

# The Indian Council of Agricultural Research

## REVIEW ON GREEN MANURING PRACTICES IN INDIA

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## PREFACE

**T**HE purpose of the present review which has been written at the instance of Dr. W. Burns, late Agricultural Commissioner with the Government of India, is to set forth as best as possible all the available information on the green manuring work done in this country. Wherever necessary, a reference has been made to some of the more important investigations carried out abroad with a view to institute a comparison of Indian conditions with those in the other countries. The review might also serve the purpose of indicating the lines on which work on the different or more important aspects of green manuring could be taken up in the different parts of India, so as to lead to an accumulation of data for filling in the gaps in our existing knowledge and thus provide a scientific background to the *raison d'être* of the entire practice of green manuring in India.

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Department of Agriculture, U.P.  
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B. K. MUKERJI  
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## I. INTRODUCTION

**G**REEN manuring is by no means an innovation in India. From very ancient times the practice of burying leaves, twigs and loppings from trees has been followed by the cultivators in areas where the proximity of forests renders such material easily available. In common, however, with many other agricultural practices in India and abroad, the history of the scientific development of the subject of green manuring dates back only to very recent years. The agricultural excellence of green manuring is now fully appreciated in the major part of this country, and the practice has established itself firmly in most of the provinces and States. The phenomenal increase in the acreage under the improved varieties of sugarcane has specially given much impetus to this subject, which now warrants considerable attention on both the part of the agricultural experiment stations and the cultivators.

The importance of nitrogenous and organic manures in improving the fertility of the soil is an established fact all over the world. Indian soils lack particularly in nitrogen and organic matter, containing on an average 0.03 to 0.07 per cent nitrogen and 0.6 per cent carbon against 0.1 to 0.17 per cent nitrogen and 3.0 per cent organic carbon in the European and American soils. The necessity for an extensive use of organic nitrogenous manures to supplement the essential nutrients specially lacking in our soils is, therefore, obvious. Artificials may play some part in intensive farming but an extensive use of such fertilizers is generally precluded due to the poor economic condition of the farmers in this country, and also in consideration of the greater need of organic matter in the soil for better tilth and nutrient status.

The destruction of farmyard manure, by its being used as fuel, imposes very serious restrictions on the available quantity of a valuable indigenous supply of organic manure. Even if the whole of the cattle-dung could be conserved and made into manure, the supply would meet only about two-fifths of the requirements for the total area under cultivation in India. In Sind, now in Pakistan, where due to the introduction of extensive irrigation facilities the cropping intensity has considerably increased in recent years, the available supply of cattle-dung can hardly meet the growing demand of the cultivators, specially for such exhaustive

crops like potato, onion and sugarcane. Similar conditions prevail in Bombay where as a result of increased cropping under canal irrigation, the rate per cart-load of farmyard manure has more or less become prohibitive and even then it is hardly possible to get enough supplies. In Uttar Pradesh also, the shortage of cattle-dung is acutely felt, specially where the introduction of the newer and heavier yielding varieties of sugarcane coincides with the introduction of a new supply of water as following the opening of a new canal system or tube-wells. More or less similar difficulties are experienced in the other parts of India as well.

These and other considerations led workers all over India to search for some other form of organic manure which could supplement the existing meagre supply of farmyard manure. Composting, however simple the technique might be, has not yet become very popular in rural areas due to many difficulties amongst which the scarcity of water, labour and time are some of the most important. These difficulties are further accentuated in the case of an average cultivator with small and fragmented holdings. The use of oilcakes as manure has recently received some favour; but the relatively high cost and uncertain availability of some of the common oilcakes and also lack of enough experimental data to establish beyond doubt their manurial efficiency have led to their being adopted only on very limited scale.

Green manuring, therefore, seems to be the only suitable alternative which offers itself as an easy means for meeting our manurial requirements. The consensus of opinion is that green manuring can increase and even maintain the productivity of soil. Experiments and experience have in general established the superiority of sunn over other green manuring crops, and naturally, therefore, sunn has received the greatest amount of attention in this country from scientific workers and cultivators alike. *Dhaincha* is another which has also established itself as a successful green-manuring crop, specially in the Bengal and South India. *Pillipesara* which is a recent introduction has already attained much popularity as a green manuring crop in Bombay-Deccan and Madras. However, there are certain very important considerations which limit the universal adoption of green manuring as a general farm practice. Some

of the most important factors determining the feasibility or otherwise of the practice of green manuring are : rainfall ; irrigation facilities ; crop to be used as green manure and main crop to be green manured ; prevailing system of crop rotation and nature of the soil.

Apart from the factors cited above, the question of the economics of green manuring looms very large, as for any other scheme of farm husbandry in this country. Dobbs [1915] in his excellent review on green manuring laid considerable stress on the question of green manuring versus an alternative paying crop. Although there has been much discussion on this subject until very recently, very little information is yet available on this important point. Allan [1935, 1937] perhaps summarises the position in its proper perspective, namely, that no cultivator is out to grow a green manure crop if there was any possibility of getting as an alternative a cash crop out of his land. It may, however, safely be mentioned that green manuring sugarcane has practically become an established farm practice, but for the common *rabi* crops the question of the economics of green manuring remains practically as obscure as ever.

## II. GREEN MANURING CROPS

**M**ANY species of crops, both legumes and non-legumes are grown and used as green manure. But the crop of most universal use is sunn which has established itself in the majority of tropical countries and has received the greatest attention in India. Green manuring crops may be actually grown on the field and ploughed in or may be brought from outside. The latter practice is generally followed in areas where, for certain reasons, it is difficult to secure a good stand of the crop to be raised for green manuring. In some tracts, the leaves, stems and tender twigs of certain trees are used as green manure. