations have to be equipped with small Laboratory facilities for estimating the combined nitrogen in rainwater by the Kjeldal method.

Similarly the availability of phosphorus to plants depends on the weather conditions. The need for a response to phosphate increases as the rainfall increases. Rainfall affects the soil temperature, which, in turn, significantly influences the rate of phosphorus fixation in the soil. The findings of the Rothamstead Experimental Station, confirm these statements. For e.g. at Rothamsted in 1953 the apparent uptake of broadcast superphosphate was about 5 % of applied, while, in 1954 about 17% of the same broadcast fertilizer was apparently used (Report of the Rothamstead Experimental Station for 1954). The difference in the uptake is attributed mainly to the weather conditions. The aspect of the influence of weather conditions on the uptake of phosphorus requires considerable study as the fruitful findings can be used with advantage to economise the use of phosphatic fertilisers, keeping the local weather conditions in view.

### *Reclamation of Saline and Alkaline soils—by Afforestation*

by

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*Intrdouction.*—There are large areas of land which are saline and alkaline lying mostly along the east coast of the Madras State. These areas are found either as saline flats for a considerable distance as a belt along the sea coast or as extensive grounds by the side of river or eroded areas. Generally these areas are barren without any substantial plant growth and hence very unproductive. Very often, these lands are not even useful for the browsing of village Cattle. The ryots who own such lands finding them uneconomical, do not pay any attention. Reclaiming these unproductive areas is a great necessity. As our country is thickly populated per unit area compared to other countries, the maximum utilization of the land for productive purposes has to be the aim in national development.

Though the problem of reclamation of saline and alkaline lands have been receiving some attention in the past, due progress could not be made due to the exorbitant cost involved and the striking results which were not achieved in short period of trials. It has to be taken into consideration that these areas have become saline or alkaline, not within a very short span of period, but has been due to a considerable period of deterioration brought about both by nature and the artificial environment brought about by man and his animals. Thus the problem being a case of a long standing evil, measures of reclamation have to be gradual. Spectacular results cannot be expected within a few years of scheme of work. A long range programme of gradual evolution of the unproductive land into a productive one can alone be fruitful.

*Reclamation methods.*—Reclamation of the saline and alkaline areas by mechanical methods of washing and draining and the chemical methods of adding soil amendments are prohibitively costly, though these may be advisable and very effective in small areas. Reclamation through agronomic practices depends to a large extent on the stage of the preliminary reclamation that has been done to the soil. For bringing these areas for cultivation and following suitable agronomical practices, the soil fertility and soil texture have to be improved and this could be cheaply and efficiently done by the addition

of organic matter. By growing plants in these areas, the dead remains of the plants add the organic matter required, break up the soil and bring it into a condition suitable for further progress in reclamation work. As such a programme of *biological reclamation*, with the first step of growing such plants that could thrive in such areas will be proper approach.

*Biological approach by plant growth.*—Though generally, the saline and alkaline areas are devoid of good plant growth, there are a number of species of plants which are capable of thriving in such soils. In the extensive botanical surveys conducted by the Botany Section of the Madras Agricultural Department in the study of the Floras of Tirunelveli and Ramanathapuram districts and the Back-water Floras of East and West Coast, a large number of species which appear promising in their natural habitation and by introducing and acclimatizing (of such plants have been noted in the saline and alkaline areas. By selecting such of those species) other species from similar areas both in the country and outside, the barren areas can be stocked with plants for gradual reclamation. The following are the possible lines of biological reclamation.

(i) *Introduction and multiplication of leguminous plants* which thrive on these barren alkaline and saline areas. A few leguminous plants and *Indigofera oblongifolia*, *Tephrosia purpurea*, *Crotalaria verucosa* have been found to be coming up satisfactorily in certain Saline areas. A thorough survey with the object in view will give a large number of species which could be multiplied. Introduction of legumes both annuals and perennials from other States and from foreign countries can also be tried. The successful growing of the above legumes and species as *Crotalaria juncea*, Berseem, etc., which nitrogen content, and fertility of the soil and also improve the biological life both microscopic and macroscopic as the bacteria, fungi, amoebae flagellates, worms, etc.

(ii) *Growing of grasses.*—It is well known that the grasses in general help to improve the physical and chemical condition of the soil besides providing fodder for animals. A few species as *Chloris barbata* C. *Wightiana*. *Eragrostis* spp., *Sporobolus* spp., *Dinebra retroflexa*, *Trachys muricata*, etc., are found growing well in certain saline and alkaline areas. Multiplying these grasses and trials with new introduction will make the barren area enriched with organic matter left by profuse fibrous root system of the grasses.

With controlled grazing facilities the areas can be made suitable of carrying more animals which in turn will enrichen the soil with their dung. The classical example of the mixed farming in Germany described by Dr. G. T. Wrench in the May issue of *Indian Farming*, 1911 may be an example. In a sandy tract in Germany which was unfit for cultivation and had only 13 to 14 inches rainfall, an experiment was conducted by Dr. Bartsch. The farm was very poor and uneconomical and had actually changed several hands. Dr. Bartsch started his farm with 13 sickly cattle, grew fodder to feed the animals. Their manure he composted and return to the soil. This initial manuring produced more fodder and by stages his animal improved, his fodder crops improved and in course of time came in cereals followed by cash crops and the farm became productive one.

(iii) *Growing of plants which remove salinity and alkalinity from the Soil.*—Workers in Australia claim that growing of salt bushes as the various species of *Atriplex* held to remove the salinity and alkalinity from such soils to a considerable extent. In Madras State, *Atriplex repens* is a common species in some saline flats; *A. Vesicaria* introduced from Australia has also established well in South India. Various other species introduced from foreign countries can be tried for the above purpose. Salt ranges grown with *Atriplex* species from important pasture areas for sheep in Australia. It is possible that a number of other non-leguminous plants and grasses have the capacity to utilise the salts in the Soil and improve the condition. Extensive trials will lead for valuable results.

(iv) *Growing of trees and shrubs.*—Even in highly saline areas in some places a number of species of shrubs and trees have been noted; tree species as *Salvadora persica*, *Hibiscus tiliaceus*, *Macaranga peltata*, *Rothia trifoliata*, *Thespesia populnea* and shrubs like *Jatropha* species, *Vitex altissima*, *Dodone Scaveola* spp. are commonly met with. By growing these shrubs and trees good quantities of green leaf can be periodically incorporated to improve the soil. Further, these may serve as pioneer species of afforestation and for further establishment of useful trees for fodder or fuel or even for more production purposes as fruit trees.

*Conclusion.*—The reclamation of saline and alkaline areas by the biological method of growing plants, will be the appropriate approach as a preliminary for bringing the area under crops. When a crop is to be grown in a particular area, the success depends not only on the chemical and physical condition of the soil but also on the biotic relationships. In a more or less barren soil, satisfactory biological, physical and nutritional standards could be brought about successfully by the nature's own source as the plants. Other methods as addition of soil amendments of reclamation through washing away the salts can only be supplementary to the above biological approach.

*A brief note on soil amendments (to reclaim Alkaline and Saline lands)*

by

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## INTRODUCTION

Alkaline soils are of wide occurrence in the State of Madras and though the actual areas has not been determined it is estimated to be large enough to consider it as serious problem. It is roughly reckoned to be more than 7 lakhs of acres. Such soils are mostly met with in the interior of the penninsular portion where rainfall is scanty and insufficient to wash out the soluble salts from the Soil and where irrigation from tanks and saline streams has created alkaline areas owing to the salinity of the irrigation water and lack of drainage. In Madras State the alkaline lands are found in the Cauvery-Mettur Project area as also in the Central and Southern Districts where saline patches are found as a result of irrigation from wells with brackish water. In Madurai district, extensive areas of alkaline lands have



developed under Periyar Irrigation system on account of poor drainage and rise of sub-soil water. Reclamation of such alkaline lands is very important problem in the Agriculture of Madras State and if done successfully will sufficiently enhance the production of food and cash crop.

*Work done in the State.*—(1) Early attempts to reclaim alkaline lands were carried out in the areas under the Periyar irrigation system by methods based on the traditional practices of the ryots in those areas viz., use of bulky organic manures like green leaf, green manure and farm yard manure and tank silt. Salt resistant crop were also grown. The methods were no doubt effective but the improvement in crop yields was very slow and not spectacular enough to become popular with the ryots.

(2) Reclamation methods based on knowledge of soil Chemistry was first attempted at the Central Farm Coimbatore in 1936 in a field which had become very alkaline by irrigation with brackish well water. Sulphur was applied at 100 lbs. per acre and within three months an appreciably good effect was noticed. In the course of three to four years a normal crop of Sorghum could be raised in the field.

(3) In the Trichinopoly District, nearly one-eighth of the Ayacut area of Kattalai high level canal had become alkaline and no crop could be grown successfully. The alkalinity was found to be due to defective drainage and high water table (within two feet of the surface). The irrigation water did not contain any appreciable quantity of harmful salts. A white incrustation of salt covered the surface of the area and there was no vegetation. Based on the Pot-culture studies using soils from the above area and different soil amendment, plots were laid out at mettumarudur, a place in that area in 1937 and gypsum at 10 tons per acre and sulphur at one and two tons per acre were used as soil amendments. The soils of the area contained water soluble salts ranging from 0.2 to 1.0 per cent. and the pH varied from 9.0 to 10.1. They were sticky when wet and almost impervious to water. Calcium salts were absent and the surface soil contained about 0.3% of Sodium Carbonates and bicarbonates and the alkalinity was due to a high degree of alkanisation (70 to 80) and exchangeable sodium in the clay (the total exchange capacity varying from 5 to 24 milliequivalents per 100 gram of soil). When the soils were analysed three months after the application of gypsum there was no trace of sodium carbonate in the gypsum treated plot while the original soil contained as much as 0.10%. The gypsum treated plots gave 1050 lbs. of paddy grain. One year after the plots were laid out and reclaimed while in the second year the yield rose to 2,500 to 3,000 lbs.

(4) Experiments were also conducted at Seethambalpuram in Tanjore District for three years from 1949 to 1952. The soils of the Cauvery-Mettur Project area represented by the above village are poor in organic matter, low in plant nutrients and fine fractions. Though the soluble salt content of the soils was low, the degree of alkanisation was very high. The sodium salts increased with depth. The results of these experiments indicated that sandy alkaline soils of this type can be reclaimed by the application of green leaf in

combination with gypsum and lime. Application of mere lime or gypsum was not found to be very effective and ameliorants in combinations with organic manures like green-manures has to be used for successful reclamation. It was also found that growing of salt resistant paddy strain like S.R. 26-B was useful for the reclamation of milk alkaline lands in this area.

*Future work that can be carried out in the State.*—The following items of work have to be tackled for the future in the State.

1. Survey of alkaline and saline lands in Madras State to assess the extent of such lands.
2. Study of the Soil profiles of the saline and alkaline areas and proper classification of the soils.
3. Trials of the existing methods of reclamation in some typical areas and extending later to other areas, if successful.
4. Trial of different cultural practices and soil amendments for reclamation.
5. Laboratory studies on the physico-Chemical properties of the soils of the area before and after reclamation.

*Cultural practices:*

- (a) Trials with salt resistant crops like Daincha, Cotton, Ragi and Suitable paddy varieties.
- (b) Tillage operations like deep ploughing, bunding, scooping, etc.
- (c) *Crop Rotation.*

Two course: Cotton and Paddy.

Four Course: 2 years. Cotton, Paddy, Green Manure and Paddy.

*Soil Amendments:*

- (a) Gypsum.
- (b) Molasses.
- (c) Sulphur.
- (d) Ground lime Stone.
- (e) Farm Yard Manure.

*A note on crop rotations with cotton in Madras State*

by

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1. American Cotton in the Madras State is raised mainly in winter as both an irrigated and unirrigated crop, and to a limited extent in summer as an irrigated crop in the Southern districts. Irrigated American cotton raised as a winter crop is most commonly grown in garden lands under wells in rotation with jowar, ragi and Bajra. It is also raised in some places in rotation with Paddy and summer groundnut.

2. Irrigated American Cotton raised as a summer crop is normally rotated with Paddy only, in the tankfed wetlands in the Southern districts of the State and as such no trials with any other rotational crop was found necessary for these areas.

3. The unirrigated American Cottons are usually rotated with cereal crops or groundnut, as the case may be, depending upon the time of receipt of rains.

4. The unirrigated deshi cottons in the central and southern zones of the State have their own systems of rotation.

5. The experiments undertaken on irrigated American and unirrigated deshi gave the following results:—

(1) *Irrigated American Cottons*.—The response of irrigated American Cotton, when rotated with cereals like Jowar, ragi, bajra as also groundnut and sunnhemp were studied at the cotton Breeding Station, Coimbatore, during the years 1931-1934. The yields of cotton obtained from plots "after bajra", "after cholam" "after ragi" "after groundnut" "after sunnhemp" and "Fallow" are given in the table below for the three years.

Rotation	Yield of Kapas Lbs. per acre			Mean % on Cholam	
	1931-32	1932-33	1933-34		
Cotton after Cumbu (Bajra)	412	490	804	569	96
Cotton after summer Cholam (Jowar)	430	505	842	592	100
Cotton after Ragi	511	555	813	626	106
Cotton after Groundnut	627	650	783	687	116
Cotton after sunnhemp	744	919	821	825	140
Cotton after Fallow	753	662	854	756	128

It would be seen from the above table that the yield of cotton after green manure (sunnhemp), fallow and groundnut, were better than the yields after the cereals. Of the three cereals tried viz., cumbu, cholam and ragi, the yield of cotton after ragi was better than the other two. A study of the economics of these rotational crops, however, indicated, that on the whole, cholam would have to be preferred. Ragi and groundnut demanded more water which is the main limiting factor in Coimbatore, cumbu is a poor yielder with a straw of inferior value as cattle feed as compared to cholam; and neither leaving the field fallow or raising a green manure crop of sunnhemp, would find favour with the majority of cultivator in this tract. Thus, "summer cholam—cotton rotation" would seem to be the most economical and practical proposition under the existing conditions in the Coimbatore irrigated cotton tract. Next in order would come "Ragi—Cotton rotation", in areas where water supply is sufficient in the wells.

(2) *Unirrigated Desi cottons in Coimbatore Tracts.*—A rotational experiment with desi cotton, comprising of 12 crop rotations, replicated six times, was conducted at the Cotton Breeding Station Coimbatore during the years 1941-47.

The data obtained are presented in the table following.

Crop Rotations	Yield in pounds per acre.			Cholam Grain/ Straw
	Cotton kapas	Bengal Gram	Grain	
Cotton year after year . . . . .	212	..	..	..
Cotton-Cholam-Bengal gram . . . . .	372	229	155	1,700
Cholam-Bengal gram-Cotton . . . . .	297	441	167	3,502
Bengal gram -Cotton-Cholam . . . . .	368	335	..	1,813
Cholam-Cotton . . . . .	254	..	159	2,609
Cotton-Cholam . . . . .	398	..	118	1,774
Cotton-Bengal gram-Cholam . . . . .	392	422	..	1,928
Bengal Gram-Cotton-Cholam . . . . .	366	307	463	231
Cholam-Cotton-Bengal gram . . . . .	375	200	168	4,098
Fallow-Cotton . . . . .	263	..	..	..
Cotton-Fallow . . . . .	373	..	..	..
Cholam year after year . . . . .	..	..	148	2,578

It would be seen from the above table, with unirrigated desi cotton, the yields of cholam and cotton in the three course rotation incorporating a pulse crop like bengalgram were better than cotton after cotton or cholam after cholam.

*Method of reclamation of alkaline and saline soils with reference to 'crop rotation'*

by

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The salinity or alkalinity of a soil is primarily due to the parent rock from which the soil has formed, though climate, weathering agencies and agronomic practices play an important role in their formation. The reclamation of such soils is by the application of soil ameliorants to aid in the replacement of the sodium ions or changing the sodium carbonate or the hydroxide into a sulphate. This is accomplished generally by the addition of finely ground gypsum or sulphur.

The ploughing in of large quantities of green manure or cattle manure, when available, liberate large volumes of carbon dioxide during decay and with the calcium may form calcium bicarbonate. The

inclusion of green manures, therefore, in the crop rotation in an alkaline soil, will go a long way in correcting the alkalinity. *Dainchav* (*Sesbania aculeata*) is a popular green manure in this respect being highly tolerant to alkali soils and the growing of this green manure is an accepted practice in Madras State for the reclamation of alkali soils.

Of many other field crops for inclusion in the rotation in alkaline and saline soils, *Ragi* (*Eleusine coracana*) is a reputed alkali tolerant crop and is grown successfully in many alkali soils of Madras. There are some varieties of paddy also which are salt tolerant. Lucerne is another alkali resistant fodder crop and its inclusion in the rotation has a subsidiary effect in its efficacy in opening up the sub-soil with its deep penetrating root system and thus improving drainage conditions. Some grasses are also very effective in this respect. Very many cash crops like chillies and tobacco are also highly salt tolerant and are grown in large areas in Ramnad district.

Among trees, Casurina, Babool, are known to grow well even under high salt concentrations.

It is not known precisely why certain crops tolerate alkalinity and grow in such soils while others are unable to do so. The distinguishing characteristic of an alkali soil is its exchangeable sodium content while in a saline soil, the plant injury is due to the osmotic pressure of the soil solution which reduces the availability of water. In the case of alkali soils it is suggested that many crops grow poorly not because of the alkalinity or OH concentration but because the plants are unable to obtain adequate supply of nutrients, etc., phosphorus, one of the major nutrients which may form highly insoluble compounds. This happens to other minor nutrients like iron and manganese also. Detailed investigations are therefore necessary to study plant behaviour in relation to alkaline and saline soils.

### *Crop rotation in Madras State*

by

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*Introduction.*—In countries where Agriculture is advanced, the same crop is not usually grown continuously on the same field. Changing the succession of crop systematically is known as crop rotation.

The need for crop rotation is based on the following findings. A deep rooted crop is rotated with a shallow rooted one so that both the deep and shallow layers of the top soils are utilised efficiently for crop production. A pulse crop is introduced as a component in rotation as it is able to fix atmospheric nitrogen and enhances soil fertility. Tuber crops like sweet potato are fixed up in the pattern of rotation, to eradicate deep seated perennial weeds like nut grass

as the deep tillage of the soil done during the harvest of tubers helps in destroying them. Continuous cropping of the same kind increases population of insect pests and incidence of diseases. The introduction of rotation has a great effect in reducing the virulence of their attack and helps to increase crop production.

In other parts of the world, in countries where Agriculture is advanced, rotations have been fixed by long range experimentation and are adhered to very strictly. This is one of the main reasons for the steady increase of soil fertility in all these countries. In India, the cultivator through his age long experience has fixed up rotations and is following them. This is broken either when new crops are introduced or when the economic return of one of the crops shoots up at a tangent. Scientific experimentation on rotation has been done in the Bombay and Madras States and has been taken up in other states also.

In Madras State Agricultural Research Station, Koilpatti has to its credit a large number of economic findings which have been passed on to the cultivators. At Coimbatore and Tindivanam also certain work has been done. The chief findings at the three places are as below.

(1) *Agricultural Research Station, Koilpatti.*—The three major rainfed crops of the black soils are rainfed Karunganni cotton (*Gossypium arboreum*) Cumbu (*Pennisetum typhoides*) and Irungu Cholam (*Sorghum dochna*). The best rotation has been found to be the two course rotation namely cotton and Cumbu. When Irungu Cholam is decided to be grown, three course rotation with Cumbu followed by cotton followed by Irungu Cholam has been found to be the ideal. It is economical to precede the Cotton crop with cumbu than with Irungu cholam. This has come out of a major finding namely the Irungu Cholam crop depresses the yield of the succeeding Cotton crop to an extent of about 15 per cent. which has been termed as "Cholam effect". Various ameliorative methods were tested and the most effective among them was the method of sowing Irungu Cholam with Indigo at 12 lbs. seeds per acre. Since Irungu Cholam (fodder crop) is sown thick the Indigo crop lingers on and does not pull down the yield of the Irungu crop. After the harvest of the Cholam the Indigo pulls up with the help of summer showers and the resultant crop which gives from 1,000 to 2,000 lbs. of green matter per-acre, is incorporated in the soil. This method is successful when there is normal summer showers. Latest method to get over "cholam effect" is to add P.O. in the form of the Superphosphate at 30 lb. P.O. level to the Irungu Cholam crop. The succeeding crop of Cotton received Ammonium sulphate at 20 lbs. Nitrogen level per acre. By this method the Cholam effect is nullified, irrespective of the fact whether there are some showers or not. Cotton rotated with pulses gave an increased yield of 28 per cent. but is not economic. Continuous cropping of Cotton is found to depress the yield of crop by 30 per cent as compared to cotton grown after Cumbu. Continuous cropping of Cumbu has no ill effect on the crop. The cultivators had known about this several centuries back and follow a practice known as "Cumbudi Cumbu" where phenomenal yield of 1,500 lbs. of grain per acre is obtained as against the normal yield of 500 lbs. The high yield is also partly due to the heavy dose of 10 tons of farm yard manure per acre received year after year by the crop.

(2) *Agricultural Research Institute, Coimbatore.*—At Coimbatore, Bengal gram (*Cicer arietinum*) and Cholam (*Sorghum durra*) and Karunganni Cotton (*Gossypium arboreum*) are the common crops of the rainfed areas. The inclusion of Bengal gram tended to increase the yield of the other two crops. The "Cholam effect" is not felt at this place as only a thinly spaced grain crop is being cultivated. The Bengal gram crop was more beneficial to the succeeding Cholam crop than to a Cotton crop. In this place also, continuous cropping of Cotton was found to be uneconomic.

(3) *Agricultural Research Station, Tindivanam.*—The introduction of groundnut in the rotation increased the yield of cereals significantly. "Cholam effect" was felt by groundnut spreading-varieties when grown immediately after Cholam.

*Future work.*—Planned experiments of crop rotation containing deep and shallow rooted crops and leguminous crops are necessary not only for rainfed areas but also for the wet and garden land crops. These experiments should also include optimum spacing and optimum manuring which go hand in hand in making a particular crop rotation successful in a tract.

*Conclusion.*—Supply of rotation takes a long period and does not give phenomenal results but the results obtained would prove useful for several generations. The rotation followed by the cultivator from the tract is to be taken as the standard and has to be improved upon by introducing leguminous crops as well as newly introduced money crops. A country wide experimentation would result in formulating economic crops rotations which will not only increase the income of the cultivator but also will build up the fertility of the soils of this country.

*References :—*

1. Memoirs of Department of Agriculture, Madras, 1954.
2. Memoirs of Department of Agriculture—Agricultural Research Station, Koilpatti, 1950 by B. W. X. Ponnaiya.
3. Economic Black soil cropping by B. W. X. Ponnaiya, L. Sivagnanam and V. Durai Raj.  
Madras information, Vol. IX, No. 12 December 1955.

*Need for the study of agro-climatic analogues of India*

by

K. S. Yawalkar

The introduction of plants has been a fundamental factor in the agricultural improvements of different countries and will continue to be so to meet with the new situation and problems that may arise. More than 95 per cent of the cultivated crop plants of the United States are of exotic origin and more than three fourths of them are natives of the old world.

The study of the plant geography is now receiving more and more attention by those who want to intensify the work of plant introduction. Vavilov (1940) recorded that "Cultivated species, as well as their closely allied wild relatives, in their evolution, during the course of their distribution from the primary centres of species-formation have been differentiated into definite ecological and geographical groups." After conducting expeditions to various primary regions of the origin of cultivated plants, Vavilov said that an enormous diversity of species and varieties formerly unknown were recorded. For wheat alone 800 botanical varieties were recorded by the Soviet Expeditions, while the previous workers had recorded only 191 varieties. By a comparative study, under various environmental conditions, of the Agro-ecological and geographical groups that can be formed of these plants; he recorded 19 such groups with reference to cereals such as wheat, barley, rye, oats and grain leguminosae such as beans, lentils, chick-peas, etc., and flax of both seed and fibre forms.

To determine which of the World regions are most likely to supply new material, requires an intimate knowledge of the climates and soils of the world in relation to the country which has undertaken plant introduction work. Material needed for specific needs should be obtained from as nearly similar climates as possible, in order that the plants may grow as naturally as possible. The necessity of the formation of similar agro-ecological and geographical regions of the world has been pointed out by Metaggart (1940). According to him the following are the seven clearly defined principles for introduction of plants.

- (1) A climatic, soil and vegetational surveys to determine the ecological environment.
- (2) The research for desirable plants by exploration in similar climates of the world.
- (3) Imported material to pass through quarantine.
- (4) Preliminary testing in conveniently placed testing centres to determine their potential value.
- (5) Seed multiplication for wider and more detailed trials.
- (6) Detailed trial of selected species under normal agricultural practice and comparison with standards.
- (7) The successful species to be given over to State Departments and other agencies for widespread trials.

From the above discussion, it is clear that the comparative study of the different countries to find out the similar climatic regions, forms the important step in plant introduction scheme. Thus at this point the study of the agro-climatic analogues of the various countries of the world can help to a great extent because the purpose of such studies is to formulate an agronomic and horticultural approach to ecology and to promote research along the lines of crop ecology as it affects plant introduction, plant adaptation and the exchange of varietal plant material among the various agricultural areas of the world.



"Climatic analogues" are areas that are enough alike with respect to some of the major weather characteristics affecting crop production, particularly during the growing period to offer a fair chance for the success of plant material transplanted from one area to its climatic counterpart. The objective of this study is to organize, define and analyse the various distinct agro-climatic conditions prevailing in the different parts of one country and to compare them with various agro-climatic regions of another country in order to ascertain "Climatic analogues". There are two types of climatic analogues such as (1) the year-round climatic analogues and (2) the seasonal climatic analogues.

Meteorological data of the weather stations of the two countries under study are to be utilized as the main source of material for this study. The elements of comparison are:—

- (1) Mean monthly and yearly temperatures.
- (2) Average monthly, seasonal and yearly precipitation.
- (3) Precipitation-effectivity indexes and ratios.
- (4) Length of frostless periods, and
- (5) geographical latitudes.

Phenological records of a number of varieties of common crops grown in various parts of both countries, as well as the crop geography, vegetative-cover belts, and soil and physiographic characteristics are also taken into account. After all such elements of the environment of a given meteorological station of one country have been computed and studied, a research is to be made among the meteorological stations of another country for a similar climatic and latitudinal environment. The environment in one country found most nearly to resemble that of the places of another country under consideration is recorded as climatically analogous to it. A check to these established climatic analogues is made through:—

- (1) a comparative study of phenological data of some common crop varieties grown in climatically and latitudinally fairly analogous areas of both countries, and
- (2) the comparative studies of the summation of the accumulated day-degrees required after planting to bring a given variety to a definite phenological stage or to maturity.

Dr. Nuttinson of the American Institute of Crop Ecology which is devoted to the problems of plant introduction and adaptation, has prepared the agro-climatic analogues of North America with various European and Far Eastern countries. To quote the results of one such study the United States year round climatic analogues for the Steppe Belt of Ukraine are found in western and eastern Nebraska, South eastern Wyoming, Western South Dakota, North Central Montana and some parts of Minnesota. As a check to these established agro-climatic analogues he studies the phenological behaviour of spring wheat. From this study he reported that the beginning of spring wheat sowing taking place approximately between March 15 in the most Southern areas of the Steppe Belt and April 20 in the northernmost areas of that belt corresponds to the beginning of a

wheat sowing period of the climatically analogous areas in Nebraska, North and south Dakota and Montana. Harvesting of spring wheat in the Steppe Belt of Ukraine begins between July 12 and July 22, which suggests the beginning of the dates of harvest in Nebraska and South Dakota. Dr. Nuttonson also reported that the best corn varieties of the Ukranian belt are the American varieties such as "Minnesota 13", "North Dakota White", "Brown County" and "Minnesota 23".

Realising the importance of plant introduction work, the Indian Council of Agricultural Research have sanctioned small "nucleus" scheme which is functioning in the Division of Botany of the Indian Agricultural Research Institute since 1946. Up to date, more than 3,000 samples of varieties of various agricultural crops have been imported from various foreign countries and a few promising varieties have been already selected out of these on the basis of their performance for special qualities. Looking at the progress already made, the possibilities of such organized plant introduction are almost unlimited. In order to facilitate the quick interchange of plants between countries and to increase the percentage of successful plant adaptation in our country, and looking at the useful services rendered by the American Institute of Crop Ecology to plant introduction work of United States of America it seems highly important to start the work of agro-climatic analogues in India.

**Literature Cited :**

1. Mudaliar, C. R. (1953) Plant introduction and improvement of grasses and legumes Part I.  
*Madras Agri. Jour* XL (5) : 220-228.
2. ....(1953) Plant introduction and improvement of grasses and legumes Part II .  
*Madras Agri. Jour* XL (6): 266-78, 1953.
3. McTaggart, (1942) Plant introduction.  
*Aust. Commonwealth Coun. Sci. & Indust. Res. Pamp. No. 114, 1942.*
4. Nuttonson, M. Y. (1947) Ecological crop geography of Ukraine and the Ukranian agro-climatic analogues in North America. American Inst. of Crop Ecology International agro-climatical series Study No. 1., 1947.
5. Singh, H. B. (1952) The romance of plant introduction.  
*Ind. Farm (New Ser.)* 1. (10) : 22-25, 1952.
6. Pal, B. P. & Singh, H. B. (1951) Some promising recent introductions of crop varieties.  
*Ind. Jour. Genetics & Plant Breeding* 11 (2): 215-16, 1951.

PAPERS ON SUBJECT No. 5

*Value of shelterbelts and windbreaks in (a) soil conservation and  
(b) in reducing losses in fruit cultivation*

by

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Soil Conservation Station.

Wind is a potent force which is responsible for the impoverishment of the soil. It effects adversely the major assets of a country viz., grazing and agriculture. The damage is not restricted to arid and semi-arid areas alone but extends all over—the damage being more acute in the former areas because the climax vegetation found therein does not offer sufficient protection to the soil. Wind erosion occurs on both sloping and level lands, and unless checked, puts the land out of production in a short time.

In bare lands where wind has a free play it sweeps away the finer, more fertile practices leaving the coarser, unfertile ones behind thereby reducing the fertility of the land. The spectacular advance of the Rajasthan desert and consequent losses in fertility of land and reduced yields of crops in the Punjab, Uttar Pradesh and Rajasthan is directly attributable to the action of wind.

*Principles of control.*—Obstacles placed at right angles to the direction of the prevailing wind, check the erosive action of wind by causing stilling conditions which reduces wind velocity and correspondingly decreases its capacity for lifting soil particles.

The remedial measures consist in having a good vegetative cover on the soil. Wind erosion is not a problem in areas under grasslands or forests. On agricultural and marginal lands belts of trees, commonly termed "windbreaks" considerably reduce the damage caused by land.

The area protected by a windbreak depends upon the height of the trees and varies generally up to a limit of ten to fifteen times the height of the windbreak on the leeward side. Since winds must rise, rather than pass through the windbreak, there is a reduction in the velocity of the wind on the windward side as well and the protection there is to the extent of about five times the height of the windbreak.

The factors which determine the degree of effectiveness of windbreaks and shelterbelts are :

- (1) Replication of belts at suitable intervals: In order to exert protective influence on large areas, windbreaks and shelterbelts must be planted in parallel belts at a distance where the zone of influence of the preceding belt ceases.

- (2) **Direction:** Shelterbelts and windbreaks must be aligned at right-angles to the direction of the prevailing wind in order to be effective. Where direction of wind is variable the zone of influence is considerably lessened and here long, unbroken belts of vegetation would prove more effective than short, broken or curved strips.
- (3) **Density of the Stand:** In order to afford maximum protection windbreaks must present a more or less solid wall in order to break the force of the wind. A windbreak with single row of trees and bare trunks will allow considerable wind to pass through then one in which there are grasses and small shrubs to the windward side and taller trees on the leeward.

Windbreaks which have their greatest density close to the ground give greatest protection while those which are fairly open near the ground surface and denser above have their greatest influence some distance to the leeward.

Shelterbelts and windbreaks are of value both in conserving soil and water as well as in reducing losses in fruit orchards.

1. *Value of shelterbelts and windbreaks in soil conservation.*— Windbreaks and shelterbelts reduce wind velocities thereby preventing the blowing away of the top soil and checking wind erosion.

2. Belts of vegetation have an ameliorating effect on the temperature and aridity extremes. Aridity is one of the principal causes of accelerated erosion, for in such condition the soil particles are more friable and loose when they are readily removed by wind.

3. Windbreaks and shelterbelts add organic matter to the soil which promotes Micro-biological activity in and about the land occupied by the belt and improves the structure and physical characteristics of the soil therein.

4. They protect the land on which they stand from the erosion action of the rain drop. They absorb the force of the falling water and allow it to fall harmlessly to the ground below, thereby reducing its splash action, preventing the puddling of the soil and the sealing of the pore-spaces.

5. Windbreaks and shelterbelts promote the infiltration of water into the soil, thereby increasing the underground water supplies which benefits the supply of water in wells and tanks. The action consists of:

- (a) the fallen organic matter from the 'break acting as a blotting paper which soaks up the falling water; and
- (b) the trunks, fallen twigs and debris on the ground offer mechanical resistance to the flowing water, which gives the latter more time to soak in the ground.

6. The time lag caused by the mechanical action of standing trees and fallen debris reduces velocity of flowing water thereby causing deposition of the soil particles carried with it and keeping the flowing water clear.

7. Windbreaks and shelterbelts stabilize drifting sands.

8. If of sufficient area, windbreaks and shelterbelts provide pasturage to cattle, they, therefore, help in reducing the pressure of cattle on critical area, thereby protecting such areas from erosion by wind and water.

9. Windbreaks and shelterbelts provide wood for fuel on maturity, thereby preventing cowdung from being burnt as fuel and diverting it to agricultural fields to improve their physical structure and fertility.

10. They prevent soil from desiccation and rapid drying away. They also increase the soil moisture content.

*Value of shelterbelts and windbreaks in reducing losses in fruit cultivation.*—1. Windbreaks and shelterbelts protect fruit orchards from cold and hot scorching winds thereby reducing losses in the yield of fruit.

2. By reducing the velocity of wind they prevent fall of blossom and immature fruit thereby reducing losses in fruit cultivation.

3. Windbreaks and shelterbelts break the force of the wind and prevent fruit trees from being distorted, felled, lopped or broken.

4. Windbreaks and shelterbelts prevent the dry, fallen leaves of the fruit trees from being swept away by the wind, thereby improving the structure and organic matter content of the soil. This increases the fertility of the soil and increases the yields of fruits.

5. The increased infiltration of water in the soil and reduced desiccation thereof in orchards protected by windbreaks increase the quantity of water available for the fruit trees thereby cutting down expenses on watering.

6. Windbreaks and shelterbelts are havens for insectivorous birds which by devouring insects harmful to fruit orchards reduce damage to fruit crops.

### *Wind-breaks and Shelter belts*

by

The Horticulturist to the Government of Bombay, Poona.

Wind-breaks and shelter belts may in their simplest form be strips or groups of indigenous trees left when stumping new land, or they may be formed of single or multiple rows or groups of planted trees. Single-row planting, though economising space, is not very effective particularly if one or two trees are in poor condition or

have dried. When multiple rows are employed, one row should be of tall fast-growing tree and the other of slower or more bushy ones.

Wind-breaks are used to prevent erosion of the soil by wind and also by water. In addition to these functions, they reduce evaporation and provide shelter for live stocks and crops. Total stoppage of wind penetration is not desired nor it is desirable. On this account, it is important that correct density is obtained, a certain amount of wind percolates through the belt and acts as a cushion for diverting wind which comes from above the windbreaks.

The sheltering effects of wind-breaks are felt at 2-5 time its height on the windward side and from 10-20 times on the leeward side.

Windbreaks for providing shelter to orchards against desiccating winds and winds of high velocity, have been extensively used. Unprotected orchards suffer losses both in trees and crops. Depending on the velocity of winds trees of different age-group may suffer injury. Total destruction of a crop may result from winds of 35 to 50 miles per hour. Continuous low winds, though without any effect on older trees, may cause young trees appear mis-shapen with a peculiar 'blowover' effect on one side.

High winds are generally accompanied by low relative humidity and high temperature. Apart from causing serious mechanical injury, one of their most serious effects is killing and scorching of leaves and young growth.

Windbreaks reduce wind velocity and minimise loss both of trees and crops. The drying power of wind is reduced in about the same proportion as its velocity. In the immediate lee of the most effective windbreaks evaporation is reduced as much as 65 per cent. Fruit drops are also considerably reduced due to lowering of transpiration.

The disadvantages of wind-breaks and shelter belts are :—

- (1) Fewer orchards can be planted per acre.
- (2) Shading by the windbreak affects both growth and production, especially to the north of a mature east and west windbreak row.
- (3) They may serve as host plants to disease causing organisms and insects.
- (4) In cooler regions, orchard heating may have to be started earlier.

Where possible windbreaks should be planted a year or two before the proposed plantation so that this green belt may be come effective earlier. The first row of main plantation should be 40 ft. away from the wind break. At a distance of 10 ft. from the windbreak row, a trench 3' to 4' deep is dug to prevent roots from interfering with the normal growth of permanent plantation.

Planting distance between trees of a windbreak should be 5-6 feet which may be planted in rows 10-12 feet apart, with the trees in one row opposite the spaces in the other row.

In Northern India, common windbreak trees are Jamun (*Eugenia Jambolana*), Eucalyptus, mango seedling, sheeshum (*Dulbergia sissoo*), Mulbery & Ber (*Zizyphus jujube*).

In South India, *Erythrina indica*, Red sanders (*Pterocarpus santalinus*) and *Millingtonia hortensis* are common windbreak trees. Casuarina and Cashew are also important windbreak trees in coastal areas.

In between the above tall growing trees, some protective thorny hedges are also planted which make them more effective and fill up the space between their trunks. They are Dedenia, Cactus, Aloe, Yucca and Duranta.

Carambola, Neem (*Millia azadirachta*) and bamboo are also planted as wind break in some localities.

#### *Value of shelter belts and windbreaks in Reducing losses in Fruit cultivation*

Fruit Specialist, Fruit Research Station, Anantarajupet

Windbreaks have a very important role to play in the proper maintenance of an orchard. Strong winds do a lot of damage to orchard crops, particularly to bearing trees. Branches are broken, fruits are blown off or scarred. In certain cases even the leaves may be whipped off. In all such cases windbreaks are very effective in reducing all such damage.

Height of the windbreak trees is more important than its thickness. The most effective wind break is a double row of tall growing trees. Care should be taken to see to the direction from which strong winds usually blow and windbreak should be provided in double rows along that side. The windbreak plants also need care in the shape of manuring and irrigation. To prevent competition between the windbreak and the main plantation, a trench of 3' deep may be dug at about 10' from the row of windbreak to cut off all roots. This process should be done once in two or three years and is very important.

In Andhra State the following are found to be good as windbreaks.

1. Eucalyptus.
2. Red sanders.
3. Silk Cotton.
4. Jambolana.

Almost all the fruit growers have realised the value of windbreaks and we scarcely come across any orchard without a windbreak.

Bananas among fruits has a special place. It is grown from one to three years at the most in a site and as such no windbreak can be raised. Especially on the East Coast where high winds are often experienced in the North East monsoon, short varieties like mauritins are recommended.

*Value of shelterbelts and wind breaks in soil conservation*

by

The Central Silvi Culturist, FRI, Dehra Dun

Windbreaks and shelterbelts are effective measures of soil conservation under conditions of low rainfall. The direct reduction (because of Wind breaks) in the velocity of winds protects the soil from erosion from wind and the obstruction to the flow of water reduces erosion from this cause also. However the effects of such plantings are not confined to mechanical protection of the soil alone. Apart from their utility as a source of a fuel and fodder and other forest produce, wind breaks and shelterbelts reduce the velocity of wind by reflecting it near the ground and thus cause a significant reduction in evaporation of soil moisture. The moisture so saved is available for production of crops. They also prevent the movement of shifting sand and thus afford protection to the adjacent areas, in very arid or desert regions. They moderate climatic extremes, temper hot winds and reduce the ill effects of cold ones. This results in considerable savings in cost of heating farm buildings and makes them more comfortable for men and animals in all seasons. They also control snow drifts and increase the retention in the soil of moisture derived from snow. They provide suitable habitats for game birds and animals and beautify the environment.

For these reasons windbreaks and shelterbelts are very effective measures for conserving the soil and moisture, for raising crop yields and reducing expenses on fuel and feed of farm animals. In many regions protection against severe wind is essential to obtain full yields or in extreme cases any yield at all. Losses due to lodging by wind are also avoided if the crops are adequately sheltered.

If windbreaks are rationally planned and occupy a reasonable area, the resultant increase in yield may more than offset the loss which may occur due to that part of the area going out of cultivation and reduction in field along the margins due to root competition and shade. It has been estimated that if only 6 to 8% of the farm area is given over to windbreaks it is possible to obtain the maximum yield from the soil. Of course such plantings can only be effectively attempted in case of large field or farms otherwise they might occupy a large proportion of the cultivable area and thus prove uneconomic.

Windbreak are patches or rows of trees adopted for protection of individual fields or farms while shelterbelts are planned patterns of tree plantings covering large areas, designed to provide a net work of windbreaks for a natural zone of treeless plains.

The effectiveness of windbreaks is a function of their height and compactness. The protective effects on the leeward side extend to distances up to 50 times the average height although ten to twenty



times is considered the practical limit; on the wind-ward side the practical range is 2-5 times the height. They should not be so compact as to restrict wind penetration or the advantages may be greatly reduced. If the correct density of planting is adopted, a certain amount of wind percolates through the belt which acts as a cushion for diverting wind which comes from above the wind. Dense shelterbelts have certain serious drawbacks. They produce drastic reductions in wind velocity and intensify diurnal variations of temperature to a degree which may be undesirable.

A windbreak of a given type does not reduce the velocity by a given figure but more nearly by a given percentage or proportion at all times. This percentage, at most positions, increases as the wind velocity increases so that if a 5 m.p.h. wind were decreased by 20% or 1 m.p.h., a 25 m.p.h. wind might be decreased by 25 per cent or 3.75 m.p.h.

Wind breaks may consist of groups of trees or of one to many rows of trees. They may be impenetrable to wind, penetrable in the lower part or penetrable all through although the best results are obtained if a certain amount of wind passes through. The choice of species depends on the local conditions but when multiple rows are planted tall fast growing rows should be on the wind ward side and slower growing trees on the lee-ward side. Single rows are rarely satisfactory as occasional gaps may impair their effectiveness seriously.

Windbreaks and shelterbelts have not been created in India on a significant scale on a systematic pattern. However experience in other countries notably U.S.S.R. and U.S.A. where they have been planted over vast regions has amply demonstrated their exceptional value for soil conservation and related benefits. Experience in China, North and South Africa, Canada, Palestine, Scotland, Hungary, etc. bears out these conclusions and farmers are enthusiastic about benefits in the form of increased crops yields and reduced expenses for fuel and feed. Among the species generally planted are both coniferous and broad leaves species notably the various species of (*Eucalyptus* e.g., *E. maculata*, *E. corynocalyx*, *E. maideni* (Tanganyika), *E. rostrata*, *E. robusta*, *E. resinifera*, *E. globulus*, *E. rudis*, *E. maideni*, *E. ceotryoides* (Italy) *E. melliodora*, *E. cinerea polyanthemos* (South Africa).

Other species which have been found suitable are:—

*Cassia siamea*, *Cupressus lusitanica* (Tanganyika), *Grevillea robusta*, *Cedrela* spp. *Albizzia* spp. *Nhaya* spp. *Terminalia sericea* (Nyasaland, Kenya, Uganda etc.) *Prosopis* sp. (Sudan), *Acacia cyanophylla* (Palestine), *pinus pinea* (Italy) Scots pine, norway spruce, beech, larches, douglas fir, *Thuja plicata* (Scotland), *Cupressus arizonica*, *C. lusitanica*, *Pinus halepensis*, *Juniperus virginiana* *Populus alba*, *P. nigra*, *Acacia baileyana* (South Africa) *Populus* spp. *Ulmus*, *pumila*, *Eleagnus angustifolia*, *Morus alba*, *Fraxinus pennsylvanica*, (U.S.A. Southern Great Plains) oaks, pear, birch, ash, scots pine, crimean pine, crimean pine, black locust, Russian olive, apricot, Cherrytree, *Haloxylon* spp. poplar scots pine, elm *Alianthus glandulosa* etc. (U.S.S.R.).

For the various semi arid regions of India *Prosopis* spp. *Acacia* spp. *Alianthus excelsa*. *Eucalyptus* spp. *Azadirachta indica*, *Melia azadarach*, etc. would appear to be suitable.

*Value of 'Shelter Belts' and Wind Breaks*

by

Sri C. Balasubramaniam, Agricultural Meteorologist, Coimbatore.

Plenty of literature is available on the utility of "Shelter belts" and "Wind Breaks". In Russia, a scheme has already been put in practice on a 20 years basis to prevent damage to crops and soils by Cyclones and hurricanes in vast stretches of land by creating suitable shelter belts and wind breaks. In Madras State no large scale planting of shelter belts and wind breaks on a systematic basis has yet been attempted. Though there are no vast stretches of "Steppes" in South India, as in Russia, yet there are some taluks in the Districts of North Arcot, South Arcot, Salem, Coimbatore and Tiruchirapalli where the problem of damage to crops by high winds is a common occurrence. In addition, along the east coast of the Madras State comprising the districts of South Arcot portions of Tanjore and Ramanathapuram Districts, occurrence of cyclone seems to follow a narrow cycle of 3 to 5 years and the occurrence is invariably found to be towards the end of November. If suitable shelter belts and wind breaks are established along the Coastal area, it will be possible to minimise considerably the damage done to crops by gales and cyclones. Data are available to prove that the velocity of wind gets reduced by 20-40% if it penetrates 100 feet through a thick forest and by 50% within a distance of 200 feet. The wind retains only 7 per cent of its original velocity when it has penetrated 400 feet into a forest.

The need for "Shelter Belts" and "Wind Breaks" has long been established. This requires only carefully planned implementation on a large scale. "It has been the history of tree planting throughout the world that the establishment of wind breaks and shelter belts has not progressed fast enough to keep pace with needs, without some assistance by the Government. The thousands of miles of shelter belts that now protect millions of acres of farm lands in Russia, the mile after mile of tree strips in Jutlands, without which farming would be impossible, similar planting in Hungary, the 18510 miles of tree belts planted in the great plains shelter belt from North Dakota to Texas and the 911 million trees planted to shelter belts and wind breaks in the Prairie Provinces of Canada—all owe their success to sound Government policies put into effect through well administered and Government assisted projects" (U.S.A. Department of Agriculture year Book 1949).

*Value of Shelter-belts and Wind-breaks in reducing losses in fruit cultivation*

by

Deptt. of Agriculture, U.P.

Wind exerts a considerable influence on the growth and productivity of the fruit trees. The high winds are instrumental in causing damage either directly or indirectly to the trees. Besides the direct damage to the trees in the form of breakage of limbs and branches, excessive flower and fruit drop and tearing of the leaves, the winds with high velocity cause an excessive evaporation from the surface

of the soil and also favour increased transpiration from the leaves of the trees. The importance of the indirect damage caused to the trees through increased loss of moisture from the soil and leaves, is not fully realized by the growers as such a loss usually escapes unnoticed by them. The effective control of the wind in a fruit orchard is achieved by providing a shelter-belt or a wind-break which serves the purpose of lessening the force of wind and thereby reducing the damage to the trees.

In almost all the fruit growing areas of Bombay State high winds especially blowing from south-west during summer and monsoon seasons cause considerable damage to the fruit trees. The damage caused by strong winds is observed to be rather severe in banana plantations. The entire leaf blades of the banana plants are torn apart into ribbons which gradually dry up and thus result in decreased photo-synthetic activity in the plant. In cases of severe damage the plants even bend down and the pseudostem along with the bunch may also break causing loss of fruit in an immature stage. The production from such badly affected plantation is reduced to even less than half. The planting of wind-breaks around the banana plantations has been found to be of immense help as the growth and fruiting of plants in such plantations is normal. The existing practice all over the State is therefore to have a temporary wind-break of Shevari (*Sesbania aegyptica*) plants on the south and west boundaries of the plantation. The provision of wind-breaks around banana plantations helps in the reduction of transpiration from leaves especially in areas where the temperature during summer rises very high. Loss of moisture from the leaves of the plants increases with the rise in temperature and fall in humidity. Hot dry winds with high velocity lead to increased loss of moisture from the leaves and surface of soil by removing the humid air from the close vicinity of the evaporating surfaces. By the provision of wind-breaks around the plantation the velocity of the wind is considerably reduced thereby helping to maintain the humidity in the plantation. This may be gauged from the fact that in one of the experiments conducted in U.S.A., it was found that with a given air temperature and relative humidity, evaporation was found to be 2.2 times as rapid with a wind velocity of 5 miles per hour as in a calm atmosphere.

The fruit plantations along the coast in Konkan region of the Bombay State, are worst affected if left exposed to the strong gales of monsoon winds blowing from the Arabian sea. At times violent cyclonic storms caused by occasional disturbances in the sea sweep over the coastal areas and thus destroy the plantations in the region. During the last 15 years the chiku, mango and banana orchards at Bassin, Dhanut and Gholwad in Thana district have been completely destroyed not less than three times by cyclones from the Arabian Sea. The planting of shelter-belts of *Casurina equisetifolia* around plantations in coastal area has been found to be very effective in preventing the damage by winds to the fruit trees.

Although no experimental data are available in this State regarding the effect of wind-break on the growth and production of fruit trees, the research work carried out in U.S.A. has shown that the citrus plants in coastal orchards of California when protected from wind attained the same size in 3 years as against that attained

by plants in 5 years when fully exposed to the wind. It was also observed that after the citrus trees reached the bearing age, the yield of trees protected from wind was 3 times greater than that of trees fully exposed to the wind.

It is generally recommended that the shelter-belt should consist of closely spaced double row of tall quick growing, fairly erect and preferably drought resistant trees having dense foliage. In order, therefore, to be very effective, a wind-break should be sufficiently high and dense. Ordinarily a wind-break is believed to be most effective for a distance of about four to five times its height and has some effect over twice that distance. The first row may consist of tall growing trees and the second one of low growing trees. *Millingtonia hortensis*, *Erythrina indica*, *Casurina equiseti-foila*, *Eucalyptus*, *Morus sp.* and *Thespesia populnea* are some of the trees which are mostly grown in shelter belts in the Bombay State.

The only serious objection to the growing of wind-breaks is that they shade and compete with the trees for soil moisture and nutrients and thus adversely affect the growth and production of the trees in their close vicinity. To overcome this difficulty it is suggested that the wind-breaks trees should be planted at least 20-25 feet away from the first row of orchard trees.

From the various advantages as detailed above the provision of wind-breaks is of paramount importance for a successful commercial orchard enterprise, and hence should form an essential feature in the planning of an orchard.

#### *Value of "Shelter Belts" and "Wind Breaks" in reducing losses in fruit cultivation*

by

Daljit Singh., I.C.A.R., New Delhi

The usefulness of wind breaks and shelter belts have been amply demonstrated in various fruit growing tracts of the world. Well established wind break belts serve to protect orchard trees and reduce wind velocity and moisture evaporation from the orchard soil to a great extent. They tend to prevent the soil from "blowing" and drying out quickly. Reduction in flower and fruit shedding and prevention of mechanical injury to the fruit or tree, are the clearest manifestations of the influences of wind breaks in certain periods. Particularly in cyclone infested localities, the value of effective wind breaks can never be over-emphasised.

Yield per acre and quality of fruit are materially influenced by wind breaks during the seasons of damaging winds. We find that such seasons come often in various fruit growing areas of the world. This all the more leads to the justification of planting and maintenance of wind breaks as a part of the orchard enterprise. So much so, that a well managed wind break has become an important asset to the orchardists as an assurance toward better income. Therefore, the windbreak trees are considered an integral part of the orchard set up, as is wheel to a wagon or a carburetor to the gas engine.

In California one can scarcely see a citrus grower who at one time or the other has not seen the results of severe wind injury in unprotected orchards, particularly in regions where the periodic desiccating winds (the so called "desert" winds or *loo* common in India) have partly defoliated trees and blown off an appreciable amount of fruits. Such devastating effects of hot winds in India are quite common. In such areas especially in some parts of America (*viz.*, Fontana Farms, Fontana; San Joaquin Fruit Co., Tustin; the Irvine Co., Irvine.). Community plantings of wind breaks of miles long has proved more beneficial than scattered ones. The effects of such wind breaks has sometimes even changed the climatology of the place. The naturally recurring winds are deflected upward from one wind-break to the next, reducing the ground velocities and hence major losses are averted in horticultural crops. Greig (1941) from Auckland (New Zealand) stresses the importance of shelter for not only because it prevents citrus trees from being broken or blown off, but also because it reduces the constant rubbing of developing fruits against steam and thorns, resulting in so many abrasions and blemishes. It is also of extreme importance that it reduces transpiration from the foliage by reducing air currents and thus conserves moisture during periods of drought. Bates (1924) states that "in the immediate lee of the most effective wind breaks evaporation is reduced as much as 65 per cent".

Generally there are three types of winds against which protection is to be provided :

(a) *Continuous winds of low velocity.*—These winds do not effect the mature trees as they can withstand such winds due to their stiffness and weight. It is only the young trees which are at times "blown over" on one side if winds continue to blow at some seasons.

(b) *Coastal winds.*—Fruit orchards situated within the range of winds coming off the ocean, say one to five miles inland, are adversely affected. Their velocity may not be great but the temperature is upset which is detrimental for the tree growth and fruit setting. Blanchard (1934) made interesting studies on Eureka lemon trees in Ventura country, California where the coastal winds prevail. The data furnished by him clearly demonstrates the advantages of wind-break belts.

*Influence of coastal wind and wind-breaks on yields of young Eureka Lemon Trees*

	Average number of fruits per tree with	
	no wind-break	with wind-break
Nine year old trees . . . . .	97	710
Four year old trees . . . . .	95	288

(c) *Winds of great velocity.*—These are winds of great velocity ranging from 35 to 50 miles per hour of great strength. These are usually accompanied by low relative humidity and high temperature, not entirely because they originate on the desert, but because of dynamic compression accompanying their origin (Young, 1933). They occur at irregular intervals and are not serious every year. They whip the trees violently, strip off leaves, break branches, and tear off much fruit. The fruit which is left untorped is reduced in value by scarring and bruising.

Sometimes high winds are so hot and the relative humidity so low, that the leaves are simply killed by scorching. Extensive killing of small twigs take place. Growth is usually best on the lee side of the trees, making the tree unbalanced and less able to carry a good crop of fruit.

*Frequency or spacing of windbreaks.*—Measurements and tests taken over many years by the extension service and the U.S. weather bureau have revealed that the relation between height of windbreak and horizontal distance of protection is 1 to 4 (Wahlberg, 1941). In other words, a hundred foot windbreak will usually provide protection for 400 feet of orchard—13 to 15 tree rows. Practical experience in several wind exposed areas has shown that a square 10-acre orchard could well have a middle windbreak located 330 feet from the outside wind-break. Such a plan will give almost perfect protection. According to Naik (1949) the sheltering effect of a wind break of moderate density is felt for over a distance, which is from two to five times the height of the windbreak on the windward side and upto about 20 times on the leeward side. Prew (1955) making windbreak studies on plains in Auckland reports that on the level land shelter trees 50 feet to 60 feet high give good protection from wind for 4 to 5 chains and partial protection for rather more than double that distance. Bates (1944) gives some estimates of the area protected by wind breaks of different heights. If 3 rods or 49.5 feet be taken as tree height, the following areas, very conservatively estimated, should show 10 to 15 per cent reduction in wind at their extremes:

Windbreak length	Area protected
6 rods . . . . .	9 square rods
12 rods . . . . .	36 square rods
72 rods . . . . .	1,296 square rods or 8.1 acres
150 rods (one-half mile) . . . . .	4,464 square rods or 28 acres

The most generally effective wind-break is a reasonably long belt of trees that offers protection from winds of various directions through nearly half of the complete circle. Such a windbreak belt fulfills the purpose of field protection much better than a small group or block of trees. In the plains region it is particularly important to have protection through the summer from all winds of Southerly origin. The area protected by such a tree belt is triangular in

shape, but until it reaches out about 12 times the height of the trees the possibilities of distance protection are not fully utilized. Thus, the value of the protection afforded increases as the square of the length until the latter is at least 24 times the height.

In the more exposed wind districts one can justify devoting 10% of the orchard area to windbreak protection i.e., one acre out of every ten. Heavy losses will be borne by many districts every time the wind blows until such time that these communities become windbreak conscious. Greig (1941) recommends intermediate shelter around the various sub-divisions of an orchard to be not greater than two acres each.

#### *Systems of windbreaks*

(a) *Diagonal Grille System.*—In California this system has been devised to facilitate uninterrupted cultivation, irrigation and other operations in the orchard. It is particularly adapted to the middle wind-break, but has also been used for the main outside plantings.

One row of citrus trees is removed to accommodate the grille planting. A space of 48 feet is thus provided in an average orchard. Short diagonal rows, accommodating from four to six seedling plants at four feet apart in the row are established at an angle that will make these rows perpendicular to the direction of the prevailing winds. The perpendicular distance, then between the diagonal windbreak rows can be varied from 10 feet to 24 according to the orchard working plant adopted.

(b) *Lattice or Wooden wind breaks.*—They vary from 28 to 34 feet in height as compared with 100 to 150 feet growth secured from the euclyptus. According to Wahlberg (1941) their costs vary from 1.50 to 2.50 dollars per running foot, depending on height and material used. The average protection afforded by them is 3 to 4 rows, whereas the living windbreak will extend protection to 12 to 16 rows, depending on the height. Wooden wind breaks are expensive but provide quick protection. They do not add to the attractiveness of landscape. One can see several designs of lattice windbreaks erected in orange country, in California, U.S.A.

*Choice of Trees for wind breaks.*—No haphazard combination of trees will be desirable. A successful windbreak needs a row of shrub, an evergreen row of trees, tall trees and some not so tall, some faster, growing than others and they should all be adaptable to the areas where they are planted. In a right combination, they must produce an effective windbreak in shortest time practicable.

Many varieties of trees are available for planting as windbreak, but only those varieties should be selected which are suitable to the local climatic and soil conditions. Growers who find it necessary to use wind breaks should be mainly guided in their choice of species by the local experience available. If possible the trees selected should be immune to the attack of the insects and diseases. An ideal windbreak must be upright in growth and occupy as little a space as possible, should be tall, mechanically strong, rapid growing and of a density sufficient offer the necessary resistance to the prevailing

winds. In areas of frost pockets where orchard heating is not practiced, it is desirable to select trees of somewhat open type. Such trees permit breezes or air currents to flow through and thus reduce the cold pockets resulting from poor air drainage. Places where orchard heating is practiced it is preferable to have a dense windbreak, especially if the cold is likely to be accompanied by a breeze which so dissipates the heat that orchard heating is inefficient.

In California for most of the citrus groves blue gum or *Eucalyptus flobulus* is recommended, inter-planted with a shorter but dense type such as the Monterey cypress (*Cupressus macrocarpa*). In Arizona this combination is becoming more popular (Wahlberg 1941). *Tamarix articulata* (Athel) is admirably adapted to desert growing conditions.

Gilman (1952) reports "double decker" windbreaks in Clinton county, New York State, U.S.A. The orchard was surrounded with a windbreak of trees and a wind break was planted right through the orchard as well. Rows of lombardy poplars were planted side by side with red pines. The quicker growing but short lived poplars reached 60 feet in height in 15 years. These will be succeeded by the slower-growing, more permanent pines.

In West Cornwall (England) experience has shown that *Pinus radiata* and *Querculix* are sufficiently wind resistant to form adequate wind breaks in these warmer countries. For colder countries in the North and in Scotland, *P. contorta*, *P. montana* and *Olearia albida* are quite satisfactory wind breaks, (Arnold-Forster, 1951).

Uzziel (1953) from Israel recommends *Cupressus pyramidalis* as a permanent windbreak, but in wind swept sites and in the larger groves *Cupressus arizonica* or *C. horizontalis* do well. Near the sea *Tamarix articulata* succeeds on light soils but needs hard pruning owing to its spreading habit. *Ricinus communis* and *Sesbania aegyptiaca* can be used as temporary windbreaks both growing very rapidly, but the former is a host plant for many citrus pests. Where *Casuarina* and *Eucalyptus* are used they should not be planted less than 12.5 m. from the first row to avoid severe root competition.

In the warmer parts of Auckland, New Zealand, the very quick growing *Albizia lapantha* may be used as a temporary shelter due to its extremely rapid growth habit, (Prew, 1955). *Metrosideros tomentosa* (pohutukawa) and *Cryptomeria japonica* (Japanese cedar) are successful as shelter trees against wind blowing from seas carrying salt. They can withstand salt injury very well. Greig (1941) from New Zealand states that the following trees be considered for permanent shelter on the Southern and Western boundaries of an orchard: *Cupressus lawsoniana*, *C. benthami*, *C. arizonica*; *Pinus radiata* (*insignis*), *Cryptomeria japonica*, and *Acmena floribunda*. For intermediate shelter in the orchard, *Hakea saligna* and *barberry* *Berberis vulgaris* are useful. According to him for a temporary shelter the black wattle (*Acacia decurrens*) is to be preferred to *Albizia lapantha*, as the timber of the former is stronger and of denser shelter.



Naik (1949) from South India recommends the red sanders (*Pterocarpus santalinus*). *Millingtonia hortensis* and *Erythrina indica* as suitable for wind-breaks, while in sandy coastal areas *Casuarina equisetifolia* is popular. The Cashew is also found to form an effective windbreak because of its tendency to form practically an unbroken screen with its dense top growth.

Bajwa and Kaura (1951) made trials on windbreak trees at Attari and recommend certain combinations of windbreaks for Punjab. *Terminalia (Terminalia arjuna)* should be alternated with low growing spreading trees like Jujube (*ber*) or camphor. *Shisham (Dalbergia sisoo)* also goes well with camphor. Other combinations suggested are Safeda (*Eucalyptus rudis*) with camphor or *Shisham*; Jaman (*Eugenia Jambolana*) with *ber (Zizyphus Jujuba)* Mango (*Mungileparindica*) with *Kagzilime, Semla (Bombax malabaricum)* also makes good tall wind break.

Katyal (1956) writing on windbreaks states that in the plains of North India *Shisham, Kikar (Prosopis Julifloria)* bael *Jamun*, mulberry, seeding mangoes, eucalyptus and *ber* are successful as wind-break trees. For temporary windbreak hedges quick growing trees like *arhar* and *Jantar (Sesbania aegyptiaca)* should be planted. *Carambola (Kamrakh)*, paper mulberry tree, *nim* and bamboo are also sometimes used. Combinations of windbreak trees and a hedge is also effective. Some hedges and thorny plants like *Dedonia, Duranta, Cactus, Aloe, Yucca* and *phulai* are recommended.

**General.**—For proper development of the windbreak ample space should be allotted between the property line and the wind-break belt. Where heavy wind losses occur the removal of a row of orchard trees is well justified in order to make way for the wind-break. After the wind break is planted it should be nourished properly and not left to itself. It requires the same attention as the orchard does. In fact, it is a good practice to give the two rows next to the windbreak, and the windbreak itself, a more generous allowance of fertilizers than the average application in the remaining orchard.

A wind break on every 10 acres should be the goal to produce better grees and sizes of fruit specially in the windy regions of fruit cultivation.

#### References :

1. Arnold-Forster, W. (1951)—Wind shelter and wind Tolerance. *J. Royal Hort. Soc.* 76 (10):341.
2. Bajwa, Bal Singh and Kaura, N. R. (1951)—Wind breaks for Orchards. *Pb. Farmer* 3(4): 114-116; Oct.-Dec.
3. Bates, C. G. (1924)—The wind break as a Farm Asset. *Farmers Bull.* 1405.pp. 1-22: U.S.D.A. rev. 1944.
4. Blanchard, V. F. (1934)—Depressing effects of wind on growth and yield of citrus trees. *Calif Citrogr.* 19:pp. 206.
5. Ferber, A. E. (1951)—Farmers Plant Trees to Battle the weather. *Soil Conservation Am.* XVII (2) : 42-44; Sept.

6. Gilman, William (1952)—Double-Decker windbreak. *Am-Fruit Grower* 72(9): 18; Sept.
7. Greig, A. M. W. (1941)—Planting trees and shelter Belts. *N.Z.J. of Agr.* 63. (1): 58-60, July 15.
8. Katyal, S. L. (1956)—Wind breaks will protect your crops. *Ind. Fmg.* 6 (1): 36-37; April.
9. Larue, R. G. and Rounds, M. B. (1948)—Citrus Industry: Vol. 2: pp. 284-298; *Univ Calif, Press Berkeley and Los Angeles*.
10. Naik, K. C. (1949)—South Indian Fruits and their culture pp. 65-66: *P. Varadachary & Co., Madras*.
11. Prew, H. A. (1955)—Shelter for Auckland Home Gardens and Orchards. *New Zealand J. Agri.* 90 (6); pp. 579-587; 15th June.
12. Uzziel, M. (1953)—Windbreaks for citrus groves (Hebrew) *Hassadeh* 34: 94-96.
13. Wahlberg, H. E. (1941)—Windbreaks for Orchard Protection. *Calif. Citrogr.* 26 (12): 359, 372-373, October
14. Young, F. D. (1933)—Desert winds in Southern California and their effect on citrus trees. *Citrus Leaves.* 13(3): 16-18.

*Value of sheter belts and wind breaks*

by

Shree Bishan Man Singh, U.P.

(a) in soil conservation and . . .

(b) in reducing losses in fruit cultivation.

The destruction of soil by water and wind is called soil erosion. For the control of erosion various conservation measures are adopted. Among them are 'putting up of shelter belts and wind breeks'.

*Shelter belts.*—Shelter belts are planned patterns of tree plantings for the protection of a natural zone of treeless plains and for controlling erosion on plough lands. The size of shelter belts in planned according to the intensity of rainfall, slope of the land and wind velocity.

In established forests, which are ideal shelter belts, the thick grass cover, the forest vegetation, and forest litter reduce the rate of water out flow, enhance its penetration into the soil and protect it from being blown away by the winds. The rain water thus stored in the subsoil is subsequently used by the vegetation and maintains steady supply of water to the rivers after the rainy season. It increases humidity in the forest and the surrounding area and moderates the extremities of the climate.

In setting up new shelter belts all these objectives have to be kept in view, consequently they have to be put up on the windward side and on the higher level of the slope. The area under shelter belts should be sufficiently large, both in length and in breadth, otherwise the objectives narrated above will not be achieved.

When it has been decided to establish a shelterbelt in a treeless plain the question arises: what to grow, how to grow and what preliminary steps are necessary to ensure success for this programme. The most important measure is to conserve moisture in the soil for the proper germination, growth and development of the vegetation. For this it is necessary to have all the area surrounded by strong embankments, leaving openings to admit water from neighbouring higher lands. After this all the enclosed area should be divided into contour banded small plots, so that all the enclosed area may uniformly be covered by water after every precipitation.

During the rainy season and after that grasses and other vegetation will come up, they should be strictly protected from the ravages of the cattle goats and sheep.

In the enclosed area collected water will get sufficient time to percolate in the soil. The roots of the vegetation will help increase in-take rate of water and the water holding capacity of the soil. In areas of light rainfall the small amount of water thus conserved will prove most beneficial for the growth of grasses, trees and other vegetations.

The selection of trees will depend upon the type of soil and the climate conditions of the locality. On hard and desert soils, where rainfall is low, only thin leaved (conifers), tap rooted trees like babul, Kuril and others should be preferred in the initial stages, later on Shisham, Nim, Peepul, and other fodder bearing trees, which are also drought resisting may be introduced. After pre-sowing treatment, babul seeds may be sown in Desi plough furrows, but for Sheesham, Nim and Peepul trees pits will have to be dug and prepared.

As I have said above much greater attention should be paid to develop under-growths, in the absence of which the earth surrounding the young seedlings will be carried away by water erosion, forming rills and gullies in between the newly planted trees.

On plough lands lying on slopes in heavy rainfall areas shelter belts or forest strips of proper breadth and suitable intervals, according to the degree of slope, should be put up across the slopes. Every row of trees and under-growth will impede the flow of water and thus will help in conserving both water and soil and will provide excellent protection to crops of individual fields and orchards against the evil effects of water erosion, strong hot and cold wind and the frost. In such localities fruit and fodder bearing trees should be given preference over other kinds of trees.

*Wind-breaks.*—Windbreaks are one or more rows of trees maintained for the protection of individual fields or farms and orchards against the destructive action of strong hot and cold winds, frost and erosion also to some extent. As the name suggests they prove more useful for protection against winds than for conserving soil and water.

In order to achieve full advantage from wind breaks they should be set up at proper intervals on the windward side for protection against strong winds and in the north and west to save young trees from frost. Closely grown Jamun trees round the orchards provide excellent wind breaks. Crops plants like Jowar (Sorghum) closely sown in rows of two or three near young fruit trees and Jowar and Arhar crops in fields on the north and west provide protection against frost.

PAPERS ON SUBJECT No. 6

A brief note on previous work done on the Water Requirement of crops in India

by

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Coimbatore

Not only in Madras State but in India itself very little work regarding water requirement of fruit crops has been done.

Leather (1912) and Singh and Mehta (1938) and Rahija (1934) found that Transpiration ratios are lowered by manuring. Rahija also observed that wheat crops manured with farm yard manure made more economical use of water than that a manured with an equivalent dose of ammonium sulphate. Sethi (1936) reported that under conditions obtaining at Shajahanpur optimum returns in Sugar-cane yield were obtained with a considerably lower water duty when Nitrogen fertiliser was applied at 100 lb./acre. Ragi, Yaghoklar, Wagle, Apte, and Kulkarni (1943) observed that the interaction between nitrogen application water duty was significant, indicating the value of higher manuring with higher irrigation. Singh *et al* showed that varieties of plants have got significant differences among themselves as regards use of water and that length of life cycle exercises great influence over the water requirement of varieties. They also found that there is generally a fall in water requirement with increase in soil moisture content till 37% in the case of cereals and 45% in vegetables and gradual rise of water requirement above these optima. The plants have either two or three critical periods when they require the largest amount of water. These periods cover different number of days in different crops but always happen to be located in seedling, pre-flowering and ripening stages. Experiments conducted on Sorghum by Kanitkar and others (1942) revealed that there was distinct economy in water use when complete fertiliser and farm yard manure were used. Farm yard manure also cut short the life period of the plant. Plants grown in different soils gave varying values for transpiration ratio.

The following conclusions were drawn by Khanva and Rahija after a study of the relative efficiency of water requirements in relation to manurial treatments.

1. Manure applied all at the same time, decreased the water requirements as compared to application of manure in two doses, one at plating and the other at earthing up.
2. The application of Potash reduced the water expenditure per unit of dry matter produced.
3. The application of fertilisers gave statistically significant increase over no manure in the relative efficiency of water requirements.

*Pattern of future Research.*—Inability to secure the requisite amount of water checks growth and reduces yield and often a relatively small amount of additional available moisture at a critical

period will make possible material increases in the size of the crop. The minimum water requirement in terms of units of water required for producing unit amount of dry matter of fruit trees should be determined under various soil types. The variation in water requirements among different varieties and how the relative water requirement of fruit trees effect the yield of different species, are also worthy of investigation. The influence of soil moisture, on the water requirement *i.e.* how a deficiency or excess of soil moisture, affects the growth and water requirement of fruit trees, is also a profitable line of investigation. The influence of soil conditioners different kinds of organic and inorganic manures etc., on the water requirement is another line of attack as also the effect of different chemical sprays on the plant. Plants subjected to X-ray or other radiations electro magnetic waves, or even sound waves are reported to have made varying responses in their general or some particular behaviour: How far such conditions affect their water relations is also a fertile field of study and much work has to be carried out in these lines as the knowledge of water requirement of fruit crops is scanty.

### *Water Requirements of Important Fruit Crops*

by

Shri T. R. Narayanan, Plant Physiologist, Coimbatore

Water requirements are closely related to drought resistance as well and as such fundamental studies on one will necessarily have a relationship to the other aspect as well.

The inter-relations between soils, their mineral composition soil moisture and the yield of crops ramify into a host of interconnected factors. The usual approach to problems relating to water requirements and moisture relations in the so called "practical approach" where the effects of particular treatments applied to soils and crops are studied to secure information on just these points. Though this method has the advantage that the limited information sought for can be obtained by any enlightened agronomist, there is the more serious disadvantage that the information gained is relevant solely to the conditions of the particular experiment and are applicable to other conditions only at some risk of inapplicability. Seldom is any insight gained into the fundamental processes at work or even on factors underlying the actual effect observed, so that the ultimate cost, in terms of labour and time involved in such piecemeal investigations often works to a very high figure. This is particularly true in regard to all studies relating to the water requirements of crops where eventually engineering aspects are also involved.

The proper method in such problems, one that would also prove ultimately more economical of effort and expense is to make a fundamental analysis in terms of specific conditions of soil and plant properties. In a study of the water requirements of fruit trees for instance, we might include the permeability and moisture characteristics. The soil and plant properties are so chosen as to be capable of ready measurement and co-relatable with field characteristics of the particular soil types wherein the fruit trees are usually grown. Among the specified conditions we may include the rate at which

water is made available to the trees, either overground or underground, flow or sprinkler type and the designs of the drainage systems to be adopted for each soil type and method of supplying water and the various means of conserving the moisture made available to the trees.

Measurements on these varied and at the same time specified conditions would provide data on the fundamental aspects that would enable us to forecast with accuracy other plant responses under similar conditions.

The disadvantages inherent in this "fundamental" approach are: firstly the services of scientific workers who are specialists in the field are needed, secondly the results cannot be expected at command as the work will necessarily be slow.

In recent times a number of sensitive devices are available to determine the soil moisture characteristics—various workers have developed modifications of the "tensiometer" which can measure the "Soil water suction". It consists essentially of a permeable membrane, usually a conical or tubular probe of unglazed ceramic ware attached to a manometer. Less direct methods are also useful; these rely on the moisture absorbed by various absorbers such as plaster blocks, fibre glass or nylon cells—over specified periods of time and determining the moisture absorbed either by weightment or by measuring. The exact material to be chosen will depend upon the range of moisture content likely to be encountered. Similar, sensitive methods are available for also measuring soil permeability, the over all infiltration rate, the field capacity, moisture equivalent, and maximum water holding capacity of different soil types.

In the case of fruit plants (*e.g.* citrus, Mangoes and Bananas) the extent and efficiency of the root system the transpiration and assimilation rates are vital characteristics that need to be studied. In orange for instance it has been found that the rate of movement of water in the roots is of the order of 5 cu. mm. of water per sq. cm. of roots surface per hour. Whereas in coffee it was only 0.25 cu. mm.

Apart from the use of radioactive isotopes in studies on plant nutrition and water movements, other sensitive methods are also available nowadays to measure the "stream velocities" *i.e.*, rate of sap movement in trees. For example Huber and Schmidt have devised a thermo electric method where a brief local application of moderate heat at one spot on the plant body is measured at other points on the plant body by means of a very sensitive thermo couple.

From the Agronomic viewpoint it is necessary to know in the case of fruit plants, how much water the plant needs at

- (1) different stages in its life cycle.
- (2) different seasons of the year.
- (3) and under different manurial schedules.

Properly planned investigations are obviously necessary to have reliable information on both the fundamental and the strictly "applied" aspects of this problem of determining the water requirements of fruit crops.

*Water requirements and different systems of irrigation of important fruit crops*

by

The Horticulturist to the Government of Bombay, Poona.

The fruit plants differ very widely in their water requirements. The water requirement of a plant is largely influenced by the species and the conditions under which the plant is growing. The fruit trees with different growing habits and varying inherent characteristics show great variation in their moisture requirements. Amongst the fruit trees, the plants such as Zizyphus, anona species, etc., are not very exacting in their water requirement whereas plants such as guava, citrus and pomegranate require regular irrigations. Although no experimental data is available here, it is experienced that the herbaceous plants like banana require heavy and frequent irrigations. Mango does not require any irrigation except during the initial period of 4 to 5 years. Chiku, grapevine and papaya plants require continuous irrigations for their successful growth and fruiting.

The quantity of water and the time of its application depend on type and nature of the soil, and the depth of the root-system of plants. The fruit plants growing on light and sandy soils as in Gujerat region need more frequent irrigations than those growing on medium black type of soils in the Deccan, as the former have less water holding capacity as opposed to the latter. Because of the shallow root-system and the herbaceous nature of the plant, it is found that the banana requires an ample and frequent supply of water for putting forth vigorous growth. It is observed, however, that the papaya plant, although herbaceous and shallow rooted does not require heavy irrigation like the banana. On the contrary, excess of moisture in the soil damages the roots of the papaya plant. The mango, because of its extensive root-system does not require any irrigation after 4 to 5 years from planting as the deep foreing roots draw upon the supply of water from the deeper strata of the soil. Contrary to this, the Chiku trees which have also deep root-system, however, are required to be irrigated regularly.

Under the conditions obtaining in Bombay State the fruit crops like citrus, guava and pomegranate produce vegetative growth as well as fruits almost throughout the year. Their cropping is, however, regulated to only season of the year by giving forced rest to the trees by with-holding the water-supply during certain periods of the year. In this way the water-supply of these trees is limited to that part of the year, when the trees are growing and bearing fruits. It has been observed at the Ganeshkhind Fruit Experiment Station, Poona, that for successful growth and production, the mosambi orange trees do not require more than 1.5 acre inches of irrigation. Similarly, the water requirement of Bhokari grapevine has been found not to exceed 2.0 acre inches.

In view of the complexity of factors involved in determining the water-requirements of a particular fruit, it is not possible to lay down a scheduled programme for irrigation. However, the quantity



and time of application of irrigation for different fruit trees are usually based on the general outlook of the condition of the trees and dryness of the soil.

Of the various methods of irrigation in vogue, the surface irrigation is the only method followed in the State. Various methods like basin, ring, bed and furrow are employed for irrigation fruit orchards. Although the actual method of irrigation followed by growers depends on the type of fruitcrop, topography, nature of soil and source of irrigation, the most common practice of irrigating the orchards has been the ring or bed method. The main consideration in adopting these methods has been mostly the shortage of irrigation water, without taking into consideration the actual water requirements of a particular fruit.

In order, therefore, to find out a proper method of irrigation, for grape and mosambi orchards, planted on medium black soil experiments were conducted at the Ganeshkhind Fruit Experiment Station Poona. Two methods of irrigation *viz.*, basin and furrow were tried. The observations have shown that there is no advantage of the furrow method of irrigation over the basin method in so far as the production of trees is concerned, although the furrow method has consumed more water. This would show that the furrow method of irrigation is more wasteful of water in these fruit crops. In another experiment on Basrai banana in medium black soil it has, however, been found that the trench (broad furrow) system of irrigation is superior to the bed system as the plants under the former system of irrigation gave better yield than those in the latter.

On the basis of the results of the above experiments, it may be suggested that in case of fruit crops like citrus, grape, pomegranate guava, papaya, etc., the best method of irrigation would be the basin system leaving a ring of about one to two feet in diameter around the main trunk of the trees. In case of fully grown trees when the crowns of adjacent trees touch each other, it would be desirable to irrigate the trees by bed system which is a modified form of controlled flooding. The trench (broad furrow) system of irrigation is the only method best suited to banana and as such may be profitably adopted in banana plantations.

#### *Water requirements of important fruit crops*

by

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No systematic trials have been conducted on this aspect of fruit culture in this state. But from our experience of orchard management for nearly twenty years the following are some important observations.

*Mango.*—During the South West and North East monsoon period depending on the rains, the young (about one to three years old) plants have to be irrigated by hand watering whenever there is continuous break of about a week. After the close of the North East monsoon the same plants require to be hand watered or irrigated systematically throughout the summer months once in three or four

days for older plants and almost every day or on alternate days for younger plants of about one year old. Once the mango reaches four years, except during the hot summer months, it does not require any irrigation and the two monsoon rains are more or less enough for the plant.

*Citrus.*—Citrus crops require systematic irrigation through out the life. The young buildings or seedlings require irrigations more frequently but in small quantities. As the plants grow in age they have to be irrigated very profusely but at longer intervals. During good monsoon years they rarely get any irrigation at all during the monsoon.

It may be mentioned in this connection observations made on a newly laid out acid lime plantation. It required 28 irrigations in the second year, 23 in the third, 13 in the fourth year, thus showing clearly that as the tree grows it required lesser number of irrigations, though in quantity it may require more water than a young plant.

*Bananas.*—Bananas require more water than other fruit crops, Irrigations are given at weekly intervals generally, but it may vary from 5 days to 10 days, depending on the age of the crop, nature of soil, climatic conditions and other environmental factors.

In conclusion it may be stated that no precise figures or data can possibly be given regarding the water requirement of fruit crops, since so many factors such as, rainfall and distribution, nature of soil, situation of the orchard, inherent characters of the variety and so many other factors, that it is difficult to give any definite idea of the water requirements of fruit crops. Only an approximate requirements of the important fruit crops are give above.

*Different systems of irrigating fruit crops with a view to economising on the use of irrigation water.*—The main criterion in irrigating fruit crops is to supply enough moisture to the feeding root zones to make them completely wet and also give the roots scope for absorbing all soil nutrients etc. Hence it would be useless if the other portions of the root area (non-feeding portions) are irrigated. Hence every care should be taken in properly wetting the feeding root zone area.

The main systems of irrigation are (1) Flood system, (2) Check system, (3) Basin system and (4) furrow irrigation. Depending on the kind of fruit plant the proper system of irrigation has to be adopted. Among the four systems basin system is most economical. Next in economy comes furrow system of irrigation. Flood system is the most expensive of all.

### *Water requirements of Important Fruit Crops*

by

Dr. L. B. Singh, Horticulturist, Fruit Research Station Saharanpur

The exact water requirements of important fruit crops of India are not known. No work seems to have been done in this direction. The principles which are involved may, however, be stated.

A number of factors generally need close study before any idea can be formed in this regard. These are (i) species of the Plant; (ii) age of the plant; (iii) physiological stage of the plant, such as flowering, fruiting, dormant or actively vegetative; (iv) nature of soil; (v) time of the year; (vi) climate including rainfall, humidity, temperature and wind velocity etc. All these factors effect water requirements of plants.

The soil-moisture properties which influence the uptake of moisture by plants are mainly (i) field capacity and (ii) permanent wilting percentage. These soil-moisture properties jointly determine the amount of available moisture which alone is used by plants for growth. But the entire range of available moisture cannot be utilized by plants and the extent to which it can be done depends on soil texture. Moreover, permanent wilting percentage of a soil may reach during different periods of a year and thus, the water requirements of plants may vary from season to season within the same year.

For the determination of water relationship of different fruit trees, the following studies are needed:—

(i) Soil moisture studies involving determination of field capacity and permanent wilting percentage during different seasons for a number of years.

(ii) Transpiration and evaporation losses in relation to season and climate.

(iii) Root distribution of different species in different soils.

(iv) Study of the symptoms of water deficiency by observing wilting of leaves and rate of fruit growth.

*Methods of Irrigation.*—Different methods of irrigating fruit trees can be broadly classified into:—

(1) *Sub-soil irrigation.*—The methods by which water is applied below the surface of soil.

(2) *Surface irrigation.*—Different methods designed for flooding the soil surface.

(3) *Sprinkling or spray.*—Water being distributed by sprinkles or nozzles.

*Surface irrigation.*—There are three methods of surface irrigation namely, Basin, Ring and Furrow.

(a) *Basin method.*—In this method basins are made around the trunks of trees and water is fed through channels perpendicular to the tree rows. The size of the basins is generally small and the method is inadequate for grown up trees as the water does not sufficiently cover the root zone of the entire tree.

*Modified basin.*—Basin system of irrigation admits modifications similar to those practised in citrus orchards of California where basins are square or rectangular and vary in size according to conditions of soil type, age of tree, slope of land and size of irrigation channels. There may be one tree basin or those serving many trees. In applying water on coarse textured soils with flat grades, the basins nearest to the source of water are filled first. This water is then drained from the upper basin to lower one and so on till the entire "tier" is irrigated. In fine textured soils, this order is reversed.

In the above modification, the irrigation is uniform, excessive leaching is avoided and water can be used with greater economy and to the maximum advantage.

(b) *Ring method.*—This is a natural modification of the basin method, having all its advantages but without its defects. The basin is replaced by a circular furrow, known as ring, placed some 9" or 1 ft. away from the trunk. These rings are connected in series and fed through alternate channels running parallel to the treerows. It is most suitable for irrigating young trees with the least wastage of irrigation water.

*Modified rings.*—Even, ring method can be modified to suit mature trees with wide canopy. The outer ring may be flattened out into rectangle form to facilitate even distribution of water in the root zone which normally extends a little beyond the spread of branches. However, the soil disc around the trunk of tree is retained as usual.

On a level piece of land, this method may be of great advantage for the irrigation of established orchards.

(c) *Furrow-irrigation.*—In this method, the entire land of the orchard is cut into furrows which may be curved, zigzag or parallel, depending on the topography of the land. The length and width are adjusted according to the soil characteristics, size of the tree and spacing. The finer soils on flat land allow longer furrows than the coarser soils. On slopy piece of land, fine soils permit only shorter furrows than the coarser ones.

The main object is to adjust the speed of the flow in such a way as to allow enough time for irrigation water just to percolate down to the desired depth and not further.

Furrow irrigation can not be practised on steep slopes where erosion is excessive and also on porous soils on flat land.

### *Water Requirements of important Fruit Crops*

by

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Water is essential to plant life in several respects. Its presence is constantly required for maintaining the protoplasmic activity. The plant food elements in the soil should first be dissolved in water before they are taken in by the roots. The dissolved food elements have to be translocated in a channel of water through the conducting

tissue to the leaves where they are synthesized into organic compounds. Water is, therefore, not only a medium for the solution, absorption and transmission of plant food elements but its presence in sufficient quantities in the tissues is essential for maintaining the various vital processes. In fact, it is on the availability of water that the whole mechanism of plant is adapted to function. It is required in different quantities by different plants.

*Factors influencing the water requirements of plants.*—Many factors operate singly or in combination to influence the amounts of water consumed by plants. Their effects are not necessarily constant, but may differ with locality and fluctuate from year to year. Others are related to the natural influences like climate, water supply of soil and topography.

(1) *Rainfall and Humidity.*—Rainfall received during the growing season reduces the irrigation requirements. Evaporation and transpiration are accelerated by days of low humidity and slowed during the periods of high humidity. If the average relative humidity percentage is low during the growing season, a greater use of water by the fruit trees should be expected. Evaporation of water from the land and plant surfaces takes place much more rapidly where there is moving air than under calm air conditions. All these conditions, therefore, influence the time of application and the amount of water to be applied. Mandarins in Wynad, Coorg, Assam and Tripura can be grown under rainfed conditions, but in the plains of Madhya Pradesh, irrigation is essential for this fruit.

(2) *Winds.*—Hot, dry winds and other unusual wind conditions during the growing period affect the amount of water used by the trees. The growing season, which is tied rather closely to temperature, has a major effect on the seasonal irrigation needs of fruit plants. Average differences in water requirement of 3:2 and extreme differences of 5:1 has been reported for plants of the same kinds grown in dry air and moist air. Increasing the evaporating power of the air through wind velocity has much the same effect (Bews and Aitken, 1925).

(3) *Wind Breaks.*—The situation and environment of the orchard also exert profound influences on the water requirements of fruit trees. Thick wind break belts or well wooded areas in the vicinity tend to reduce the soil moisture requirements in the same way as these will be increased in the open or exposed situations.

(4) *Nutrient supply as related to types of soil.*—When the soil solution is poor in any indispensable element more water must be taken up by the plant to obtain a sufficient amount of this element to fulfil its needs. But, this is true only within certain limits. The ability of plants to withdraw nutrient materials from the soil in proportions is quite different from those in which they occur there. Montgomery and Kiesselbach (1912) report that the water requirements are considerably lower on fertile than infertile soils and that manuring increases the efficiency with which water is utilised by the plant. This increase in efficiency is not proportional to the increase in vigour induced by the treatment, and there is not a corresponding increase in absorption of mineral nutrients (Muencher, 1922).

A heavy soil requires more water at one time than does a light soil, but irrigations may be much less frequent. Fortier (1927) holds the contention that light and frequent irrigations are best on sandy soils, heavier and less frequent on the heavy types.

(5) *Soil moisture*.—It is said that as the moisture approaches the extreme in a wet soil, the soil solution is diluted. Therefore, a condition is reached which is quite comparable to that in a "poor soil". Hence, more water is needed to absorb a given amount of nutrients. In this case the poor aeration attendant upon a soil moisture content above the optimum may also affect the water requirement. Poor aeration means a relative dilution of the oxygen content of the soil, a condition which leads to unusual root respiration. The immediate effect is the reduced absorption of both water and nutrient substances. Reduction of the latter exceeds considerably to that of the former and consequently gives rise to a higher water requirement.

It seems a strange perversity of fate that the soil conditions and soil treatment which are most likely to result in a restricted root system, such as heavy soils, hardpan, waterlogging, puddling and baking, are those which lead to an increased water requirement of the plant.

(6) *Cultivation* :—

*The influence of cultivation upon water Requirements of Plants in different soils (After Widtsoe, 1911)*

Type of soil	Not cultivated	Cultivated
Sandy loam	603	252
Clay loam	535	428
Clay	753	582
Type not given	451	262

An interesting data furnished by Widtsoe (1911) clearly shows that the cultivation does affect the water requirement of plants. In every case, the water requirement was materially reduced by cultivation, in one case it was reduced to more than one-half. It had a much pronounced influence in certain soils than in others. It therefore, implies that cultivation affects the water requirements of plants by effecting a better aeration of the soil, which in turn leads to a significant increase in the supply of available plant materials. It may also increase soil moisture content, but not to an extent equalling that for the nutrients.

(7) *Light*.—In the light of what has been said in the case of nutrients, it should not be inferred that the water requirement of plants is entirely governed by its nutrition. Experiments made by Hasselbring (1914) on tobacco, show that the amount of water

absorbed. is quite independent of the amount of mineral constituents taken in. The average ratio of water to ash for six plants grown in the open was 2,548 while for six plants under shade was 1,718. This applies only to the water-ash-ratio of plants growing in full sun light and in shade. Different condition holds for water-dry matter-ratio in sun light and shade. This is probably due to the influence of sun light in promoting photosynthetic activities and the storage of elaborated materials.

(8) *Planting Distances as Related to moisture supply.*—Planting distances in the orchard are determined largely by the available moisture supply and the growing habits of the particular species or variety. By giving more space between the trees, a larger foraging space for each tree is provided and more soil is, therefore, available to draw the moisture from. On the other hand, in closely spaced orchards composition for moisture is greater. Kearney (1908) reports a very notable example of an intelligent and a successful application of the above principle from North Africa. In some of the olive orchards under irrigated conditions with ample rainfall the distance is 18 to 22 feet whereas, near Sfax, in Tunis, the trees were planted 60 to 80 feet apart, making only 7 or 8 to acre. This makes possible a profitable dry-land industry without irrigation.

Many irrigated fruit plantations, especially those closely planted bear satisfactory crops of well-sized fruit for a period of years; then as they become older and their roots more fully exploit the area, growth of top and size of crop and fruit decline and the plantation becomes unprofitable. Profitable productive life can be materially lengthened by wider spacings.

(9) *Inherent characteristics of different kinds of fruits.*—The growth habits and other inherent characteristics of the varieties and kinds of fruits being different, they differ in their moisture requirements and drought resisting ability. As a general rule, all xerophytes require less water than mesophytes. A fruit grower should as far as possible have some knowledge of the differential needs of the fruits he desires to grow. For example in South India, Naik (1949) states that mango after about the second year of planting does not require much of water whereas the sweet orange cannot grow and fruit well without frequent and timely irrigations all through its life. Experiments conducted in Michigan in 1927 with peach trees, grown from seeds, showed a range in water requirement from 115 to 268, expressed in terms of units of water per unit of fresh weight of wood and roots. Contardi and others (1950) working on transpiratory coefficient of Malbeck and Semillon grape varieties report that the variety 'Malbeck' must transpire 359 litres of water to elaborate each 1 kilo of dry matter. In fruit production these differences in the water requirements carry two suggestions of practical importance.

- (1) That, certain species of certain fruits can do more than others with a given amount of water,
- (2) secondly, that the same species of a fruit plant will produce more vegetative growth with a given supply of water under certain conditions than under others.

(10) *Cultural Practices.*—Cultural practices like training, pruning, manuring etc., have some influence upon the growth and performance of fruit trees. A cordon trained plant demands less moisture than an unpruned or a relatively less pruned tree. Such practices exert severally and collectively on the soil moisture requirements of the trees.

(11) *Total water requirements of plants themselves and additional requirements to compensate for evaporation, run-off and seepage:—*

(a) *Amount of water used by the plants themselves.*—Thompson (1916), working on the peach, calculated 11 acre inches of water requirement of 9 years old peach orchard, Hilgard (*Ibid.* P. 263) estimated 9 acre inches as the water requirement of 15 year old orange trees in Southern California, Druggar (1912) for a 30 year old apple tree estimated 4,500 gallons. Harris, K. and others (1936) working in Arizona have shown that mature Washington Navel orange trees remove from the soil as much as 30 acre-inches of water in the course of a year, and Marsh grapefruit trees as much as 42 acre-inches. It is, therefore, of utmost practical importance to provide the fruit trees with as nearly optimum conditions as possible to secure the economical use of water.

(b) *Additional requirements to compensate it for Evaporation, Run-off and Seepage.*—A large part of the irrigation water applied to the orchards is consumed by evaporation, transpiration, runoff and seepage. The exact percentages removed in these ways vary greatly, depending on the seasonal distribution of rainfall, the rate of any precipitation, the topography, the character of soil and sub-soil, the atmospheric humidity and other factors. Shantz (1911) made measurements in the Great Plains area and found that approximately one-half of the total rainfall was lost by run-off. Furthermore, considerable amounts of rainfall are intercepted by the vegetation and are evaporated before ever reaching the soil. Clark (1937) has shown that as much as half of 0.5 inch rain fall in 30 minutes amounting to 29 tons per acre, may be thus dissipated. Bowman (1914) reports that in the forest, where conditions are more favourable than in most fruit plantations the reduction of run-off and evaporation, probably not more than 35 per cent of the precipitation is actually available for tree growth. It is, therefore, evident that only an extremely small percentage is finally held by the plant as a constituent of the protoplasm or is used in the manufacture of chemical compounds. The greater portion of the water is required to meet evaporation. Since the water requirement is a ratio between the water used and the plant material produced, it is clear that all other factors favouring the nutrition of plants will tend to decrease their water requirement and that all factors tending to increase water loss through transpiration will increase it.

Having a fair idea of the mean and maximum rainfall of a particular area, and its seasonal distribution, with a first hand study of soil conditions as they relate to moisture, it should not be difficult to determine the approximate requirements of growing a certain fruit crop. Some measure of the way these principles are applied to concrete cases will be clear from the statement made that irrigation



water amounting 30 acre-inches is sufficient to mature peach trees on some of the gravelly loams of Utah and 40 acre-inches on full bearing orchards on sandy loam in Idaho where the rainfall averaged 10 or less inches per year. On the other hand, heavy crops of sweet cherries, prunes and apricots are obtained without irrigation from orchards on a light sandy loam at the Dalles, Ore, with an average rainfall of 16 or 17 inches. In California, some years ago, 16 or 18 inches of rainfall annually was generally considered sufficient for the production of deciduous fruits. But, experience has shown that this quantity is not adequate as the percentage of this amount left after run-off, seepage and evaporation is too little for orchard growth. There is a growing belief that even a rainfall of 30 inches in California should be supplemented by provisions for irrigation to take care of occasional emergencies, (Tufts-1921).

### *Water Requirements of Important Fruit Crops.*

#### *1. Citrus Fruits :*

Citrus trees particularly are much more exacting in their call for water. Of sub-tropical origin they require ample supply to meet the requirements of the root system and the high evaporation rate conditions of hot weather. Being evergreen, they require different treatment. Not only are the irrigation requirements more exacting, but a much higher total requirement of water is needed to produce a satisfactory crop. In hot weather, replenishment may be needed at intervals as short as 10 to 14 days. During winter, citrus needs are little but the soils should not be allowed to dry excessively, otherwise there can be a leaf fall.

With citrus, the second foot is most important as it represents the water available to 70% of the tree root system. The top 6 inches of soil, which rapidly dries and is wetted by small falls of rain, gives no indication at all of the water available below. Thomas (1922) states that citrus roots seldom penetrate below a depth of four feet. In soils less than 3 ft. depth it is estimated that 50 to 60 per cent of the roots are in the top foot of the soil. In Arizona, grapefruit trees of four years of age on a light textured soil developed 50% of the total root system in the surface two feet of soil (Smith & others—(1936) state that 21.6 acre-inches of water are applied in Arizona to Arizona.

Much work has been done in the United States of America to assess the water requirements of citrus trees. Smith and others (1931) report that about 30 acre-inches of water per annum is applied to grapefruit trees on the Yuma Mesa in Arizona. Harris and others (1936) state that 31.6 acre-inches of water are applied in Arizona to Naval oranges in a year, and 40.7 acre-inches to grapefruit. Robertson and Nelson (1915) report that on a 10-acre citrus groves on sandy loam and loam soils in the Sierra foothills, a few miles east of Bakersfield, California, water was supplied amounting to 60 miner's inches for 24 hours (2.88 acre-inches per acre) each month during the season. Johnston (1953) is of the view that in California State water requirements vary from 12 acre-inches per acre near the coast to 36 or more acre-inches per acre in the interior. Beckett and others

(1930) found that lemons use about 2.5 inches per month, August to September, three irrigations being needed, one early in each month.

In India the practice of irrigating the citrus groves has, in general, followed certain arbitrary rules, especially in regard to the frequency of application and the amount of water applied at each irrigation. No definite information is available to the exact water requirements of citrus fruit trees in India although, with approximately 48 acre-inches applied to citrus orchards in canal colonies (now in W. Pakistan) where the average annual rainfall is of the order of ten inches, excellent results were achieved.

## 2 *Banana* :

Banana is a heavy surface feeder. Not only does it require a copious supply of water but also very heavy manuring. It has been observed in Bombay that on an average, the plants require about 3 acre-inches of water at each turn of irrigation in the hot summer months from February to May (Bombay Agr. Dept. Rep. 1929). Irrigation in most of the places is given once in eight to ten days. Near Jalgaon, irrigation is given to banana plants every three or four days during the hot weather. Irrigation intervals are reduced with the approach of cold weather. In the Godavari delta area, irrigation is applied in trenches after the rainy months, usually once in seven to 10 days depending on weather condition (Cheema & others, 1954).

In some countries the bananas are irrigated from February to May at intervals of 15 days and approximately receive 5 acre-inches per turn. This practice is adopted in the plains having an annual rainfall of about 60 inches only. An experiment to determine the water requirement as well as to see the effect of ridge planting of banana was carried out at the Modibagh gardens, Poona and it was found that in flat beds the actual quantity of water was 3.23 acre-inches, while it was 3.30 acre-inches in the trenches per irrigation. The variety used was Walha grown in medium black soil.

## 3. *Mango* :

Unlike citrus fruits, mango has extensive root system and is capable of withstanding adverse water supplies. Howard (1906 & 1910) experimenting on the root systems of various fruit trees at Pusa (water table about 16 feet below the surface) reports that all had similar systems, with one set of spreading roots in the upper 18" of the soil. From the lower surface of these roots, others drop vertically and spread out at lower levels. In mango, the second layer of roots was in the region of the water table. As the surface soil dries out in the winter, the upper set of roots ceases to function, and the rootlets die. If unirrigated these roots remain inactive from March to June and the tree depends on the lower set.

Naik (1949) says that in South India watering of mango plantations is very rarely done three or four years after planting. When the trees are young, good amount of water is given for their proper establishment and growth. During this early period, the amount of water requirement for irrigation, and the intervals between two

waterings will depend upon a variety of considerations and, therefore, it is not possible to issue any definite recommendations. Higgins (1906) suggests that from 50 to 70 inches of irrigation per year should be given from the time when the flower buds are about to open until several weeks after the fruiting is over, withholding large amount of water during two or three months preceding the flowering season.

#### 4. *Guava* :

Of all the fruit trees, guava is perhaps the most drought resistant tree. It is a very hardy tree adjusting its water requirements remarkably to the hot dry conditions. It does not suffer much if not watered during the hot months. It can also withstand the water-logged conditions for a couple of months. Irrigation ought to be given copiously on planting. Quality of fruit and yield have improved wherever the orchards have been irrigated. When the trees begin to bear in its third or fourth year, irrigation is given only during the bearing period.

Cheema and others (1954) report from Bombay that as a result of trials conducted at the Ganeshkhind Fruit Experiment Station Kirkee, it is found that guava trees can do well with 7 to 10 irrigations per year, consuming 14 to 20 acre-inches of water in addition to the annual precipitation which comes to about twenty inches only.

#### 5. *Grapes* :

Grapevines, under favourable conditions of soil and water, are fairly deep-rooting, attaining a maximum depth of about 4 feet and making a fairly abundant spread of roots in the soil. Irrigation should therefore be so directed as to moisten the soil within the root zone to a depth of 4 feet. Grapevines are sensitive to moisture conditions; hence exceptional care should be taken to avoid either a too dry or an excessively wet condition. Young vines require relatively little water, but mature and bearing vines require a considerable amount. Therefore, care should be taken that no shortage of water occurs from the beginning of the growing season upto the maturity of the fruit. The seasonal total of water for mature bearing vines varies approximately 2 to 5 feet including rainfall.

Cheema and others (1954) from India state that in the Deccan grapevines require regular irrigation throughout the year, except for a few weeks at the time of April and October prunings, and during the monsoon, when water is applied only if rainfall is insufficient. Regular irrigation is also necessary during the fruiting period (October to March) at intervals of six to eight days. De Castella (1932) suggests that under Australian conditions, after giving copious irrigation in August, the next irrigation can be given in November. Podrazanskii (1951) from Russia reports that in arid regions, the best results are obtained by irrigating at the beginning of the growing period, particularly on heavy soil. Positive results from autumn or winter irrigation are seen the following year.

## 6. *Deciduous fruits :*

In general, the range of the total seasonal requirement for deciduous orchards in the West seems to be about 1 to 5 acre-feet (Taylor and Downing 1917). Deciduous orchards should enter the dormant period with an ample supply of moisture in the soil, but never an excessive amount. This will result in winter injury and killing of the trees. Winter irrigation should be done by some method that will ensure as uniform distribution as possible through the top 6 feet soil. The winter soil moisture should be such that spring and early summer irrigation will not be needed. However, during the later growing period and during fruit development, plenty of water is essential for high yields of good quality. Abel (1927) in Utah finds danger in permitting peach trees to go through the winter with low moisture content, because lack of moisture in spring is a great cause of the death of trees. Batchelor (1916) in experiments with peaches found that heavy irrigations in June and July completely failed to produce marketable fruit but that similar treatment from mid-July to mid-September gave good results. Taylor and Downing (1917) found irrigation in the later part of the season (July & August) essential for apples in the sandy loams of Idaho. Duggar (1912) for a 30-year-old apple tree estimated 4,500 gallons.

In the case of walnuts in California, grown under irrigation, the total annual water requirement varies from about 30 acre-inches in Central California and in Los Angeles country to 34 and 44 in other parts of California. The heaviest water requirement is definitely through June, July and August during which period 60 to 65 per cent of the total annual water requirement is used. According to Fortier and Young (1933) common practice in number of irrigation varies from 2 to 7, with a general average, for areas reported, of about three.

## 7. *Small fruits :*

(a) *Strawberries.*—They are shallow rooters, most of the roots being within the surface 12 to 14 inches and a few deeper than 18 inches. Hence they require much water, and the upper 2 feet must be kept well supplied, the larger part being needed during the fruiting season. The common practice is that when fruiting begins, irrigation should be given after each picking. Hence, as often as every 4 days on the light soils and every 2 weeks on heavy soils. Amounts of water applied at each irrigation will vary from 1 to 3 inches. The total seasonal water requirement ranges from 2 to 5 acre-feet per acre.

(b) *Bush Fruits.*—They comprise many varieties and types, including raspberries, black berries, gooseberries, and currants. Their irrigation requirements lie somewhere between those of deciduous tree fruits and strawberries, as they are shallow rooted as compared with the trees but much deeper rooted than strawberries.

The greatest need of water by bush fruits is during the fruit forming and ripening period. After the bearing season only a small amount is required to maintain life and plant growth. Deficiency during the bearing season results in dry and seedy fruit and a small yield, young plants require lesser water than the mature ones. More frequent irrigations are needed for hot summers.

**General:**

Various methods have been used to determine the amount of water consumed by plants. Unit values of consumptive use may be determined for different kinds of native vegetation by soil moisture studies, lysimeter or tank measurements, analysis of irrigation data, analysis of climatological data and other methods. But the grower himself is the best judge for his trees which he observes daily. When wilting or other evidence of lack or readily available moisture is hard to detect, the condition of some of the broad leaved weeds, which may be left as indicator plants in various places in the orchard will show by drooping that they need water. Moisture meter is the latest apparatus to gauge this distress in the soil.

**Research problems for future :**

- (1) Basic research is needed to study the efficiency with which different fruit trees use water.
- (2) Relatively little is known of the relationship between the degree of soil moisture depletion and the growth of plants in various stages. Selection of varieties, especially tolerant of wide ranges in moisture during critical periods of growth, would be of great economic importance.
- (3) Other things being equal, selection of rootstocks with extensive root systems may enhance the ability of fruit trees to use water efficiently and withstand draught.
- (4) The application of water is a major concern to the fruit grower. The consumptive use of water and the factors affecting it for various kinds of fruits must be known, because they determine the amount needed to produce the crop. They are also important in designing the irrigation systems. Information is also required on total consumptive use of water, the daily rates and soil moisture status and relationships. Information on such factors would make it possible to predict in advance the time of irrigation. In areas of good rainfall, accurate short and long range forecasts are essential to good irrigation practices.
- (5) Relationships of soil-water-plant are required to be studied to know when to irrigate, how much water to apply, and at what rate. They vary with respect to crop, soil and climate.

**LITERATURE CITED**

1. Abel, T. H. (1927)—“Some observations on winter injury in Utah Peach orchards”. *Utah Agr. Expt. Sta. Bul.* 142.
2. Annual Experimental Report—*Bombay Dept. of Agri.* p. 175, 1929.
3. Batchelor, L. D. (1916)—“Irrigation of Peaches” *Utah Agri. Expt. Sta. Bul.* 142.

4. Beckett, S. H., Blaney, H. F., and Taylor, C. A. (1930)—"Irrigation water requirement studies of citrus and Avocado Trees in San Diego county, California, 1926 & 1927". *Calif. Agr. Exp. Sta. Bul.* 489.
5. Bews, J. W. and Aitken, R. D. (1925)—*South Africa Dept. Agr. Bul. Bot. Surv. Mem.* 8.
6. Blaney, Harry F. (1955)—Water and air crops: Climate as an Index of irrigation needs, *U.S.D.A., Year Book*; pp 341-345.
7. Bowman, I. (1914)—*Forest Physiology*. pp. 42, *New York*
8. Castella, F. de (1932)—Winter irrigation of vine yards, *Jour. Agr. S. Austr.* XX: 340-342.
9. Cheema, G. S., Bhat, S. S. and Naik, K. C. (1954)—Commercial fruits of India, pp. 18-19; pp. 79; pp. 173-176; pp. 251-252; 337-338. *Macmillan & Co. Ltd., Calcutta.*
10. Clark, O. R. (1937)—*Science*. 86: 591-592.
11. Contradi, Hector G., and Pimendies, Atanasio, C. (1950)—*Transpiration Y formation de Materia Seca en vid.*  
*Revista de la Facultad de Ciencias Agrarias* Vol. 2 (1): 13-20; Ano, 1950. (Rep. Argentine).
12. Duggar, B. M. (1952)—*Plant Physiology*; p. 87; *New York.*
13. Fortier, S. (1927)—"Orchard Irrigation". *U.S.D.A. Farmer's Bul.* 1518.
14. Fortier, S. and Young, A. A. (1933)—"Irrigation requirement of the Arid and Semi arid lands of the Pacific slope Basins". *U.S.D.A. Tech. Bul.* 379.
15. Gardener, V. R., Bradford, F. C. and Hooker (Jr) H. D. (1952)—*The fundamentals of fruit Production. Mc-Graw-Hill Book Co. Inc.* pp. 3-19. 1952.
16. Harris, K. Kinnison, A. F. and Albert, D. W. (1936)—Use of water by Washington navel oranges and March grapefruit trees in Salt river valley Arizona. *Univ. of Arizona. Bull. No.* 153: 441-96; August.
17. Hassel Bring, H. (1914)—*Bot. Gaz.* 57; 72-73.
18. Hayes, W. B. (1953)—*Fruit Growing in India. Kitabistan, Allahabad (2nd Edition).*
19. Higgins, J. E. (1910)—The Mango in Hawaii, *Hawaii Agr. Exp. Sta. Bul.* 12.
20. Hilgard E. W.—*Ibid* p. 263.
21. Howard, A. (1906)—First report on the fruit experiments at Pusa. *Pusa Agr. Res. Inst. Bul.* 4.

22. ——— (1910)—Second report on the fruit experiment at Pusa. *Pusa Agr. Res. Inst. Bul.* 16.
23. Hutchins, W. A. (1916)—“Irrigation Practice in growing small fruits in California.” *Calif. Agr. Exp. Sta. Cir.* 154.
24. *Ibid.* *Bul.* 285. 1913.
25. Johnston, J. C. (1953)—Citrus Irrigation. *Calif. Citrogr.* 38 (8): 270-271, 284; June.
26. Kearney, T. H. (1908)—*U.S.D.A. Bur. Pl. Ind. Bul.* 125.
27. Montgomery, E. G. and Kisselbach, T. A. (1912)—*Nethr. Agr. Exp. Sta. Bull.* 128.
28. Muenscher, W. C. (1922)—*Am. Jour. Bot.* 9 : 311-324.
29. Naik, K. C. (1949)—South Indian Fruits and their culture. *P. Varadachary Co., Madras*: pp. 74-78.
30. Podrazanskii, A. N. (1951)—When to irrigate vines (Russian) pp. 325-328: *Vinodelie N.* 6: 11-13.
31. Robertson, R. D. and Nelson, J. W. (1915)—“Irrigation and soil conditions in the Sierra Nevada Foothills, California”. *Calif. Agr. Expt. Sta. Bull.* 253.
32. Roe, H. B. (1950)—Moisture Requirements in Agriculture. pp. 325-338; *McGraw Hill Book Co. Inc. New York.*
33. Shantz, H. L. (1911)—*U.S.D.A. Bur. Pl. Ind. Bul.* 201.
34. Smith, G. E., Kinnison, A. F. and Carns, A. G. (1931)—Irrigation investigations in young grapefruit orchards in the Yuma Mesa, *Ariz Agr. Exp. St. Tech. Bull.* 37.
35. Spurling, M. B. (1950)—Irrigation Efficiency. *Jour. of Agr. S. Austr* 53(9): 385-391 & 398: April.
36. Taylor, E. P. and Downing, G. J. (1917)—“Experiments in the irrigation of Apple Orchards”. *Idaho Agr. Exp. Sta. Bull.* 99.
37. Thomas, E. E. (1922)—Studies on the Irrigation of Citrus groves. *Univ. Calif. Bull.* No. 341 : March.
38. Thompson, R. C. (1916)—*Ark. Agr. Exp. Sta. Bull.* 123.
39. Tufts, W. P. (1921)—Letter to one of the authors dated March 21st.
40. Van Slyke, L. L., Taylor, O. M. and Andrews, W. H. (1905)—*N. Y. Agr. Exp. Sta. Bull.* 265.
41. Veihmeyer, F. J. and Hendrikson, A. H. (1955)—Water: Irrigating Orchards in Dry regions. *U.S.D.A. Year Book*, 1955.

*Different systems of irrigating fruit trees with a view to economising on the use of Irrigation water*

by

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"Intelligent irrigation seeks to know water requirements of different crops, the means by which to determine when the water needs to be applied, the process of effective and economical use of water and the careful practice of such uses."

Fruit trees need readily available moisture in the soil at all times, during the year. Their requirements cannot be wholly met with by rains which are seasonal, scarce and irregularly distributed. It is, therefore, essential that some arrangement for artificial irrigation is made to ensure the supply of water according to the needs of trees. A good irrigation system should aim to reduce to the minimum the loss of water applied. The common methods of irrigation employed are basin, check, furrow and flooding. Recently, irrigation by sprinklers is coming into use in foreign countries.

1. *The Basin System.*—The basin system of irrigation is popular in Northern India. It is perhaps the only system adopted in the case of newly planted trees. A circular basin is made around the tree by throwing a ridge of earth by means of a spade. The ridge should be sufficiently thick and strong to hold the irrigation water. In size, the basin should be large enough to include the outer drip of tree branches. While making the basins, care should be taken to earth up the trunks of trees all round to form protective rings so that when the water is supplied to the basins, it does not come in direct contact with the trunks. The protective ring of which should measure about one foot on each side of the trunk. The water is usually turned direct from the supply ditch into the basin. It is economical to run one supply ditch in between the two rows of trees rather than have one for each row. As soon as the first basin served by a supply ditch is filled with water, the inlet is closed. In this, way a uniform application of water to all the trees served by one supply ditch can be ensured.

As the trees advance in age, the size of the basins is enlarged. But, as soon as the trees develop a spread diameter of about 10 feet, the basin method is usually replaced by flood irrigation.

2. *Flood Irrigation.*—The flood method of irrigation is possible on level land. It is obviously a wasteful method if practised in young orchards, but when trees reach their prime, the flood method of irrigation has given excellent results. Combined with the basin system of irrigation, the Flood Method is most ideal where rainfall is low and the soils are calcareous. Thus, alkali salts are washed down and their subsequent coming up is prevented. Of course, under the Flood Method of Irrigation, the soil must be fairly deep and well-drained.

3. *Check method of Irrigation.*—This method of irrigation is popular with orange growers of South India. It consists of making bunds of about one foot high which run between tree rows with cross



bunds at right angles to these so as to form a basin covering the entire area reserved for each tree. It has no place in young plantation where cover or green manure crops are raised. This system of irrigation works well on heavy soils where the water is absorbed very slowly and stands for a relatively long time to give adequate covering. It ensures quick covering of surface, uniform wetting of land and comparatively small loss by percolation.

Two types of check systems are commonly used. The rectangular check method is well-suited to sufficiently level ground and the contour check system for contour lands. The latter type is used extensively in the irrigation of orchards and the claim is made that it requires little or no grading beyond the construction of the levees.

4. *Furrow System.*—The furrow system of irrigation is not known to be practised anywhere in our country, but in view of its adoption on an extensive scale in other countries, it is appropriate to mention briefly some of its salient features.

The furrow system can be successfully used in almost any type of topography and usually gives the best control and most uniform results especially when the depth of wetting is considered. It is suited to level or very slightly slopping areas. 4 to 8 or even more furrows are made at equal distance between the tree rows with a double mould board plough or Bund Former. Water is admitted into the furrows from the main feeding channel. Water applied thus in furrows tends to move downwards with little lateral movement, the maximum lateral movement having been found in California to be about 30" from the centre of the furrow. The length of furrows should not be too great as otherwise moisture penetration is not satisfactory. On hill slopes, furrows exceeding 250 to 350 feet are considered undesirable. Weimeyer and others (1955) state that on sandy soils the length of the furrows is about 300 feet; on loam or medium texture soils 600 feet is used; on clay soils longer furrows are some times used.

Ordinarily 4 to 8 furrows are made between every two or three rows of trees, additional furrows are also often zigzagged. In young plantations, 2 furrows, one on each side of the row are also recommended. The furrows should have a uniform grade throughout their length to be most effective or they may be level, but some cross slope in the field is not detrimental. Phelan and Wayne (1955) are of the view that furrow irrigation is usually expensive from a time and labour standpoint. Properly operated, it is fairly efficient in its use of water. It is the most widely used system of irrigating fruit plantations and probably the most practicable where the water is delivered to the areas in flumes. The penetration of water at the head of the furrows is usually more than the requirements of trees, but the same at the lower or farthest end is seldom sufficient and this ununiformity of water distribution brings about a variation in the vigour and cropping of trees. Fertilisers and manures applied in the furrows cannot be properly and evenly distributed in the soil. The ill effects of ununiform distribution of water and plant food can be considerably minimised by regulating the length, the depth and the gradient of furrows. Thus, shallow furrows prove more satisfactory than deep furrows.

5. *Overhead Sprinkler Irrigation System*.—Overhead Sprinkler application of irrigation water has recently come into considerable use where it has been necessary to employ pumps to elevate the water to the orchard level. There are various methods more or less widely used by means of which the water is applied in the form of spray somewhat resembling rainfall. The development of some pressure is essential in all the forms. This pressure is obtained by pumping the water from the original sources into the main supply line, by which it is carried to the distribution lines equipped with perforations or special nozzles that develop the spray. The nozzles can be stationary, oscillating or rotating which provide a very even distribution. This is by far the most practicable method of distributing irrigation water on steep slopes or comparatively uneven lands. The cost of installation including both pumping and distributing equipment is greater than for flumes and the construction of basins or furrows, but the maintenance and operating cost are lower. Some large scale users of irrigation report that an acre-inch applied by means of overhead sprinklers actually goes nearly as far as 2 acre-inch applied in furrows (Gardner and others 1952). It is the system coming into greater use in the U.S.A., Australia and some of the European countries. The main disadvantages of sprinkler irrigation are its relatively high cost of installation. In many cases, these may be largely offset by lower cost of operation and maintenance than would result from surface methods. This method may, however, serve to spread infection of certain leaf spot and other fungal diseases.

*Reference :*

1. Bamesberger, J. G. (1955)—Water. Preparing Land for efficient Irrigation. *U.S.D.A. Year Book*; pp 279-285.
2. Cheema, G. S., S. S. Bhat; Naik, K. C. (1954)—Commercial fruits of India, pp. 175-177, *MacMillan and Co., Ltd., Calcutta*.
3. Dutta, N. P. Bains, S. S. and Chatterjee, G. D. (1954)—Spray Irrigation. *Sci. & Cult.* 20 (6): 292-293: Dec.
4. Fortier, S. (1927)—“Orchard Irrigation”.—*U.S.D.A. Farmers’ Bul.* 1518.
5. Gardner, V. R., Bradford, F. C. and Hooker (Jr.) H. D. (1952)—The Fundamentals of Fruit Production. VII. Irrigation. pp. 117-128. *3rd Edition: Mc-Graw-Hill Book Co. Inc. New York*.
6. Hayes, W. B. (1953)—Fruit growing in India, pp. 45-48. *Kitabistan, Allahabad*.
7. Phelan, John T. and Wayne, D. (1955)—Water. Surface Irrigation Methods. pp. 258-266; *U.S.D.A. Year Book*.
8. Roe, C. E. (1950)—Moisture Requirements in Agriculture. Farm Irrigation. pp. 132-152; 203-261. *McGraw-Hill Book Co. Inc. New York*.
9. Spurling, M. B. (1951)—Sprinkler irrigation of Citrus. *J. Dept. of Agr. S. Austr.* 26: August.

*Water Requirements of Imports Fruit Crops*

by

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Everyone of us present in this meeting knows it well that water, is an important plant constituent be it a herb, shrub or a tree. It comprises 35 to 95 per cent of the leaves depending upon the stage of their maturity 70 to 90 per cent of most of the fleshy fruits and 60 to 90 per cent of roots and 38 to 65 per cent of fresh wood. It is essentially required for the build up of plant tissues as well as for the production of plant materials particularly the photosynthetic production of carbohydrates. It is a medium in which the nutrients occur in solution in soil and are taken by the plant. Every plant, therefore, requires water for its maintenance as well as for the successful conduct of its life processes like flowering, fruiting, fruit ripening etc. The quantity of water required by each plant however differs according to the (1) kind of plant (2) its age and size (3) the type of soil in which it is growing, (4) the climatic conditions, (5) the methods of soil management *viz.*, cultural, irrigational and manurial treatments and (6) the amount of crop borne on a tree. It is very essential that a fruit grower should know, how much water a particular tree requires at various stages in its life for its efficient functioning. Unless a grower has this knowledge he is likely to err to his disadvantages either by applying too liberal irrigation which may go to waste if it is in excess of plant requirements or by applying too little quantity of water so that the fruit tree suffers due to lack of moisture and may be affected adversely either temporarily or permanently.

The water requirements of most of the fruit trees are met with partly by rain water and partly by irrigation water which may be supplied from a Canal, a Persian-Wheel or a Tube-Well, etc. The fruit grower is mostly concerned with the supply of irrigation water and he should be equipped with all necessary knowledge for controlling the quantum and frequency of irrigation according to the needs of trees which may go on changing with the change in climatic conditions, increase or decrease in the cropping capacity of trees, cultural and manurial practices and other allied factors. Unless and until he is able to do it he would not be able to keep his trees in a condition conducive to efficient functioning and his economic outturns would be adversely affected which in the long run would hinder the development of fruit industry. It is therefore imperative that if the fruit industry in our country has to be developed on sound lines the fruit growers should be guided from time to time about the required quantity of water to be applied to different fruit trees, in different regions at different periods in the year according to their age, health, and vigour as well as the amount of crop borne on them.

Such a knowledge is made available to fruit growers in other horticulturally developed countries on the basis of continuous research work done by the horticulturists on the irrigational requirements of fruit trees in different regions and under different conditions of soil

and climate but in our country no systematic trials have been conducted so far on the results of which we could base our recommendations to the growers. Whatever irrigational practices are being followed they are not based on any experimental data. While in other countries the horticulturists have established after continuous research work, the quantity of water to be applied to each fruit crop, its frequency and mode of application, we have yet to initiate such experiments in different regions to have any definite idea regarding the irrigational requirements of fruit trees. In the United States of America for example they have worked out the seasonal variations in soil moisture in different regions under different fruit trees, the optimum quantity of water required by different fruit crops at different periods of the year, the affect of varying amounts of irrigation water applied to different fruit trees especially on the cropping over such a long number of years and under so widely varying ranges of soil and climate that they are in a position to guide their growers almost with mathematical accuracy regarding the total amount of water to be applied as well as its distribution. But in our country it has to be regretfully pointed out that we as yet do not know to any precise measures even the requirements of our fruit trees in different climatic regions. In fact no work worth the name has been done on the irrigational requirements of fruit trees so far and very little published information is available on the subject.

The members, I believe, have had an opportunity to study the brief notes on irrigational requirements of some important fruit crops supplied by the Agricultural Chemist, Andhra and it would make evident the fact that how vague are our impressions regarding the irrigational requirements of even some of our most important fruit trees. The position in other States, as far as I know, is not in any way better than this and it is high time that we should take up research on this problem in some systematic way.

As the honourable members know it that irrigational experiments are essentially long range trials which would need enough trained personnel and adequate funds for their successful conduct we may not be in a position to plan too ambitious a programme for such a research work to match that of other horticulturally developed countries due to our comparatively limited resources. But I am sure we can embark upon the project immediately by tackling some simple but essential problems at some of our existing horticultural stations where facilities by way of trained personnel and uniform plant material exist and gradually we can switch on to more complex problems as our experience and resources grow. The right approach, in my opinion would be, to initiate experiments at different regional stations proposed by the Horticulture Sub-Committee to find out the optimum quantity of irrigation water to be applied to different fruit trees as well as the interval and methods of irrigation. When we progress satisfactorily with these problems we can extend the scope of work to find out seasonal variations in soil moisture under various fruit trees under different types of soil and climate by including private orchards in the scope of our study and we can tackle some other allied problems.

*Different systems of irrigating fruit crops with a view to economising on the use of irrigation water*

by

B. S. Bajwa, Fruit Specialist, Punjab.

The selection of an efficient irrigation practice for any orchard needs essentially a sound knowledge of the physics of soil moisture and a clear understanding of the use of water by the plants. When the water is applied to the surface of the soil it moves downward by the action of gravity and capillarity. The rate of its movement depends upon the relative size of soil particles. Therefore, with the difference in the structure of the soil the rate of penetration would also differ. Water, as is known to all here, would penetrate a coarse soil more easily and quickly than in a fine soil and if an equal quantity of water is applied to a fine and a coarse soil at the same time the extent of wetness in the subsoil would differ very greatly. Since the ideal irrigation practice is the one which consists in wetting the soil mass occupied by the root system of the tree without excessive penetration below the root zone and without excessive waste by run off from the irrigated area it is imperative that different irrigation systems will have to be followed in different soils with a view to make the best use of available irrigation water.

In addition to the structure of the soil there are some other important factors like the requirements of individual fruit trees, the topography of the soil, the size of the stream and duration of flow, the method of delivery and the climate of the place which would govern the system of irrigation to be followed. Hence it is essential that every care should be taken and all the aforesaid points should be thoroughly considered before deciding the system of irrigation to be followed.

The main systems of irrigation which are in vogue in different horticulturally developed countries are (1) Flood system (2) Basin System (3) Furrow System (4) Border Method (5) Contour Checks (6) Sprinkling or over head irrigation system. All these systems have their advantages and disadvantages which need not be discussed here in any great detail and it would suffice to say that while one system may succeed under one set of conditions the other may prove useful under a different set of conditions. It is, therefore, desirable that these systems should be tried by keeping the quantity of irrigation water constant at different stations and under different set of conditions to know which system would suit under what type of conditions. The cost of labour involved in each system as well as the cost on equipment and other things etc., should also be considered to judge the suitability of any system and for this purpose experiments should be initiated at regional Stations.

PAPERS ON SUBJECT NO. 7.

*Rational of policy of large scale multiplication of seedlings from open-pollinated, heterozygous seed parents in perennial crops and the possibility of establishing nucleus plantations with appropriate combinations by way of selected male and female plants away from all possible contamination from foreign pollen for production of elite seed with special reference to the Coconut*

by

Indian Central Coconut Committee, Ernakulam

Progeny selections according to the nature of ancestors of plants based upon the phenotype of the parent and the offspring popularly known as the "maternal line selection", comprising of female parent only and no attention paid to the male, formed the standard practice from very early times in perennial crops, particularly those propagated through the seed. Although this method has been in common practice from the beginning of the history of cultivation of these crops and there was good reason for considerable success that followed adoption of this procedure of raising useful planting material, the inherent defect and limitations of this method has been recognised by research workers. While they believed that repeated selection of superior biotypes tended gradually to raise the population with respect to this character, for which selection is in practice, they, however felt for obvious reasons that selection based entirely on the phenotype or pedigree or performance was not entirely safe to depend upon as it failed to produce genetically a homozygous race.

This was true of the palms in general and the coconut in particular due to the allogamous nature it presented. Federico (2) in his classification of plants according to mode of fertilization of the flower included the palms under the class Anemophilae with immobile flowers (typus immotiflorus). Although no concrete data is available at present to assess if the coconut was wind or insect pollinated, examination of the morphology of its flower presented, however, so many features of essentially wind pollinated plants, viz., lack of showy parts attractive to insect such as tubular flowers, bright colour, strong perfume, abundance of nectar, sticky pollen with their exterior studded with knobs, spines and other projections, production of large quantity of pollen reduced in size, a distinct exposure of anthers and stigma to the air, designated to scatter its pollen to the wind, the three stigmatic teeth pointing out and standing erect at the stage of fertilization to expose larger stigmatic surface for reception of the pollen, its complete separation of sex with staminate flowers distributed separately in the same inflorescence with staminate flowers oriented at the top of the spikes and pistillate flowers at the base to facilitate cross pollination and above all the female flowers in the coconuts reaching receptive stage sometime later than completion of the period of anthesis of the staminate flowers in the flowering branch. All these features exhibited by the flower of the coconut established that coconut, particularly of the tall variety, is essentially a cross pollinated plant.

This phenomenon of cross pollination prevailing in the coconut resulted in such promiscuous crossing in nature with pollen of unknown genetic complex that the existing palms are highly heterozygous in nature. It is only to be expected that these will give rise to highly variable progeny. Jack (3) estimated that in coconut plantations hardly ten per cent of the trees proved true to parent types. This phenomenon consequently led to the very poor percentage of high yielding trees in our plantations. This variability was also observed to be persisting, although to a lesser extent, even when the selection of planting material was restricted to raising seedlings obtained from seednuts collected from selected parent trees. However, rigorous selection of mother palms and seedlings in the nursery did enable the production of planting materials which gave on an average better performance than those from unselected bulk. When breeding is a work of generations and the possibility of multiplying desirable palms by vegetative methods, is not there, the above method is the only practicable one.

Selfing as a method of producing progenies breeding true to type has also been ruled out. The parental material being highly heterozygous selfing also resulted in variable progeny. Further there was also loss in vigour, which is only to be expected in a naturally cross pollinated crop. Continued selfing to produce pure lines and utilisation of hybrid vigour are the other methods but these useful projects are also beset with considerable difficulties owing to obvious reasons. Firstly, both these ventures involved initial work stretching over a number of generations and required a large area to test the different progenies which was hardly within easy reach of research workers particularly due to the very long pre-bearing life in the coconut. Secondly, although crossing with selected heterozygous parents after finding most satisfactory compatible crosses judged from performance of the daughter material obtained from these was now a fairly practical way of utilization of hybrid vigour, it was, however, not found to be an absolutely safe way for adoption in raising plant material. Apart from this, it was also found impossible to maintain a hybrid pure without segregation of parental types in further generations due to the heterozygous nature of the parent material used in crossing. Therefore, it was observed that if any results of useful nature are to be aimed at homozygous types had first to be evolved for purposes of hybridization which involved a time taking difficult and unattractive proposition. Lastly, the experiment in breeding coconuts was rendered difficult due to the great height of the palm and consequent difficulty of controlled pollination on a large scale to secure nuts in required numbers.

Under the circumstances explained in detail and the impossibility of raising the coconut through a sexual method of propagation, the only practicable way, therefore, was the prevailing system of selection of planting material. This comprised of collection and selection of seed from the best individual mother palm with desirable characters associated with good performance of selected seedlings, viz., compact and well balanced crown, heavy yield of nuts and copra, medium size and round shape of nuts, short bunch stalks, freedom from buckling of bunches, marked resistance to pests and diseases, etc., and then sow these nuts in the nursery rows and carry out rigid selection of seedlings restricting it to those early sprouted

vigorous seedlings with good girth at collar and having large number of leaves and discarding poor 'leggy' seedlings with weak stem, pale green, narrow leaves and mid ribs. Considerable evidence has accrued in recent years in support of the use of this method of selection. Trials carried out in Ceylon (4) revealed that while no significant differences were observed in the performance of plants raised from seed selected either from individual mother palms or trees in high yielding blocks, both these methods, however, proved significantly superior to the performance of trees raised from unselected seedlings.

In recent years several modifications of this system of selection have been suggested as a means of improvement of the crops. Dwyer (1) suggested the system of "Close Breeding" for improving the coconut planting material according to which seedlings derived from individual mother trees in compact block are to be raised so that trees in the centre of the block would be almost certainly pollinated by other trees of the same family. He also suggested the use of nuts from the centre of the best plots for use as seed material for the next generation. He also suggested that selection of the same trees could be repeated for as many generations as necessary. This method of planting was used on a small scale at Kerawat Demonstration plantation for the coconut near Rabaul in New Guinea.

More recently considerable emphasis has been laid on the advisability of establishing nucleus plantations with material obtained by controlled cross pollination between selected male and female plants away from all possible contamination from foreign pollen as a means of improvement of heterozygous perennial tree crops. This method is slowly awakening the interest of research workers in recent years. A beginning in this direction has already been made in Ceylon (4) where a nucleus seed coconut garden of 200 acres near Chilaw in the Ambakalle Forest Reserve in Ceylon surrounded by forest vegetation at least 50 chains wide all round is proposed to be raised with selected seedlings derived from hand pollinated nuts raised from compatible parental combinations. Although this cannot undoubtedly be claimed as perfect way of obtaining suitable plant material but under circumstances prevailing in the coconut and the difficulty in raising large scale hybrid nuts through controlled pollination this method is bound to secure not only progenies of hybrid plants fairly approximating those raised through controlled pollination but also would serve as an improvement over the existing methods. Only future results will show how far the advantages claimed for this method are in fact true.

#### References :

1. Dwyer, R. E. P. (1939) Coconut improvement by seed selection and plant breeding. New Guinea Agri. Gaz. IV. No. 3 & Trop. Agric. Vol. XVI. No. 11. p. 246.
2. Federico, Delpino (1865) Ulteriori osservazioni considerazioni Sulla dischogramia nel regno vegetale, Milano.
3. Jack H. W. (1923) Selection of coconuts. Tropical Agriculturist. Vol. LX. March.
4. Liyanage, D. V. (1955) Planting material for coconuts. Rep. Coco. Conf. Lunuwila, Ceylon, pp. 11-17.



*Selection of Planting Material in Coconut*

by

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Coconut is a seed propagated perennial palm living upto an age of 80 to 100 years and is highly cross-pollinated in nature. That seednuts obtained from high yielding selected coconut palms produce the best coconut seedlings, has been the view held by Coconut workers in general. This conception has been held presumably on the basis of certain correlation studies undertaken with a miscellaneous population of mixed genetic constitution. However, reliable and confirmatory data on the basis of actual progeny studies of selected and unselected palms are not known. The coconut nursery Schemes sponsored by the Indian Central Coconut Committee and the State Governments, run all over the country, in the matter of distribution of selected coconuts seedlings, have been based on the above said popular conception. Recent research conducted by the Coconut Research Institute, Ceylon has belittled the value of the selected practice now in vogue. Cooke has shown that from the results of a latin square experiment that there were no significant differences in the yields of nuts and copra from the adult palms whether the original seednuts were taken from selected high yielding palms or from selected high yielding blocks. He has however indicated that selection of seedlings at the nursery stage leads to earlier flowering and subsequently to markedly high yielding of nuts and copra. The above finding disproves the value of selection of palms for securing desirable seedlings progenies. The futility of parental selection has also been brought out from the yield data. It has not been possible to ascertain a uniform trend in the individual tree performances; nor has it been possible to forecast with some amount of accuracy, the yield performances within a given seed progeny and thereby judge the relative yielding capacity of anyone tree or a batch of trees within that progeny. Therefore, with a plant material such as of a seed propagated, perennial and heterozygous one like coconut, the complexities are brought about by the huge variation in the plant performances with known progeny, aided by the influence of soil and environment, the method of selection requires a reorientation.

In the matter of seed selection the effect of environment on the growth characteristics of the Coconut cannot be underestimated. Unfavourable environment may mask favourable hereditary characteristics of the individual palms and render selection difficult. The hereditary characteristics of a palm which determine its inherent capacity for yield are constant, but the factors associated with the expression of yield such as climatic soil and cultural environment are constantly changing. Pearce has suggested the system of calibration to overcome the difficulties as, seasonal and treatment influences on plant performance. He has suggested the recording of the individual tree performances or yields carefully for four or five successive years when the trees are all under uniform treatment. When such calibration measurements are made it is possible to initiate the experiments and analyse the results statistically by employing the covariance method. It is only by this technique, that inherently better bearers may be ascertained. Dwyer has suggested three methods

of breeding and selection in Coconut and these are reviewed briefly. It will be seen that the methods followed by Cooke and Pearce are based upon the ones advocated by Dwyer as early as in 1938. In the matter of Coconut seed selection employed in this country it seems to be that only rough principles of mass selection have been advocated though not adopted in an organised manner.

Recently in Ceylon, Coconut Plantations on a small scale have been raised in a sheltered forest area, where seedlings of known parentage have been planted. The seednuts from these palms would exhibit less variability as these are not exposed to pollen of different palms. A similar experimentation in this country is also needed before any formula on the present technique of selection of mother palms, seednuts and seedlings is modified. As the present technique has to be continued till a rational one is established, it is very necessary that trials as indicated above are initiated at the earliest.

*The rationale of the policy of large scale multiplication of seedlings from open polinated heterozygous seed plants in perennial crops and the possibility of establishing nucleus plantation with appropriate combinations by way of selected male and female plants away from all possible contamination from foreign pollen for the production of elite seeds*

by

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Obviously the idea behind this work is to utilise the chance recombinations of various types of gametes freely and at random and select out the most ideal ones. In this, the plants being perennial afford a constant source of plants with same genic make up which is not often possible in an annual crop. The parents being heterozygous the gametes produced by them naturally differ in their genetic constitution and theoretically the seeds obtained from such promiscuous crossings must give all the possible recombinations especially so if the seeds can be gathered over different seasons in the year. The only limitation for the success would be the possibility of incompatible crosses arising and thereby zygotic lethality or self sterility factors or other cryptic gene combinations which might limit the number of recombinations. If the perennial parents are carefully worked out for these compatibility factors as in the case of the apples, pears and other pomaceous fruits, the scheme would certainly be a great success, especially when as envisaged in the programme dioecious plants are utilised.

A further point is the exploitation of heterosis in such combinations. Selected clones may be tested for their combining ability by polycross method taking into consideration, pest and disease resistance also. Such clones as excel in the poly cross trials may be planted together at random under isolation and allowed to produce seeds under open pollinated conditions. Seeds from such selected clones may be synthesised into a variety taking care to eliminate combinations which are below the ideal. Thus heterosis which may be expressed in these combinations may also be made use of.

## PAPERS ON SUBJECT No. 8

*A note on Virus diseases with special reference to their nature, methods of transmission, diseases they cause and methods of control*

by

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Viruses attack most of the living objects. Man, animals, plants etc., all fall an easy prey to the these diseases. This malady is not of recent origin. Smallpox was reported from China in 1700 B. C. There is every reason to believe that plant viruses have been present since ages. Diseases of plants caused by viruses, however, did not receive much attention till the beginning of the present century. Since the beginning of 1900 A.D., about 200 viruses have been recognised and their importance has greatly increased since then. In India, work on virus diseases was taken up with some seriousness about 15 years back and now studies on viruses are in progress at a number of institutions. Looking to the enormous damage these diseases cause, more attention should be paid to the studies of viruses.

*Nature of Viruses.*—Viruses were regarded as living organisms till 1935. In some cases of virus infection 'elementary corpuscles' found in certain animal and human virus diseases were thought to be the infective organisms. Amoeboid bodies found in maize, sugarcane and tobacco were thought possibly to be protozoa. Some virus diseases were considered as due to flagellates and Trypanosome like organisms. In 1935, Dr. W. M. Stanley isolated a crystalline protein from juice of tobacco plant suffering from mosaic, having all the properties of the tobacco mosaic virus. He considered the virus an autocatalytic protein presumably requiring the living cells for multiplication. In 1938, Bawden and Pirie isolated a fully crystalline form of the tomato bushy stunt virus. Further studies revealed that they were nucleoproteins separating as a jelly on high-speed centrifuging. These crystals vary in size and shape depending upon the virus and the conditions in which they are formed. Crystals of tobacco mosaic virus are needle-shaped and those of tomato bushy stunt virus are dodecahedral. Some of these bodies can be seen with the naked eye and some can be observed only under the microscope, while the virus particles can be seen only under the electron microscope.

In 1955, Fraenkel-Conrat and Robley Williams have achieved reactivation—inducing the two components nucleic acids and proteins to combine in the laboratory to form the original virus. They worked with tobacco mosaic virus. This remarkable work further supports the 'Chemical theory' of viruses.

*Methods of Transmission.*—Transmission of virus diseases is brought about in different ways. There are three main methods of transmission, namely, (i) by grafting, (ii) by insects, and (iii) by inoculation.

In experiments on transmission of viruses from the diseased to the healthy plants many of the viruses have been transmitted mechanically by rubbing the juice from the diseased plant over the leaves of the healthy ones. Another method of transmission is by grafting. Under this head use of *Cuscuta* (Amerbel), a flowering parasite, is worth mentioning (Bennett, 1940). In this method two plants are connected by a living graft. The parasite provides a medium through which a virus can be transferred from the diseased to the healthy species.

In nature only a few viruses are disseminated by mechanical means. Best example of virus which is transmitted by contact is potato virus X. Most of the spread of virus diseases in nature, however, takes place through infected vegetative parts meant for propagation, either through seed or through insects.

Many of the virus diseases are spread by the use of infected underground stems, roots, off-shoots and other parts meant for propagation. Viruses of potato, tree fruit and many ornamental plants are spread by this means.

Seed borne viruses are very few. Worth mentioning seed-borne viruses are bean mosaic, ring spot of tobacco and a virus attacking *Dolichos biflorus* (Uppal, 1931). It may be pointed out that all the seeds from the diseased plant do not carry the virus. It is present only in a portion of the produce. Transmission of virus by pollen grains has been reported in some cases, but it is of rare occurrence.

Insects are the most important agents for the spread of virus diseases and most of the plant virus diseases depend on insects for their dispersal. Insects like aphids, leaf hoppers, white flies, mealy bugs and tingids, which have sucking mouth parts, are the important insects in this matter of transmission. Of these aphids and leaf hoppers are the chief ones. Considerable work has been published on 'Insects in relation to virus diseases' and it is not proposed to deal with it in this note.

*Diseases caused by viruses.*—Earliest known virus disease in India is the spike disease of Sandal (*Santhalum album*) and so far it has not been effectively checked. Small leaf disease of cotton is another important disease. Virus diseases on cucumbar, sugarcane, potato, etc. have been reported and work has been done on them. Virus diseases on *Cariea papaya* and *nicotiana* have also been reported. Considerable work on mosaic disease of bhendi (*Hibiscus esculentus*) has been done at Poona and control measures have been suggested.

There are many more virus diseases which can be known only if there is proper virus survey.

*Methods of Control.*—It is a well known fact that the viruses cannot be controlled by chemicals. Control of insect vectors may be undertaken when the economic conditions permit it, but not much success has been achieved in the control of viruses by eliminating the insect vector by use of insecticides. It is just possible that new systemic insecticides may be more effective against insect vectors

and better results may be achieved in future. In Australia, spotted wilt of tomato has been controlled by applying poison bait to the seed-bed, which was found to be very effective in reducing the population of thrips.

By shifting the site and time of planting a crop, it is sometimes possible to avoid the insect vectors of a virus. Potatoes can be grown in some parts of Scotland without its getting infected because climate there is unsuitable for aphid vector of potato viruses.

Roguing of virus infected plants is of great value in the control of a number of virus diseases, especially those which attack crops propagated vegetatively such as potato, sugarcane, strawberries, etc. This practice is of great value in the maintenance of disease free nursery stocks.

Destruction of 'volunteer plants', weeds and other wild host plants, symptomless carriers of virus diseases also reduces the incidence of virus diseases as they serve as sources of infection to the new crop. Eradication of weed hosts of insect vectors has also given good results.

Breeding of virus resistant varieties is thought by many as the most hopeful line of attack and some success has been achieved by following this method. In America, sugar beet varieties, resistant to the curly top virus, have been produced by breeding. In India, work on breeding of virus resistant varieties of Gingelly and Lady's finger is in progress.

*Plant Viruses with special reference to their nature, methods of transmission, the diseases they cause, and methods of control*

by

R. S. Vasudeva, S. P. Capoor and T. K. Nariani

Although diseases of plants now recognised to be caused by viruses were known to exist for a long time, little or no work had been done for their elucidation till about the beginning of the 20th century. The variegated tulip flowers appeared in botanical literature in the year 1576, and the "degeneration" diseases of potato were so wide spread in the year 1775 that farmers in different parts of Europe had to abandon its cultivation. The virus of tobacco mosaic diseases, named as tobacco mosaic, was described as early as 1857. It may be mentioned here that in our country the spike disease of sandal existed perhaps long before its presence was brought to light in the year 1899 by McCarthy.

Exhaustive work on virus diseases of plants began in the two decades that followed the development of bacteriological methods of Koch. Also, the establishment of the germ theory of disease in the beginning of 20th century greatly influenced the trend of thought of the early workers who considered that most if not all infectious diseases were due to bacterial action. The distinction between viruses and other pathogens, however, was not made until the classical discoveries of Iwanowski (1892) and Beijerinck (1898) on the filterability of the tobacco mosaic virus were well recognised. The

tobacco mosaic virus was not only the first filterable virus to be discovered, but it has maintained a position at the very centre of the history of a distinct science of *Virology* ever since.

The word "virus" denotes poison or toxin, and though, it was applied for the first time to the non-culturable and invisible disease stimulus of hydrophobia (rabies) Pasteur did not make any distinction between viruses and bacteria and wrote in 1889 ".....The *microbe* of rabies has not been isolated as yet, .....: every virus is a *microbe*. Although these beings are of infinite smallness, the conditions of their life and propagation are subject to the same general laws which regulate the birth, and multiplication of higher animal and vegetable beings". It is perhaps significant that the use of the word virus even then was restricted to those infectious diseases whose causes were undetermined and such pathogens were called "filterable" viruses in order to distinguish them from bacteria. As the knowledge about viruses developed it gradually became clear that filterability was a very chancy property depending on a wide variety of circumstances, and therefore, the term "filterable virus" quietly contracted to 'virus' and became the name of a fairly well characterised group of pathogens.

Following the discovery of the virus of tobacco mosaic lot of work has been done on virus diseases of plants throughout the world, and as a result of that we now claim to know substantially about their nature. Viruses have been found to range in size from about 10  $\mu$  to 300  $\mu$ . Certain small viruses, such as alfalfa mosaic virus, are smaller than certain accepted protein molecules, such as the *Busyon haemocyanin* molecules, while certain large viruses, such as vaccine virus, are larger than certain accepted organisms, such as *Pleuro-pneumonia* organisms. With respect to size, therefore, the viruses overlap with molecules at one extreme and with organisms at the other. In spite of the fact that the invisibility of viruses and their apparent inability to multiply *in vitro* rendered customary bacteriological methods of little value in studying them, the viruses were considered as ultra-microscopic organisms because they clearly possess those qualities which are normally considered characteristic of organisms: they obviously multiply and reproduce their own kinds over generations and they can mutate and give rise to chemically distinct variants which usually resemble the parent type. It was, however, not until 1936 when Stanley purified the tobacco mosaic virus from juice from infected tobacco plants and showed that it contained a specific nucleo-protein that the real nature of viruses came to light. The virus particles were found to consist of about 6% nucleic acid of the ribose type and about 94% protein. Of special interest and significance is the fact that the virus particles appear to be utterly devoid of water and of any enzymic activity other than virus activity. The complete lack of water and crystal-like inner structure of the individual virus particles would appear to preclude the existence of metabolism of the type usually associated with organisms, yet, when introduced into the cells of hosts, these particles can direct or enter into the metabolic chain of events of the cell. On the other hand, the larger viruses, such as Vaccine virus, contained protein, lipid, carbohydrate and thymus nucleic acid, and also enzymes. Thus it will be seen that as one

goes from the small to the large viruses, there is, with increase in mass, an increase in complexity of composition, structure, and function. The viruses appear to provide, in truth, a bridge between proteins and organisms, and if Vaccinia virus, for example, could be grown on a vegetable jelly or prepared broth it could be accepted generally as an organism. In general, it may be said that viruses are made up of protein, much of it in combination with nucleic acid to form nucleoprotein which is generally regarded as the bearer of hereditary qualities in every type of organism from viruses upward. By and large, chemical analysis indicates that viruses are simplified organisms made up of the same sort of building stones as other living material.

During the past decades more than 300 different viruses attacking plants have been described. Most of our economic crops are affected by some virus or the other. The damage they do probably equals if it does not exceed that due to all other disease agents, and are a serious problem all over the world to-day. Knowledge about many of the virus diseases of plants in India has been made available as a result of investigations carried out at the Indian Agricultural Research Institute and through Research Projects sponsored by the Indian Council of Agricultural Research. Diseases like papaya mosaic, "Katte" or mosaic of cardamom, mosaic and leaf-curl of tobacco and tomato, mosaic of sugarcane and maize, several viruses of the potato crop, of beans, cucurbits, cruciferae, sann-hemp, sesamum and others have been studied in order to seek methods whereby the viruses spread in nature and the variety of plants they infect with a view to evolve suitable ways of combatting them.

*Transmission.*—There are three chief methods by which plant viruses may be transmitted: (1) by grafting healthy plants with some part of a diseased plant, (2) by inoculating healthy plants with juice expressed from diseased plants, and (3) through the agency of insects. Also, quite a few virus diseases are transmitted by some method of natural means of spread. Viruses rarely enter into true seeds, and crops grown annually from seed, with a few exceptions, such as lettuce, some cucurbits and leguminous crops, are usually free from virus diseases. But they do not become immune to infection coming in from other sources. On the other hand the plantation crops that are propagated vegetatively by grafts, or rhizomes, cuttings, setts, tubers, bulbs, etc., remain permanently affected after once contracting a virus disease. They also go on accumulating viruses and result in a loss of capital stock.

Once a virus enters a plant it usually permeates all the vegetable parts and remains there as long as they remain alive. Most plant viruses, therefore, can be transmitted by grafting between diseased and susceptible healthy plants of species that can be inter-grafted. Not all viruses can be transmitted by sapinoculation, but most of the mosaic type viruses can be spread in this way. The great majority of plant viruses are insect-borne and some of them, apart from grafting, can only be transmitted by insect agency, such as, cardamom mosaic, banana mosaic, bhendi yellow vien mosaic, tomato leaf-curl, "little leaf" of brinjal, sesamum, phyllody and potato

leaf-roll. There are several plant viruses, for example, "sterility" disease of pigeon-pea, "small-leaf" disease of cotton, and "spike" of sandal that so far have been transmitted only by grafting. Further work on these diseases is needed to be done in order to establish or confirm their insect vectors.

An ingenious method of graft-transmission of some plant viruses is accomplished by the use of the parasitic plant, Dodder (*Cuscuta* spp.) By parasitizing two plants simultaneously a living connection can be made between species which could not otherwise be grafted. This enables viruses to be transferred from host plants which are unsuitable for study to new and more suitable plants. This method, of course, has its limitations because Dodder will not transmit all viruses nor will it parasitize every kind of plant, but from an experimental standpoint it provides virus workers with a useful tool in studying an otherwise difficult virus disease.

Transmission of viruses is usually a specific thing and not something that any insect can do. Viruses can be spread widely by insects that are never sufficiently abundant on a crop to be obvious pests, and even by insects that do not breed on the crop at all. Most of these insects feed by sucking juice from plants, and they include aphids, leaf-hoppers, white-fly, mealy-bugs and thrips; but insects which feed by biting or chewing, such as leaf-beetles and grass-hoppers, have also been reported to transmit plant viruses.

Great many facts about the relationship between plant viruses and insects have been elucidated and some of them are of considerable interest. There seem to be two main types of behaviour between plant viruses and insects, first those cases where the virus is rapidly lost by the insect if it has not access to a fresh source of infection (non-persistent), and secondly those cases where the virus is retained for long periods (persistent). The non-persistent viruses are equally rapidly lost by the insects and the first plant only on which the insect happens to feed is infected, but the persistent viruses are retained by the insects for life. Between these two extremes there are viruses that show almost every intermediate type of behaviour. These differences are determined by the identity of the virus rather than that of the insect vector.

Some plant viruses such as "stunt" disease of Rice and the clover club-leaf virus (both transmitted by specific leaf-hopper, (*Nephotettix apicalis* and *Agalliopsis novella*, respectively), are said to pass through the eggs of the vector to the newly born nymphs. This is a point of some interest since multiplication of plant viruses inside an animal body would suggest a close relationship between plant and animal viruses.

Ocasionally a virus may be transmitted by more than one species of aphid but not by another kind of insect. Similarly, a virus may have several species of leaf-hoppers as vectors but no aphid can transmit it. This group-specificity, however, is not absolute because there appears to be a plant virus in the U.S.A. (the potato spindle tuber virus) which can be carried by both beetles and aphids.



*Diseases caused by viruses.*—As has already been mentioned above most of our economic crops as well as horticultural and ornamental plants are affected by some virus or the other. A large number of virus diseases of crops and other plants have been studied and many of them have been found to be new to science, while others are caused by either related viruses or strains of viruses already known. Mention may be made of some important diseases which are responsible for heavy losses year after year. Amongst the earliest described diseases is the tobacco leaf-curl, a virus that is transmitted in nature by the white-fly (*Bemisia tabaci* Gen.) and has a very wide host range amongst which are tomato, papaya, chilli, and *Zinnia* and large number of weeds. The potato crop is affected by several viruses in India, such as Potato virus X and D which cause mild or severe mosaic and foliar necrosis, respectively; Potato virus Y and A responsible for severe rugose mosaic and yellow mottle, respectively, and the leaf-roll virus. In addition, the presence of *Solanum* viruses 4, 8 and 9 has also been observed in the commercial stocks. These viruses are responsible for heavy losses in yield and degeneration of seed stocks. Diseases of the mosaic type are caused in large number of plants and by equally a large number of distinct viruses. The Mosaic or "Katte" disease of cardamom (*Elettaria cardamomum* Maton), mosaic disease of papaya (*Carica papaya* L.), mosaic disease of *chavali* (*Vigna cylindrica* Skeels.) mosaic of sannhemp (*Crotalaria juncea* L.) mosaic disease of sugarcane and those of several cucurbit crops need special mention. The "Katte" disease of cardamom which is prevalent in Southern-India, has been responsible not only for the reduction of area under cardamom plantations but also for considerable loss in yield per acre. The virus which is transmitted in nature by the black banana aphid (*Pentalonia nigroneryosa* Coq.) rapidly degenerates the affected stools so that within about a period of 3 years the plantation is rendered commercially uneconomical. Mosaic disease of papaya, which is transmitted by 6 species of aphids in nature has made commercial cultivation of papaya impossible in certain parts of the country where papaya cultivation was once a flourishing industry.

Lately, virus diseases which bring about severe reduction in leaf size, called "smalling" of leaves, accompanied by dwarfing, profuse vegetative growth, and in some cases absence of flowering or production of abortive huds, and in others 'phyllody' are fast coming in prominence. "Stenosis" or the "Small-leaf" disease of cotton, a disease which is threatening cultivation of Indigenous cottons in parts of Deccan and also in the Punjab, is of great economic importance. Such other diseases include the "little-leaf" disease of brinjal; phyllody of sesamum, *Crotalaria* spp. and several species of *Brassica*; and "sterility" disease of *Cajanus cajan*. 'Little-leaf' disease of brinjal is transmitted in nature by *Eutettix phycitis*, and phyllody disease of sesamum by a species of *Deltocephalus*. Investigations on other diseases are in progress.

In recent years new diseases—the 'Grassy-shoot' disease of sugarcane, mosaic of banana, "Foorkey" disease of large cardamom (*Amomum subulatum*) and mango malformation—have come into prominence in India necessitating close investigation.

**Control measures.**—The direct control of plant viruses is by far the most difficult one as they cause systemic diseases, and persist in the vegetative parts of the plant as long as they remain alive. Therefore, most of the methods adopted for the control of virus diseases, except where heat and chemotherapeutic treatments have been found useful, are indirect. These may be summarised as follows: (a) Use of virus free material for planting, (b) Removal of sources of infection, (c) Variations of normal cultural practices, (d) Evolving virus resistant varieties, (e) Creating immunity to infection, (f) Control of insect vectors by suitable insecticides and (g) Quarantine.

As a matter of practice every grower must make it a point to use as far as feasible, only virus-free planting material for new plantations. Most virus diseases are not seed-transmitted so that the annual crops generally start healthy and contract viruses from outside sources, usually infected perennial or alternative hosts. Mosaic of *Vigna cylindrica* is a seed-borne virus, but this disease has been completely eliminated in Poona by the use of virus-free seed of the cowpea varieties Suwannee and Alacrowder which are also comparatively tolerant to infection under field conditions.

As far the virus diseases of vegetatively propagated crops such as potato are concerned, the use of certified disease free stocks for planting has proved to be of immense value and is being universally adopted.

Virus-free material can also be obtained by treating planting material such as bulbs, cuttings, tubers, rhizomes, etc., in such manner that would destroy the virus without impairing the viability in this connection heat therapy offers a very great scope 'Sereh' and 'Ratoon stunting' of Sugarcane have been controlled by the hot water treatment of the setts in Java and U.S.A. respectively while heat treatment has also been successfully used to cure the peach trees of virus diseases and *Vinca rosea* infected with aster yellows virus. Recently the control of potato leaf roll virus in the seed tubers has been achieved in Great Britain by storing them at 37.5°C for 20-25 days in the presence of sufficient moisture.

The work on chemotherapeutic treatments in control of plant viruses has recently been introduced and a good many substances known to inhibit virus multiplication have been tested. Water solutions of quinhydrone, Urea and Sodium thiosulphate have been used to cure buds from peach trees affected with the X-disease and 2,4-dichlorophenoxyacetic acid has been used in the control of potato leaf roll. Thiouracil, the pyrimidine and purine analogues have also shown some promise in this direction but the possibilities of their practical use require to be explored.

The removal of different sources of infection by timely roguing of diseased plants and destruction of weed hosts greatly help in the eradication of both the alternative hosts of viruses and their insect vectors. A complete and effective control of the 'Katte' disease of cardamom has been achieved in the North Kanara district of Bombay province by roguing of diseased plants and rehabilitation of the plantations with healthy seedlings.

The control of virus diseases by variations of normal cultural practices has not been widely tried, though it seems to offer considerable scope. "Good-Farming" and adjustment of normal cultural practices helps to reduce the incidence of some virus diseases. By late planting of tomato in the normal autumn season of the crop, the incidence of virus diseases could be considerably reduced at Delhi. Similarly late planting of Sesamum has indicated reduction in the incidence of phyllody disease.

Another method of avoiding virus diseases is to grow virus resistant plants. Although this is rather a long-range problem, success has been achieved in several cases. Sugarcane mosaic has been controlled to a very great extent by the development of mosaic resistant canes: P.O.J. varieties in Java. Recently, interspecific hybrids of cotton (170 × Co2 and 134 × Co2) have been found to show complete immunity to the virus causing 'stenosis' of cotton in India. Cotton varieties resistant to 'leaf-crinkle' in the Sudan and potato variety, the American seedling 41,956 immune to infection with potato virus X, are further examples of this. The production of curly top-resistant sugar beets in the U.S.A. has allowed the growing of sugar beet in curly top areas where it was previously impossible to grow sugar beet.

It has been observed that the presence of one virus in the plant tissues precludes entrance of any virus which is related to the first virus. This sort of non-sterile immunity allows the possibility of inoculating a plant with a mild or attenuated strain of a virus to keep out a more virulent strain of the same virus. Such a method of protection has however, a limited scope as there is always the danger of the mild strain combining with an unrelated virus to cause more severe diseases.

The control of insect vectors by means of insecticides alone has in majority of the cases not proved effective in controlling virus diseases, although they are very efficient in putting down the population of all kinds of insects known to transmit plant viruses. This is partly because a very few insects can cause many infections and possibly partly because the application of chemicals may cause virus-bearing insects to move about more than they would otherwise and mobility of an insect vector is an important factor in the spread of plant viruses. However, there have been a few claims for the successful use of insecticides in the control of virus diseases. Weekly spraying with nicotine has been found to reduce the incidence of henbane mosaic sufficiently to produce significant increase in yield of *Hypscyamus niger* and the incidence of spotted wilt in tomatoes in Australia has been reduced from 100% to 5% by spraying with tartar emetic. The recent introduction of the systemic insecticides has opened a new field for the Virus Pathologists in the control of plant viruses.

There seems to be no doubt that the virus diseases of plants have been on the increase and new diseases are being described. A part of this increase is undoubtedly due to the introduction of viruses from one country to the other in the planting material. In order to prevent the introduction of new virus diseases, it is essential that the quarantine regulations are strictly enforced particularly attention would be necessary for checking up of the "carriers".

*Plant viruses with special reference to their nature, methods of transmission and their control (Potato)*

by

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A virus is an obligatory parasitic pathogen. Since 1892 we knew of its existence as a contagious disease affecting man, animals and plants. The virus particles, now known to be nucleo-proteins, are small usually less than 200 mu. Several viruses, each with specific reaction towards his hosts, are recognised. Thus, over 82 distinct viruses are listed and yet another 50 unclassified types still remain to be investigated (Holmes 1939). Further there may be several strains of a virus. Their number is now known to be very large possibly over 300.

Some viruses may cause little harm but many of them result in serious losses to several of our economic crops. Being rarely transmitted by the seed the losses caused to crops raised by seeds are relatively very small. Viruses are, however, the most important group of diseases effecting crops that are propagated through vegetative methods. Since there are no known methods of inactivation of most virus diseases in the host plant, once the virus finds entry into the plant it often systematically saturates the entire vegetative tissue and remains in an active state in the living cells of the host. In perenial crops, propagated vegetatively the virus not only causes disease during the current season of infection but persists throughout the life period of the hosts often in more acute state. In a brief note it is not possible to review the nature, methods of transmission and control of a variety of crop which are susceptible to several virus diseases. I, therefore, propose to confine my attention exclusively to virus diseases effecting the potato crop in India.

Although the potato has been grown in this country since nearly 350 years yet no serious attempt was made to find out the cause of low yields in this country. A systematic study was initiated only in 1935 with the establishment of the Potato Research Station at Simla (Pal and Pushkarnath, 1951). In 1938 virus 'Y' was established to be the cause of severe mosaic of *Phulwa* (Pal, 1938). Several other viruses, among which are included virus 'X' and 'D' are reported to cause mild or severe mosaic and foliar neurosis (Vasudeva 1945, 1946) Virus 'Y' and 'A' are known to be responsible for severe rugose and crinkle mosaics of potatoes (Vasudeva, 1945-1946). Leaf roll is now recognised to be the most common and widespread disease infecting the potato crop.

The serious problem which the potato industry faces today can be appreciated when some figures indicating the percentage loss caused by these diseases in the country are examined. The figures given below, based as they are on a rapid survey, only indicate the magnitude and urgency of the problem of virus diseases in Potato. The loss due to virus 'X' on *Phulwa* was estimated to be 25.5 to 92.3 per cent depending upon the virulence of the infection (Vasudeva.

1946). Critical studies carried out at Simla have shown that virus 'X' and virus 'Y' can cause heavy losses in yield in several varieties, some of which are mentioned in table below:—

*Loss in yield due to virus 'X' & 'Y'*

Variety	Percentage loss in yield due to	
	Virus 'X'	Virus 'Y'
Phulwa	24.0	80.8
Darjeeling Red Round	19.3	70.9
Uptodate	15.5	82.9
President	14.4	79.8
Great Scot	..	81.7
O.N. 2236	10.9	88.5

Since the virus diseases are widespread throughout the country particularly in the plains of India the loss of our commercial crops of potatoes due to these diseases is indeed very heavy. Further and more critical assessment of the losses is needed.

#### *Methods of Transmission:*

Studies carried out at the Central Potato Research Institute has shown that out of the several viruses known to infect the potato only leaf roll, virus 'Y', virus 'X' and virus 'A' are important in this country. The situation is similar to that prevailing in European countries.

*Leaf roll.*—This is probably the most destructive virus disease of potatoes in India. It is known to be transmitted through several aphids but only *Myzus persicae* (Sulz.) and *M. pseudosolani* (Theob), are so far known to be the vectors under conditions of hills and plains of India. Being a persistent virus the insects retain their infective ability for a relatively long period, possibly throughout their whole life time. Apart from insects there are no other known methods of dissemination of this virus in nature. The main effect of the disease is the phloem necrosis which prevents the food material, assimilated in the leaves from being translocated into the tubers and consequently there is a high concentration of starch in the leaves causing the characteristic thickening and rolling of the leaves. The tubers remain small and yields are low. Different varieties react differently to this virus.

*Virus 'Y'*.—This is yet another virus which is widespread both in the hills and plains in India. Although several species of aphids are known to transmit the disease out knowledge so far has established only two species *M. persicae* (Sul.) and *Macrosiphum geie* (Kalt), as the vectors responsible for the transmission of the disease in nature. The effect of this virus varies greatly with different varieties. In some varieties (as is *Phulwa*, *Darjeeling Red Round* and *Uptodate\**) the virus causes a severe type of mottle.

*Virus 'A'*.—Like virus 'Y' it is also an insect transmitted disease. As to the insect responsible for the transmission of the disease in nature very little is known but under laboratory conditions *M. persicae* is an effective vector. By itself the virus causes very little loss but in combination with other viruses it causes crinkling and rugosity of the leaves, and great reduction in vigour with consequent effect on the yield. In combination with virus 'X' it causes severe "Crinkle Mosaic"; a disease widespread throughout the plains of India.

*Virus 'X'*.—An elusive virus practically saturating all the commercial stocks in the country. There is hardly any plant grown under commercial conditions which are free from this virus. By itself it causes usually only a mild, often imperceptible, on most varieties. However in combination with virus 'Y' it causes "Rugose Mosaic" of potatoes and in combination with virus 'A' the severe "Crinkle" disease. It is highly contagious and can be transmitted through contact. No insect vector is known to transmit the disease.

#### *Control Measure :*

Several control measures have been proposed and it will be useful here to assess the practical utility of the measures advocated with special reference to the problem of seed potatoes in the country.

1. *Sanitary methods*.—These methods presuppose that :

- (a) the stocks propagated are raised from seed known to be free from infection.
- (b) the percentage infection is so low as to make it worthwhile to carry out roguing operations in field conditions in particular locality.

The present situation in the plains of India is such that all the crops are infected with viruses thus rendering sanitary measures is out of question. Further, the annual incidence of the virus is so heavy as to make it uneconomic to periodically rogue out the disease plants. Sanitary measures are, no doubt, effective for conditions in the hill areas where crops are grown from disease-free seed stocks. To this a reference will be made later under Seed Certification.

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\*Up-to-date it appears as a Leaf-drop streak as first year's symptom,

2. *Curative treatments.*—These are methods where advantage can be taken of such treatments which may inactivate the virus without affecting the host. Two methods have been tried:

(a) *Chemotherapeutic treatments.*—Bud-wood from peach trees affected with X-disease could be cured by soaking in water solutions of Quinhydrone, Urea and Sodium thiosulphate (Stoddard, 1942). No such effective treatment have yet been devised in the case of potatoes.

(b) *Heat treatment.*—Experiments at Rothamsted have shown that potato tubers, with diameter up to 2 cm. could be freed from the leaf-roll virus by keeping them at 37°C in a moist atmosphere for periods of 10 to 20 days (Kassanis, 1949). Experiments carried out at the Central Potato Research Institute have shown that it is likely that the leaf-roll virus gets inactivated during storage under high temperature in the plains. This process of leaf-roll inactivation has been probably occurring in nature and has apparently largely contributed towards the popularity of the varieties like Phulwa. Detailed investigations are necessary to devise means of freeing different commercial varieties from leaf-roll.

3. *Immunity treatments.*—The fact that one strain of virus can protect the plant against another virulent strain of the same virus created hope that it may be possible to immunize the commercial varieties with a milder strains so as to protect them against more severe strains of the same virus. The position being somewhat similar in that of protective vaccination against virus diseases in animals. These methods, although apparently very promising, cannot be practised on a field scale for several reasons which are indicated below :

(i) Protective inoculation of commercial stocks with a mild strain would mean wide distribution of that particular strain of the virus. Such widespread distribution of a strains of virus may had to frequent mutation of newer strains and thus add up to the list of already a large number of viruses and their strains.

(ii) The reaction of a particular variety towards any strain of virus is unpredictable and depends upon hostparasitic relation. Thus a mild strain on one variety may be the cause of severe reaction on a different variety. With the large number of strains of any virus and large number of varieties needed for varying climatic and soil conditions of the country, the problem of virus disease would indeed become further complicated by such measures.

(iii) Protection of any variety with a mild strain of any virus could not be a safeguard against another virus. In fact, two compatible viruses would aggravate the disease rather than suppress it, as is the condition already indicated for virus X, A (crinkle) and X plus Y (Ruapse.)

Immunisation of plants against several of the virus diseases is also not feasible for the mild strains of two different viruses often produce severe reaction on the host plants.

The widely advocated idea of introducing tolerant varieties (often the carriers of several viruses) present similar practical difficulties.

To sum up, immunization against milder strains or introduction of virus tolerant varieties would be an unwise step and has to be discouraged at all stages.

4. *Breeding for resistance.*—Breeding of varieties resistant to infection or hypersensitive to virus infection offers a promising field to find a lasting solution to the problem of virus diseases. Studies have brought out the following facts:—

(a) There exists marked difference in the resistance and susceptibility of the varieties which make it possible to embark on selective breeding work.

(b) Many potato varieties are hypersensitive, i.e., at the point of entry of the virus the host tissue quickly dies off thus localizing the infection within a necrotic ring. Extensive work on this line has shown that genes for field immunity exist for viruses 'A', 'B', 'C', 'D', 'X' and more recently for virus 'Y' as well. Thus, the potato variety Craig's Defiance, is field immune to viruses 'A' 'B' 'C' 'D' and 'X'. Only one or two dominant genes have been found out to control the hypersensitive reaction in most of the viruses thus making it easy to transmit the characters in the progenies.

(c) Certain varieties; like U.S.D. Seedling 41956 have been found to be immune to virus 'X' and this character is also transmissible.

Work on the above lines carried out at the Central Potato Research Institute, made it possible to pursue a planned breeding work. Suitable parents have been found which are either hypersensitive or immune to viruses and a large progenies of different crosses are under study for viruses 'X', 'Y' and 'A'.

The problem of breeding for leaf-roll resistance presents some practical difficulties, as no commercial variety has been found to possess the genes of immunity or hypersensitivity. This aspect of work needs intensive investigations, as intergeneric hybridization with the wild species of solanum, some of which are likely to possess genes for resistance to leaf roll.

5. *Control of insect vectors causing virus disease.*—Three of the four viruses mentioned in the text are transmitted through insects. If, therefore, the vector of three viruses viz., leaf-roll, and viruses 'X' and 'Y' could be controlled, virus 'X' by itself may not present much concern.

Extensive studies showed that fumigating potatoes with nicotine successfully destroyed the aphid infestation but was without effect on the spread of leaf-roll and Rugose Mosaic (Doncester and Gregory, 1948). On the other hand it is also reported that potato plots treated with D.D.T. and various other substances that effectively checked aphid infestation, contracted more leaf-roll than unsprayed plots. It seems, therefore, possible under certain climatic conditions, control of aphid vectors may offer a fair solution to the problem of virus vectors, particularly when more effective and systemic insecticides



are being rapidly thrown into market. Much more informations and studies are, therefore, needed on this aspect, particularly under conditions in India.

6. *Seed Certification*.—Work carried out in Wales showed that *M. persicae* (i) cannot fly readily when the temperature is below 18°C, (ii) the wind speed is more than 8 miles per hour, (iii) the relative humidity is above 70% and (iv) in the absence of sunshine (Davies, 1935 and 1936). Such conditions which do not favour migration or survival of the aphids exist in the cooler parts of Scotland. In India, there are large areas in the hill regions of northern India (Pushkarnath, 1952) and possibly also in the Nilgiris hills of the south where such conditions prevail. It is, therefore, not only possible but most profitable to develop these regions exclusively for production of disease free seeds for the virus-infected plains of India. Already a beginning has been made in Himachal Pradesh where a well organised system of seed certification on a scientific foundation has been established (Pushkarnath, 1952). There is, therefore, urgent need of introducing similar certification in other hill regions. In selecting the areas consideration has to be given to :

- (a) suitability of regions demarcating for production of disease-free seed potatoes and
- (b) varieties to be grown in the regions. Such varieties must not only be useful in the region where produced but for the regions where they will be used for seed.

With the developing economy of the country and larger areas coming under irrigation, the pattern of crop cultivation is bound to change. Greater emphasis would, be, in course of time, laid on crops like potatoes in regions particularly in areas where it has not been hitherto possible to grow potatoes for want of irrigation. The Conference may consider the connected problems.

700 thousand acres at present under potatoes require about 10 million maunds of seed. The expected 2.5 million maunds of disease-free foundation stocks from the hill regions would be enough to meet only about 20 to 25% requirements of the plains of India. Further, for reasons of dormancy, it is not always possible to use hill potatoes in the plains. It, therefore, follows that plains are also to play important role in production of disease-free seed potatoes. As to what steps are necessary and precautions needed for production of seed potatoes under conditions in this country this Conference may give a lead.

Some works done at the Central Potato Research Institute has indicated that there are bright possibilities of maintaining the health standard of the stocks for one or two years under certain conditions in the plains. The conditions which contribute towards successful production of disease-free seed potatoes in the hills being :—

- (a) The crop should be sown at a period when the incidence of virus is very low.

Under high temperature conditions in South Africa, disease-free seed potatoes are successfully produced, (VanDer Plank, 1944). This type of work can also be carried out in selected areas of the plains

of India. Already there are indications that crops raised in the earlier part of winter before Mid-January are relatively much free from diseases than those raised in the later part of the season. This is due to the fact that incidence of aphids upto mid-January is either nil or very low. The aphid population rapidly increases after mid-January.

(b) Considerable quantities of seed potatoes are stored in the cold storage of which there are a large number particularly in the Eastern States. These stocks are secured from March-April harvest of the plains. Date has indicated as already mentioned under (a) above that stocks are usually highly saturated with virus disease rendering the stocks mostly unsuitable for seed purposes.

The data at present available seem to indicate that the existing practice of storing the potatoes from the late March-April harvest in the present seed producing areas of the plains of India is not a sound one. The preliminary observations need most extensive study with a view to secure fuller data which may help in building up a seed potato industry and thus ensure reasonable standards of health of the seed stocks stored in the cold storage

#### REFERENCES :

1. Bawden; F. C. 1950, Plant viruses and virus diseases, Chromica Botanical Company, Waltham, U.S.A.
2. Bromson, T. E. Smith, F. F. Shands, W. A. and Simpson, G. W., 1946, Maine Agriculture Experiment Station, Bull., 442.
3. Davies, W. M. 1953, Sci. Proc. Roy., Dublin Series, 23, 106.
4. Davies, W. M. 1936, Sci. Proc. Roy., Dublin Series, 23, 401.
5. Doncaster, J. P. and Gregory, P. H., 1948, Agri. Res. Coun. Rept. Ser No. 7.
6. Holmes, F. O., 1939, Handbook of Phytopathogenic viruses, Burgess, Minneapolis.
7. Kassanis, B., 1949, Nature, 164, 881.
8. Pal, B. P., 1938, Agri. & Live—Stk., India, 8, 388-96.
9. Pal, B. P. and Pushkarnath, 1951, Ind. Coun. Agri. Res. Bull. No. 62.
10. Plank, J. E. Van Der, 1944, Nature, 153, 589.
11. Pushkarnath, 1952, Ind. Farm., No. 9, 1-5.
12. Stoddard, E. M., 1942, Phytopath., 32, 17.
13. Vasudeva, R. S. and Lal, T.B., 1945, Ind. Jour. Agri. Sci., 15, 240-42.
14. Vasudeva, R. S. and Lal, T.B., 1946, Ind. Jour. Agri. Sci. 16, 288-95.
15. Vasudeva, R. S., 1946, Ind. Farm., 7(4), 170.
16. Vasudeva, R. S. and Gupta, D. 1946, Ind. Jour. Agri. Sci. 16, 469-70.
17. Vasudeva R. S. and Ramamurthy, C S., 1946, Ind. Jour. Agri. Sci., 16, 206-8.

PAPERS ON SUBJECT NO. 9

*Exploitation of Hybrid vigour in improvement of crop plants with special reference to the Coconut*

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The term "Heterosis" is a contraction of the phrase "Stimulus of heterozygosis". In the strict sense of the term, it indicates the vigour manifest in the hybrids between two inbred or homozygous strains or varieties as compared with either parental line. This phenomenon has also frequently been described as a special instance of general principles involved in in-breeding and out-breeding. The decrease in vigour observed on in-breeding naturally cross fertilized species and increase in vigour in crossing naturally self fertilized species formed manifestations of this phenomenon. Although in the orthodox sense of the term, it conveyed the above meaning, in a wider and general sense it is designated to the vigour observed in certain hybrids whether produced artificially or naturally.

Hybrid vigour in breeding programmes is manifest in several distinct forms, *viz.*, increased plant height and size, thickness of the stem, leaf size, root system, rate of growth, winter hardiness, drought resistance, weight of fruit, yield per acre, etc., some of which are of great economic importance. Utilisation of this principle of hybrid vigour in crop improvement work, therefore, gained considerable importance in recent years since its maximum effects were always evident in the generation immediately following the cross. In succeeding generations there is a fall in vigour. It is for this reason that it is considered necessary in plants raised from seed, to repeat the parental cross for raising seed necessary for each crop if maximum vigour is to be maintained.

Utilisation of this phenomenon in the field of Horticulture and plantation crops in the past had been largely a matter of chance although it had frequently been used with advantage in spite of ignorance or misconception as to the cause of increased size and vigour in hybrids. The phenomenon has frequently been observed in the progenies of cross pollinated plants perpetuated through seed. It is however in the improvement of fruit and flower plants, that this phenomenon has been utilized to a significant degree owing to the ease with which these hybrids of the first generation when once produced could be perpetuated, without detriment to vigour, through asexual methods of propagation. In perennial plants like the coconut wherein cross pollination is the rule and propagation by seed is the only possibility, chances of evolution of a pure line is rather remote due to the difficulties involved, *viz.*, unusually long time required for the plants to each bearing stage, the large space required to test the progenies, etc. The utilization of this phenomenon in the scheme of improvement of this crop, therefore, appears to be worth pursuing.

Recent discovery of vigour noticed in hybrids of certain parental combinations in the coconut by Patel (3) opened up, however, a bright prospect of utilisation of this phenomenon in the improvement of this crop. These observations made early in the history of research or breeding in the coconut have since been confirmed by

later workers notably John and Narayanā (1), Rao and Koyamu (4) and others (2). They have observed maximum vigour in the hybrids, of the cross between two different varieties of coconut *viz.*, between Tall (mother) and Dwarf (father). Although the hybrid vigour had been noticeable in the cross between Tall × Dwarf varieties, Patel (3) however, cautioned that without exactly knowing the further performance of these progenies there was larger in recommending large scale planting of this material. However the subsequent performance of some of the hybrids has confirmed the earlier expectations of them.

Studies undertaken on the Tall × Dwarf hybrid seedlings in the nursery revealed that these were significantly superior to either of the parents in respect of the girth at the collar and height of the seedlings which at the present level of knowledge of the palm indicated the vigour and assured prolific performance in future plantation life. In addition to these, seedlings also proved superior to those of the tall parent in a variety of other useful characters, *viz.*, early splitting of leaves, possession of larger number of roots, etc. Besides possessing vigour they also came to bearing early and produced good quality copra, etc. Further studies carried out on the seedlings of the second generation of plants obtained from nuts collected from these hybrid trees also showed that splitting for parental characters although took place they could easily be discovered because the dwarf splits could be identified by their very early germination and the characteristic delicate and thin leaflets while the tall splits were conspicuous by their late germination and late splitting of leaves.

Although hybrid vigour was noticed in the coconut, its profitable utilisation in the breeding programme is beset with considerable difficulty owing to the long life of the palm and the requirement of large space necessary for raising and testing the progenies. In addition, as parents used for cross are heterozygous types similar performance from all combinations cannot be expected. In fact among a number of Tall × Dwarf crosses made and tested on a field scale the hybrids of only certain combinations appeared to be definitely superior. Evolution of homozygous parents for use in cross is a work of generations and is not of much significance. The only possibility is to spot out compatible combinations among crosses by large scale progeny tests in the field and use only these for the production of hybrids. This is a long term programme of research with only limited possibilities for the present.

If any uniform and beneficial results are to be aimed at from the hybrids attempts at evolution of homozygous types or varieties of the coconuts should precede the approved programme of hybridisation. This, therefore, involves a time taking process requiring a number of generations of selfing of desired parents to obtain homozygous types and crossing between them to spot out compatible combinations. This essential requirement in breeding suitable hybrids in the coconut makes the proposition most unattractive. There is, however, one beneficial feature which is absent in other annual crops, *viz.*, once the homozygous types useful in breeding are evolved they could easily be maintained for a long period owing to the long plantation life of this crop. The number of planting material that can be obtained from each cross will be very limited.

Under the difficult problems posed by the palm, the only feasible way open to the breeder in this crop appears to be to modify the breeding programme suitably in the light of experience gained and thus secure planting material approximating to the genuine hybrid material. This appears best accomplished by raising compatible hybrid seed material from only such combinations which have proved of sufficient merit and raise selected seedlings of this material after rouging out the Tall and the Dwarf splits in the manner already explained. This appears, therefore, to be the best method of improving the quality of planting material under the existing set of conditions prevailing. This is now being followed in respect of production and supply of hybrid seedlings at the Central Coconut Research Station, Kasaragod.

REFERENCES :

1. John, C. M. and Venkatanarayana, G. (1943). Note on the improvement of the Coconut by cross breeding. Madras Agricultural Journal. 31:pp. 75-77.
2. Liyanage, D. V. (1955). Planting material for coconuts. Rep. Coco. Conf. Lunuwila, Ceylon. pp. 11-17.
3. Patel, J. S. (1937) Coconut Breeding—Proc. Assoc. Econ. Bio. 5: 1-16.
4. Rao, M. B. S. and Koyamu, K. (1952) Hybrid Vigour in Coconut Seedlings. Ind. Coc., Jour. Vol. VI. No. 1 Oct. Dec. pp. 41-44.

*Exploitation of Hybrid Vigour in the improvement of crop plants  
Fruit and Vegetables.*

by

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The importance of exploitation of hybrid vigour has been amply demonstrated in vegetables both by workers abroad as well as in the country. Kakizaki of Japan has demonstrated that the progenies of inter-varietal crosses when compared with the selfed progenies of the parents generally yielded more than the parents, the percentage increase ranging from 40 per cent to 140 per cent. Similar results were obtained by workers in this State with both bhendi and brinjal. In brinjal, hybrid progenies yielded 17 per cent more yield over the better parent and 24 per cent over the poorer parent. In bhendi, at Coimbatore it was found crosses between varieties produced progenies with outstanding yield performance yielding upto 162 per cent. more than the parents. Hybrid vigour may therefore, be considered to offer a satisfactory method of improvement in vegetables.

Hybridisation has now been recognised as an important item in all horticultural investigations. Special attention has been paid to this work in the recent years in Madras State. Inter-varietal, and inter-specific crosses have been effected on some of our major fruit crops such as mango, citrus, sapota, banana and annonaceous fruits.

Similar work has also been in progress on important vegetable crops. While in the latter recent results have confirmed the efficacy of crossing to obtain hybrid vigour, no work on this aspect appears to have been done on fruits. The progenies that have recently been put under study in the various fruits mentioned earlier provide useful material for purpose of study of this phenomenon.

In any programme for improvement of fruits and vegetables in the country, extended application of the method would help to unravel many of the attributes that have so far gone unnoticed. This would also lessen to some extent the need for dependence on Nature's bounties to improve our crop wealth. Crossing of races and species of plants of distant habitat should form an important line of work because seedlings from such crosses always reveal the greatest number of different economic characters out of which it will not be difficult to choose the best to suit our ends.

The phenomenal success with hybrid maize in America is an eye opener to those engaged in the field of vegetable research. There appears to be a programme as is evidenced by recent reports, for large scale distribution of hybrid maize to Indian farmers through the agency of the Central Government. The success obtained in vegetable crops such as brinjal and bhendi in exploitation of hybrid vigour is so striking as to warrant similar attention on the part of the Government. Production and distribution of hybrid seeds from suitable centres may therefore, be a subject that may well merit the attention of the State agencies. The method could perhaps be simplified if recourse is had to growing two pure lines of such vegetables as may lend themselves for exploitation of hybrid vigour, side by side in nucleus plots away from all possible contamination, collecting their seeds and distributing them for extended cultivation, with of course, the precaution that the seeds of these hybrid progenies should not be used for raising the next crop.

*Exploitation of hybrid vigour in improvement of crop plants, fruits and vegetables*

by

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Of the various methods of crop improvement by plant breeding techniques in vogue, the utilisation of the heterosis exhibited by the first generation when two unrelated varieties are crossed, has attracted considerable attention in recent years in foreign countries and in India as well. Some idea of the rapid strides made by the United States of America in the exploitation of this phenomenon in the maize crop, will be obtained from the statement that in 1933, 0.1% of the total corn acreage was under hybrid corn, whereas in 1945, it had reached 97%. In 1948, the area under this crop was less by 21% than the area in 1933, but the total production in 1948 was nearly 42% more than in 1933.

Hybrid vigour is exhibited in various attributes by several crops, vegetables, fruits and even forest trees. Geneticists have attempted to explain the reasons underlying the expression of heterosis and

several hypotheses have been suggested from time to time. The theoretical aspects of heterosis provide material for several scientific papers and are often discussed at conferences, e.g., the discussion on hybrid vigour held under the leadership of Mather (1955). Several review articles, bulletins and books are also published on the subject e.g., the recent one of Gowen (1952). However, this is not the place to go into the theory of hybrid vigour and hence, the rest of the note will be confined to a brief description of the work done in Bombay State in Maize, Bajri and Cotton and the possibilities of its extension to other crops.

**Maize.**—This crop is grown chiefly in two regions of the Bombay State i.e., the Panchmahals and Belgaum, over an area of 1,27,000 and 18,000 acres respectively. As it forms a staple food of the farmers cultivating it, the agricultural department has been trying to evolve new strains and exploit the hybrid vigour by suitable methods. Our efforts in the later field have been crowned with some success at Arbhavi in the Belgaum district and hence deserve special mention.

The breeding of maize for earliness combined with high yield was initiated at Arbhavi in 1935. Systematic study of desirable plants from the local material and from foreign countries and the continuance of their progenies by artificial self pollination resulted in 16 inbred lines from local material and four inbreds lines in foreign types. These were tested for their combining ability and it was observed that two hybrids I-5 × S-23 and L-5 × S-23 gave consistently higher grain yield than local by more than 20% in the trials at the farm as well as in the district. It may be mentioned that I-5 and L-5 have been obtained from indigenous varieties whereas S-23 originated from a variety called Sahara obtained from Africa.

It is now proposed to produce hybrid seed as rapidly as possible so as to cover at least 2,000 acres in the area served by the Gokak Canal. The Indian Council of Agricultural Research have agreed to finance this project for three years in the first instance. It may be mentioned that this is the first Scheme for the production and distribution of hybrid maize from indigenous inbred lines launched in India. It has been decided to use the three-way hybrid: (I-5 × L-5) × S-23, which is as good as any of the single hybrids, so that more stages of multiplication could be accomplished without losing the hybrid vigour obtained in the first generation of the cross. It has been calculated that 15 acres will be required for producing hybrid seed to cover an area of 1,000 acres with the three-way hybrid, whereas 19 acres are required to cover the same area with a single hybrid. There is no doubt that this scheme will give us considerable experience and data for the formulation of similar hybrid maize schemes in other part of the country.

Several problems of an administrative nature involved in the production of hybrid seed are likely to be encountered. For example, will it always be necessary for Government to handle all stages of commercial hybrid seed production, or can the later stages be entrusted to a co-operative organization of progressive cultivators with some guidance and help in the beginning? These and other problems will have to be solved, if the farmers of our country are to receive the full benefits of the findings of our plant breeders.

*Bajri Pennisetum typhoides*, Stapf and Hubb.—In Bombay State, *Bajri* occupies the second largest area amongst cereals, the total reaching nearly six million acres. Of this more than three million acres are in the Deccan districts especially Ahmednagar, Nasik and Poona. *Bajri* is essentially a kharif crop of the precarious rain-fall regions and a staple food of the large population inhabiting these famine-prone localities. Therefore any improvement in the productive capacity of this crop is bound to benefit a substantial portion of the poorer inhabitants of this State.

Botanical improvement carried out at Niphad (Nasik district) since 1931 have resulted in the isolation of three high yielding strains *viz.*, 28-15-1, AF-3 and L.M. 38-39. From 1942 onwards, various inbreds from local varieties and types from outside, were crossed with a view to find out the combinations exhibiting maximum heterosis. As reported by Chavan, Patil and Chaudhari (1955) the cross between 28-15-1 and AF-3 has proved its superiority over all combinations tried and has been selected for covering the area under *Bajri* in Nasik district which is approximately 1,00,000 acres. It may be mentioned that 28-15-1 is a selection from local material whereas AF-3 is a synthetic strain obtained by crossing an African variety with a local culture. Both these types yield about 10% more than the local seed in Nasik district, while the hybrid of these two gives more than 40% increase in yield. Different methods of producing hybrids seed on a large scale were tried and it was observed that mixing the seed of the two parents in equal proportion and sowing a little closer than usual was the most practicable. It is well known that in *Bajri*, flowering proceeds from top to bottom of the spik in regular sequence and, due to protogyny, there is an interval of 2 to 3 days between the emergence of the stigma and the anthers of a flower. As a result, 75 to 80% of the flowers are cross pollinated in nature.

A project for the multiplication and distribution of hybrid *Bajri* seed financed by the Indian Council of Agricultural Research is now in operation in the Bombay State. It has been estimated that an increased production of about one Bengal Maund per acre will be obtained by the grower due to the use of hybrid seed and on an area of seven lakhs of acres, the additional production will be worth about 70 lakhs of rupees every year for Nasik district alone.

*Cotton*.—As early as 1920 Kottur suggested the possibility of producing long staple cotton by crossing Gadag-L (*G. hirsutum*) with Sea Island (*G. barbadense*). Kulkarni and Khadiolkar (1929) reported that F<sub>1</sub> hybrid population had a fibre length of 38 mm. as against 21 mm. of Gadag-1 and 40 mm. of Sea-Island. Recently, Patel and Patel (1952) have published the results of experiments which indicate the possibility of successfully and profitably growing cotton possessing extra long (1-20"), fine (fibre weight 0.1106 oz.), strong (spinning value 70s H.S.W.C.) and silky fibre from hybrid seed of American (*G. hirsutum*) × Sea Island (*G. barbadense*) varieties. The Co2 variety was used as the female parent and Sea Island (Montserrat) as a male parent. According to them, one boy can emasculate and crosspollinate about 100 flowers a day which will give about 25 bolls or 300 seeds—about 10 days work was necessary for producing hybrid seed enough to plant one acre and the total cost



came to about Rs. 20 per acre. Thakar and Seth (1955), giving further details, have stated that the expenditure on account of the crossing, use of paper bags, threads, picking, ginning etc., excluding cultivation charges comes to about Rs. 21 per pound of hybrid seed. Further, it must be borne in mind that the production of hybrid seed will have to be done under perfect technical control. Under these circumstances, the growing of hybrid cotton seems practicable only in Gujarat where the distances between plants in the row and within the row are very wide (6 to 10 feet). Moreover, it appears that the production and distribution of hybrid seeds of cotton is beset with several difficulties at each and every stage and though they are not insurmountable, it is doubtful whether the cultivation of hybrid cotton will be taken up on a large scale in any part of the country in the near future.

*Jowar (Sorghum vulgare. Pers).*—Attempts to devise practical methods for producing hybrid sorghum seed in quantity have been in progress at the Texas Agricultural Experimental Station since Stephens (1937) discovered a genetic male-sterile plant in Texas Black-hull Kaffir. Recently, Stephens and Holland (1954) have isolated a type showing cytoplasmic male sterility and it is stated that this will make the production of hybrid seed much cheaper because the hand labour required in using the nuclear gene male-steriles would be completely eliminated. In India, genetic male-steriles have been reported by Ayyangar and Ponnaiya (1936) and by Kajjari and Chavan (1953). Further, the seed of cytoplasmic male-steriles have also been imported from United States of America through the courtesy of J. C. Stephens and a programme of transferring this character by repeated back crosses to our varieties is being planned. Very recently, Chavan, *et al* (1956) have obtained data showing considerable hybrid vigour in certain intervarietal crosses. In view of the fact that Bombay State has an area of more than 9 million acres under this crop, any success achieved in evolving a method of utilising heterosis would have a remarkable effect in increasing the production and yields of this important crop.

*Tobacco.*—Tobacco is a crop which affords favourable conditions for the production of cheap F<sub>1</sub> hybrid seed. Thousands of seeds are produced by one flower; hybridization is a simple matter; the seeds retain their viability for more than 10 years; and the plants are widely spaced in cultivation. Literature contains several references to the heterosis by F<sub>1</sub> between different varieties. In Bombay State, crosses between Nipani and Gujarat strains showed very good combining ability and deserve to be exploited for the production of good quality *bidi* tobacco.

*Tomato.*—Tomato is another crop which has advantages similar to Tobacco for exploiting hybrid vigour. In fact, already there are several F<sub>1</sub> hybrids available commercially in United States of America and other Western countries. In Bombay State, several crosses were effected during 1945 to 1947 at the Agricultural College farm under the Vegetable Breeding Scheme between Farm selected Bonny Best and other varieties received from America and Indian Council of Agricultural Research Selections. These preliminary studies have indicated that certain hybrids give considerably higher yields than others. In the F<sub>1</sub> characters like size of fruit, quality and

productivity surpassed both the parents in respect of one or more attributes. The increase in yield ranged from 15-25%. In F-2, some combinations lost their hybrid vigour more than others. It was concluded that it would be necessary to test larger number of combinations in order to establish the most profitable crosses.

*Sugarcane*.—The commercial exploitation of heterosis in vegetatively propagated plants is a simple process. The Sugarcane variety Co-419 which has covered practically the whole area (approximately 1,63,000 acres) in Bombay State, may be cited as a classical example. This is a hybrid between P.O.J. 2878, the wonder cane of Java, and the medium cane Co-290 which has found considerable use both in India and in foreign lands. It has the desired habit and ratooning capacity and gives heavy yields of cane (60-70 tons per acre) and *gur* of superior quality.

*Horticultural Crops*.—Vegetative propagation of suitable hybrids can also be practised in the case of fruits and it is suspected that a number of our famous varieties are natural hybrids. It is, therefore, worth mentioning that about 1920 a cross was made with *Anona squamosa*, L. as the female and *A. Cherimoya*, L. as the male parent at the Ganeshkhind Fruit Experiment Station, Kirkee. Six trees were obtained and are still alive. The growth habit, leaf size and shape as well as the fruit of these trees showed considerable variation. However, one of them flowers normally, the size of the fruit is bigger than either parent in weight, better in quality and total yield also. It is learnt that steps are now being taken to propagate the tree vegetatively for supply to interested parties.

*Conclusion*.—The possibilities of utilising hybrid vigour in increasing the production of our crops, vegetables and fruits are immense. The foregoing notes have set out what has been achieved and what is planned in the case of a few crops in Bombay State. Examples of the nature could be enumerated *ad lib*, however, it will be realized that there is plenty to be done before the findings of the laboratory and the research station reach the actual growers of crops, vegetables and fruits in the form of hybrid seed. For example, greater efforts should be made to search for and introduce male sterility in many of the crops propagated by seed e.g., Maize *Bajri*, *Jowar*, *Tomato*, *Chillies* *Onion*, *Pumpkins* and *Cucumbers*. It is hoped that a discussion of the subject will act as a stimulus for greater efforts in evolving suitable methods of producing hybrid seed in large quantities and in solving ancillary problems like agencies of production and distribution, educating cultivators not to use the seed grown by them etc.

#### REFERENCES:

1. Chavan, V. M. Argikar, G. P. *et al* (1956):  
Unpublished.
2. Chavan, V. M. Patil, J. A., and Chaudhari, B. H. (1955):  
Poona Agric. Coll. Mag. 46:1948.
3. Gowen, J. W. (1952):  
Heterosis. Iowa State College Press.

4. Kajjari, N. B. and Chavan, V. M. (1953):  
Ind J. Gen. and Pl. Brd. 13 : 48.
5. Kulkarani, R. K. and Khadilkar, T. R. (1929):  
Agric. Res. Inst. Pusa—Bulletin No. 189.
6. Mather, K. (1955) :  
Proc. Roy Soc. B 144 : 143.
7. Patel, G. B. and Patel, C. T. (1952):  
Ind. Cott. Grow. Rev. 6:205.
8. Rangaswami Ayyangar, G. M. and Ponnaiya, B.W.X. (1937):  
Curr. Sci. 5:390.
9. Stephens, J. C. (1937):  
J. Amer. Soc. Agron: 29: 690:
10. Stephens, J. C. and Holland, R. F. (1954):  
Agron. J. 46: 20:
11. Thakar, B. J. and Seth, D. S. (1955):  
Paper read at the 6th Conference on Cotton Growing problems. Bombay.

*Exploitation of Hybrid Vigour in Bajra in the Madras State*

by.

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Crop improvement of Pearl Millet (Bajra) by the utilisation of hybrid vigour in the Madras State has been discussed. Being protogynous in nature this crop is essentially cross pollinated. Although this is a defect for crop improvement by the usual crop breeding method, it was found to be very helpful in the practical exploitation of hybrid vigour.

Taking advantage of a scheme partly financed by the Indian Council of Agricultural Research, investigations on the possibilities of harnessing hybrid vigour in Bajra was taken up in Madras in the year 1946. Preliminary studies revealed that close inbreeding reduced the vigour of plants as in the case of Maize and that the inbreds when combined manifested hybrid vigour in varying degrees depending upon the parents involved in the cross. Besides, it was also found that inbreeding upto the third generation was sufficient to make the types reveal their combining ability. Raising a crop sown with seeds of parents (inbred upto five generations) mixed in equal proportions was found to an efficient practical method of commercial production of hybrid seed in Bajra.

As a result of these investigations, two medium duration hybrids producing 20 to 30% higher yield of grain over the local types have been evolved and are under general distribution. Four hybrids of short duration capable of being grown under irrigation as well as under rainfed conditions have also been fixed and are now in trials

in cultivators' holdings. Since the yields of hybrids go down in succeeding generations work has been taken up to evolve synthetic varieties (having six or more combiners) as in maize so that the seeds can be used for a period of three to four years without the need for replacement. A world collection of germ plasm is also being made to exploit hybrid vigour to the maximum in this crop.

*Exploitation of Hybrid Vigour in Improvement of Crop  
Plants, Fruits and Vegetables.*

by

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The heterosis concept as defined by Shull is the interpretation of increased vigour, size fruitfulness, spread of development, resistance to diseases and insect pests or to climatic rigors of any kind manifested by crossbred organisms as compared with corresponding inbreds, as the specific results of unlikeness in the Constitution of the uniting parental garments. The action is more like that of complementary factors but much more diffuse. Shull attributes vigour to the effect of a change in nucleus and a relatively unaltered cytoplasm, upon each other. Not all types of combinations will give hybrid vigour while on the other hand, crossing of two apparently low vigour plants may give high heterosis.

Heterosis in improvement of forage crops, horticultural crops like annual ornamentals, vegetatively propagated plants and also in livestock have been successfully worked out.

Hybrid vigour (Heterosis) was first scientifically studied in Maize Plant which is naturally cross fertilised. In the improvement of Maize, East, Manglesdorf and other workers experimented with the inbreeding of this heterozygous plant. A number of genetic lines were separated and further inbreeding was continued. During this process, a large number of plants with defective qualities were thrown out but a few with fair amount of homozygosity and good cob formation were also obtained. Such inbred homozygous plants when they were intercrossed the hybrid plants showed a phenomenal recovery in vigour size, productivity of cobs etc. Sometimes exceeding the parents. This was confirmed on further trials and on other lines and special care was taken in selection of inbred plants to form the parents for a cross. Further complex methods of crosses were devised aimed at increase of the cob and grain size, vigour of the plant etc. Most of the hybrid maize strains used for commercial purposes are the result of bringing together four inbred strains by three separate crossings and the resultant yield was sometimes 200 percent in comparison with the parents. This classical work led to its recognition of the possibilities of exploiting hybrid vigour in other crops also especially in plants which are naturally cross fertilized viz., vegetables like Brinjal, tomato and cucumber, sugar beet, cumbu, coconut etc.

Among cereals Ramiah working on Rice (self-fertilised crop) out of 26 sets of crosses and several hybrids studied, hybrid vigour was manifested in six cases for flowering duration, in seven cases for number of years and four for height of plants. In Sorghum, Karper

and Quinby obtained, in most favourable crosses an increase in the yield of grain approximating to two and a half times that of the higher producing parent. Ganesan in Cotton found hybrids with significantly higher weight of embryo and seed than the parents.

Stewart, in Sugar Beet found that in one case the root yield of the hybrid was more than double that of either parental strain. Kakizaki in Brinjals found that plants in  $F_1$  generation exceeded in yield the better yielding parent by 17% on an average and the highest yielded 140% more than the better yielding one. Wellington in similar experiments in tomato reported increased yield in all cases. In Cucumber an increase in yield of over 30% has been reported in crosses between different varieties.

As hybrid vigour is maximum in the heterozygous generation, in plants propagated by Seed, the parental crosses have to be repeated in each generation for its maintenance. Where a-sexual propagation can be practiced as in Fruits and Vegetables, hybrid vigour can be maintained for long.

Many of the asexually propagated horticultural plants like potatoes, apples, pears, strawberries and raspberries have been selected for vigour of growth, high yield etc. which are, to a large extent the result of heterosis. Hence in this field of horticulture, scope of exploitation of hybrid vigour is ample.

The methods utilised for the exploitation of heterosis in self and cross fertilised plants differ. In self fertilised plants it may consist in utilisation of parental varieties which produce best combinations of character. The methods in case of cross pollinated ones like Maize are well known. In the case of cross fertilised perennial crops, emphasis has to be laid on the selection of desirable clones. These are evaluated by the polycross method and the clones with best combining ability selected. These may either be combined into  $F_1$  crosses or to produce a synthetic variety. The latter may be highly useful in cases of perennial forage crops and other plants which can be vegetatively multiplied. The synthetic varieties have been in some cases found to give high combining ability in even in the second synthesis.

Thus it is very desirable to exploit the effect of heterosis in all crops irrespective of their being self or cross fertilised as these hybrids very often give good returns in impoverished soils and in the words of Shull "may heterosis take the place of manures of commercial fertilisers".

### *Exploitation of Hybrid Vigour in Vegetable Crops*

by

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It has been commonly observed that heterozygosity is very often accompanied by increased vigour, and that the seedlings of the  $F_1$  generation are more vigorous than their parents. This phenomenon of hybrid vigour is believed to be the result of coming together of the greatest number of favourable growth factors.

The results of the studies in various parts of the world have shown the possible advantages of utilizing the  $F_1$  generation of hybrids, and there is an increasing interest in the production of hybrid seed of some of the vegetable crops. The different degrees of vigours obtained represent the differences in the number of dominant genes favourable to growth. Kakizaki, working with brinjal, found that "the plants in the  $F_1$  generation exceeded in yield the better yielding parent by 17% on the average. Crosses between widely different varieties usually gave a greater degree of hybrid vigour than crosses between less diverse varieties, and most of the crosses exhibiting significant increases in yield were between varieties which differed widely from each other in their characters. The cross which gave the highest increase yielded 140.8% more than the better yielding parent". In tomato, increase of 18% to 97% in yield in  $F_1$  hybrids have been observed. But the greatest benefit from  $F_1$  hybrid in some countries has been derived when resistance to diseases has been combined with heavy yielding ability. In the  $F_1$  of crosses between certain varieties of cucumbers and increase in yield of over 30% has been reported. In onion one hybrid was more than three times heavier than either parent. Other hybrids were outstanding in shape, size, uniformity, and time of maturity.

Thus it seems highly probable that the increase in yield, resistance to disease, vitamin and mineral contents, etc., which are associated with hybrid vigour, could be successfully utilized in a number of vegetable crops. But, since hybrid vigour is at a maximum in  $F_1$ , the cost of producing such seed by artificial pollination may in some cases be unprofitable. Where the sexes are borne on different plants or on different flowers, as is seen in most of the cucurbits, crossed seeds can easily be obtained. Or, in crops like tomato, brinjal, capsicum, etc., where each pollination can give numerous seeds, the production of crossed seed can be practiced commercially, as any increase in yield would repay the extra cost involved in producing the  $F_1$  hybrid seed. Within recent times, however, the making of crosses has been greatly simplified in some vegetable crops, like onion and tomato, due to the use of male-sterile types.

It is, therefore, suggested that co-ordinated Schemes, on the lines of hybrid maize schemes, may be started for a period of 5 years in the first instance, with a view to gathering information on heterosis and dominance of the more important economic characters, study of suitable combinations possessing distinct benefits over commercial varieties of vegetable crops, use of male-sterile types already available in other countries and exploiting the possibility of the use with leading commercial varieties of this country, search for new male sterile types in the indigenous material and their use in the production of hybrid seed.

*Exploitation of hybrid vigour in the improvement of crop plants  
fruits and vegetables*

by

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In the context of the objective of a 40% increase in agricultural production within the next five years, set before us by the National Development Council, it is imperative that attempts should be made

to exploit all possible methods of increasing agricultural production. Exploitation of heterosis or the vigour which often results from crossing two unrelated varieties or strains needs special attention in this connection as a quick, cheap and easy method of attaining part of this objective.

1. *Hybrid Maize in India.*—Hybrid vigour has been exploited since a long time, though unconsciously, in asexually propagated plants; it is in maize, however, that planned, purposeful use of this phenomenon has been successful. The story of the development of hybrid maize in the U.S.A., where practically the whole vast corn-acreage is now cropped to hybrids is too well known to need more than a mention here. In India, too, with 9 million acres under maize, work, sponsored by the I.C.A.R. in the last decade and half, in some of the states and at the Indian Agricultural Research Institute has resulted in a number of promising hybrids. Thus, four double crosses have been tested and released for distribution in the Punjab while in Bombay a three-way cross has been found high yielding and is presently under multiplication. At the Indian Agricultural Research Institute some 50 or so very desirable inbreds have been isolated and they have been put into appropriate single and double-crosses of which 5 or 6 are extremely promising. As a short-term programme, extensive trials at a large number of locations of some standard double crosses imported from America have shown that some of these like N.C. 27, Tex. 26, U.S. 13, Dixie 11 and 22 etc. can be utilized in certain locations. Further, the inbreds going into these double crosses have been obtained with the kind co-operation of the USDA; it has proved possible to maintain some of these inbreds and synthesis in India the double crosses. N.C. 27, Texas 26 and U.S. 13, thus obviating the necessity of importing these seeds year after year resulting in a considerable saving of our foreign exchange resources. In addition, work of a fundamental nature has also been taken up here, such as studies on the relative efficiency of selfing and sibbing in inbred production, utilization of genetic markers to isolate spontaneous monoploids and induce monoploids through apomixis, induction of chromosome doubling in such lines to obtain homozygous lines at one step etc.

2. *Hybrid vigour in self-pollinated crops.*—Optimistic attempts to extend this method to other crops have, however, run into a number of practical difficulties, especially in the economic production of hybrid seed. The separation of the sexes and the coherence of female flowers, resulting in a large number of seeds per pollination, are two ideal characters for hybrid seed production, present in maize, but absent in most other crops. Since maximum vigour is shown in the  $F_1$ , in crops raised from seed, a continuous supply of planting material can be kept up only by repeating the crosses year after year. But, in most agricultural crops with perfect flowers, this places a serious limitation on the commercial exploitation of heterosis. In some horticultural crops, however, more favourable botanical and economical conditions are found. The flowers are relatively large, easily handled, and one pollination produces many seeds; moreover, the produce from one plant has a significant commercial value. Under these conditions hybrid seed production even by hand pollination is

economical. Work at the Indian Agricultural Research Institute has, for instance shown that it is feasible to exploit hybrid vigour in the following vegetables.

(i) *Tomato*.—The flowers are large and easily operated upon; the fruit contains a large number of seeds and as such seed production by hand pollination is feasible on a large scale. A number of hybrid combinations have been tried; among these a hybrid between *Sioux* (an American Introduction) and *Meeruti* (selection from a local type) has been outstanding with 25-30 per cent increased yields. Hybrid vigour manifests in this crop, not so much in increased fruit size, which would be an undesirable feature in marketing but in the production of a large number of fruits and especially in a larger early picking, a point of very great marketing importance.

(ii) *Brinjal*.—Here also economic hybrid seed production is feasible. One hybrid, named "Pusa Purple", a cross between "clustered White" and "Muktakeshi" strains, has proved promising, especially in Delhi and U.P. This hybrid has given 45-50% higher yield than the best parents and has uniform attractive fruits (Pal & Singh; 1949).

(iii) *Bhindi*.—Seed production by hand pollination is rather laborious in this case, since the number of seeds/fruit is rather low. It was, however, found that emasculation can be considerably simplified by scraping off the undehisced anthers from freshly-opened flowers and dusting the stigma with the desired pollen. No bagging was found necessary. In this way 80-90 per cent hybrid seed production was obtained. One selection, "Pusa Makhmali", has proved to have high combining ability and especially in a cross with "Long White Darbhanga", gives 60% increase in yields. It was also found that hybrids between 5 edged and 8-edged types were much more vigorous than those between two 5-edged or two 8-edged types themselves, suggesting the importance of genetic diversity. (Singh, Joshi & Gupta, in press).

In dealing with horticultural crops, however, the plant breeder must be careful and exercise proper judgement; increase only in those components of yield, which are commercially acceptable should be selected. Big size in vegetables may not always be desirable nor increase in plant size because the growers have been accustomed to the spacing and cultural methods applied to the present varieties and extensive changes in this may upset the economics of production.

In two other important cash crops, Cotton and Tobacco also, it has been found worthwhile to exploit hybrid vigour, in spite of the laborious methods of seed-production necessary because of their self-pollinated nature. In Cotton, inter-specific hybrids, especially between *Gossypium hirsutum* and *G. barbadense* have shown considerable improvement in fibre qualities such as fineness and staple. The economics of hybrid seed production has been worked out in this case; it has been found that a pound of hybrid seed, which is sufficient for dibbling in an area of one acre, can be obtained at a cost of Rs. 20 and that the improvement in quality fully compensates for the high seed-cost. Pilot projects, sponsored by the I.C.C.C. for the production of hybrid seed, are being run in Madras and Bombay.



where this hybrid has given excellent performance, though it does not do well in upper India. Intervarietal hybrids in *G. hirsutum* have been shown by recent work at the Indian Agricultural Research Institute, to exhibit considerable vigour with increased yield and better staple; extensive search for suitable combinations is being undertaken.

Considerable hybrid vigour is known to be exhibited by crosses between unrelated strains of *Nicotiana rustica*, the chewing tobacco, as much as 30 per cent increased yields, mainly as a result of greater leaf size having been recorded. Hybrid seed production is comparatively easy and since the produce of about 200 pollinations will be enough to sow an acre, likely to be economical. The situation in *N. tabacum*, however does not appear to be as favourable for the exploitation of heterosis, as important qualities like flue-curing and nicotine content may be adversely affected.

3. *Heterosis in cross-pollinated crops*.—In another group of crops, cross-fertilized in nature to a great extent, it has been possible to exploit hybrid vigour by utilizing certain special features; thus, in the pearl millet, *Bajra*, advantage has been taken of the protogynous nature of the perfect flowers and it has been found, both in Madras and Bombay, that sowing mixed seeds of desirable parent varieties results in the production of more than 75% hybrid seed. As a result of further work, high-yielding hybrids have been evolved in Madras and Bombay and are at present being tried in the cultivator's fields (Rao, Nambiar and Menon, 1951; Chavan Patil and Chaudari; 1955). It may also be pointed out here, that with close planting selfed seed is likely to be eliminated by the competition at an early stage. *Bajra* is cultivated under conditions where other recognized methods of increasing yield such as manuring or irrigation are not practicable. As such, the only immediate possibility that presents itself for the amelioration of this crop is the use of hybrid seeds. Further, it has been shown that heterozygotes are more stable under varying environmental conditions and may be better able to withstand the overall effects such as the onset of drought, and hence give a more uniform and reliable performance under the conditions in which this crop is usually cultivated.

Another such crop where high yielding hybrids have been built up at the Indian Agricultural Research Institute is *Radish*. Here the plants are self sterile and compulsorily out pollinated. It is found that 90% of the seeds obtained by planting local and Chinese types, alternately, in concentric circles, are hybrids resulting from cross pollination. The plants grown from such seeds have been found to yield 30-60% more than the better parent. A closely analogous situation exists in a number of other cruciferous plants esp. the *Brassicæ*. It is highly desirable that this method of hybrid seed production should be tried in these crops also.

*Hybrid vigour in fruit and forest trees*.—In many fruits, however, which are propagated as clones there seems to be little to be gained by attempting to utilize hybrid vigour, though some of the varieties at present under cultivation may have been originally selected for their vigour. Vegetative propagation enables us to maintain and multiply these highly efficient representatives of their kind with comparative ease; in fact, many of them are too unbalanced to

be successfully propagated sexually. Their usual short-comings, non-setting due to unreliable pollination or lack of disease resistance cannot usually be corrected by obtaining hybrids. In the case of some forest trees, however, it is probable that the use of hybrids will be worthwhile, both for the greater vigour and establishing-capacity of hybrid seedlings and for their quicker growth and earlier economic returns. This aspect is especially interesting in view of our attempts at reforestation to halt soil-erosion.

*Special techniques for large-scale production of hybrid seeds.—*

It is clear, however that a large number of our economic plants will not lend themselves to such methods for exploiting hybrid vigour because of their self-pollinated nature, floral structure or limited number of seeds set per fruit. Recently, information obtained from certain basic studies has, however, pointed towards some methods by which these bottle-necks can be overcome; some of these methods may be briefly considered here.

(a) One such method depends on the multiple-allelic system of self-incompatibility common among the *Brassicæ*: strains homozygous from the *S* factors can be had by bud pollination and interplanting of two compatible, unrelated stocks homozygous for different alleles will result in 100% hybrid seed production (Old-land and Noll, 1950). This plan would be satisfactory where the cropping value does not depend on the fertility of the hybrids, as for instance in cabbages or brussel sprouts. The homozygous lines can be maintained, if necessary, by vegetative propagation. In the case of plants where seed yield is important, a double cross involving four lines with different 8 alleles will have to be utilized. This  $S_1S_1 \times S_2S_2$  gives single cross  $S_1S_2$ . Similarly  $S_1S_1$  crossed with  $S_3S_3$  will give  $S_1S_3$ . Interplanting  $S_1S_2$  and  $S_1S_3$  will give 100 per cent hybrid seeds. It has also been suggested (Lewris, 1952) that the revertible mutations which often occur spontaneously or on treatment with X-rays and makes self-pollination possible, should be used to obtain lines homozygous for the *S* genes, where bud pollination is not feasible. The doubtful availability of a continuous and wide stream of such mutations, which will be necessary for the full exploration of combining ability extent in the variety, however, is a serious drawback to this elegant scheme. It must also be seriously considered in these cases, whether other methods of improvement such as the building up of synthetic strains, mass pedigree selection in diploids and induced tetraploids etc. would not be more promising.

(b) Another very promising line of approach would appear to be the utilization of male sterility, which is practically a genetical means of achieving emasculation. A number of types of male sterility have been reported, depending on nuclear genes or genomes and certain cytoplasm genes as in Onion or Sorghum. Antherless mutants or mutants with non-dehiscing anthers have been reported in a number of millets; (Ayyangar and Ponnaiya, 1937, 1939; Ayyangar and Krishnaswamy, 1931) recently a male sterile jowar has been reported from Bombay, which has shrivelled empty anthers; it has been proposed to utilise this mutant in the production of hybrid sorghums (Kajjau and Chavan, 1953). At the Indian Agricultural Research Institute, a comprehensive collection of male sterile lines of tomato and Onion have been built up. In tomato, lines are available which

are stamenless or whose anthers do not dehisce or are empty and shrivelled. An extensive back-crossing programme is underway with the object of transferring these characters to the parental lines of the outstanding hybrid *Sioux* × *Meeruti* and already considerable success has been achieved in transferring male sterility to these lines. In onion, a set of three cultures necessary for hybrid seed production.—1. male sterile line, 2. its male fertile counterpart, needed to maintain and multiply the male sterile line and 3. The other parent going into the cross—have been obtained and hybrid seed has been produced and is to be tested for its performance under our conditions. In this connection it may also perhaps be pointed out that these exotic hybrids have rather poor keeping quality and it may prove necessary to introduce the male-sterility character into local, indigenous well adapted red-skinned types. A similar type of sterility depending upon the interaction of genome and cytoplasm has been put to use in America for the production of hybrid Sorghum, replacing the less efficient method of hotwater emasculation. Here also a male sterile line, maintained and increased by pollination with its male fertile counterpart, is put into hybrid combination with a selected, comparable parent. Since, however the seed production of the hybrid is the economic consideration, care has to be taken to select and use a parent which would be capable of restoring male-fertility to the hybrid. Such a system of hybrid seed production is already in use in America and will be of immense benefit to our ryots if it can be introduced into our types.

(c) Recently, there have been indications that male-sterile but female fertile plants can be obtained by treatment with suitable chemicals. It has been reported from America, that spraying with dilute solutions of Maleic Hydrazide in the early stages of the development of the plant, often suppresses the formation of staminate flowers without interfering with the production of pistillate flowers in some cucurbits (Wittwer & Hillyer, 1954). Work at the Indian Agricultural Research Institute has shown that the same chemical when sprayed in a solutions on the seedlings of wheat, results in plants which are male sterile, but set seed abundantly when pollinated with normal pollen (Sikka and Swaminathan, 1956). This might be the method of choice for hybrid seed production in self pollinated plants where number of seed/fruit is very low. It is interesting to recall in this connection that evidence for the existence of hybrid vigour in wheat crosses has been presented by Engledow and Pal (1934) and Pal and Nek Alam (1938). Further, recent work at the Indian Agricultural Research Institute has shown that hybrids between some Indian varieties and some exotic South American varieties like Rio Nigro, Frontiera and others possess considerable heterotic vigour; this can be beneficially exploited if this method of producing male sterile lines can be further standardized.

(d) A third and indirect method of reaping the benefits of heterotic vigour, in plants apparently unsuited for the normal techniques, is the utilization of the polycross method, especially in leguminous forage crops. This method consists, essentially, in planting vegetatively multiplied clones of several highly self-sterile plants in a polycross nursery and allowing each clone to be randomly pollinated by all the other clones. The seed from each clone is harvested and tested for its desirability, and the clones with the best performance are

further multiplied vegetatively. Later, the best clones may be tested in pairs in isolation to test their specific combining ability and suitable single crossed seeds obtained from these may be put into double crosses. Alternatively, a number of desirable clones, say six, may be planted together and left for natural pollination. The bulked seed is sown and again left for natural agencies; this cycle is repeated for 3 or 4 generations. The end-product is a balanced heterotic population of high vigour and yielding ability.

REFERENCES :

1. Ayyangar, G. N. R. & Krishnaswamy, N. (1931) *Indian J. Agri. Sci.* 1.
2. Ayyangar, G. N. R. & Ponnaiya B. W. X. (1937) *Curr. Sci.* 5.
3. Ayyangar, G. N. R. & Ponnaiya B. W. X. (1939) *Curr. Sci.* 8.
4. Chavan, V. M. & Kajjani N. B. (1953) *Indian J. Genet.* 13;
5. Chavan V. M. Patil, J. A. and Chaudhri, B. B. (1955) *Poona Agri. Coll. Mag.* 46.
6. Engledow, F. L. and Pal, B. P. (1934), *J. Agri. Sci.* 24.
7. Lewin, D. (1952) *43rd. Ann. Rep. John Innes Hort. Institution.*
8. Oldland, M. L. & Noll C. J. (1950) *Proc. Amer. Soc. Hort. Sci.*, 55.
9. Pal, B. P. & Nek Alam (1938) *Proc. Indian Acad Sci.* 7(B)
10. Pal, B. P. & Singh H. B. (1949) *Ind. Fmg.*
11. Quinby, J. R. & Martin J. H. (1954) *Advances in Agronomy*, 6.
12. Rao, P. K. Nambiar, A. K. and Menon. P. M. (1951) *Madras agric. J.* 38.
13. Singh, H. B., Joshi, B. S. and Gupta, P. S. In press.
14. Sikka, S. M. Swaminathan, M. S. (1956) *Proc. Conf of Wheat Res. workers, Simla.*
15. William, S. H. & Hillyer, J. G. (1954) *Science* 120.

*Exploitation of Hybrid vigour in improvement of Maize, Onion and Strawberry*

by

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*Hybrid Maize.*—It is now a well-established fact that by the use of suitable hybrid maize seeds, we not only can meet our requirements of maize for food and industry but would be able to double the present yield and release it for other crops. This would enable us either to (i) reduce our corn acreage or (ii) produce enough for increasing demand of industry and for feed. The work at the Vivekananda Laboratory with hybrid maize was started in 1948. Some 53

strains of double cross hybrid maize seeds imported from America and 35 V.L. (Vivekananda Laboratory) strains have been tried. V. L. strains were made by crossing the imported inbred lines, single-crosses and double-crosses with the Indian varieties, inbred and single-crosses. Taking T. 41 (one of the best U.P. selections) as standard, it has been found that some 12 U.S. hybrids and 15 V.L. strains would out-yield T.41 by 70 per cent. The results of trials at I.A.R.I. New Delhi verifies this. All the U.S. strains are dent maize and some of the V.L. strains are flint. One of the interesting facts emerged from our work was that seeds produced from the same inbreds in different regions would give similar yields. We found that seeds U.S. 13 and N.C. 27 produced in Almora from their inbred parents are similar to the seeds produced in U.S.A. This has also been verified by Mr. Johnson who is undertaking a comprehensive yield trial of hybrid maize.

The technique of production of hybrid maize seed have been worked out and several workers have been trained in this simple technique. It has been found that if hybrid maize seed could be produced in small units scattered over different regions, it would not only be desirable but would introduce a new profitable agricultural industry in the rural area.

The possibility of male sterile inbred maize lines for production of hybrid maize have been successfully utilised in producing a double cross hybrid maize seed without detasseling. The yield of these hybrid maize produced without detasseling will be determined after this year's harvest.

*Hybrid Onion.*—The male sterile lines of onion seeds have been imported from the U.S.D.A. and used for producing hybrid onion. For the male parents indigenous inbred lines Shahjehanpur, Almora local and Patna red have been utilised. Compared to the parents, the yield of the hybrids were 80 to 150 per cent higher. Results of this year's trials with 65 different strains of onion will indicate the most desirable combination. Storage quality of the hybrid onion strains is also under study.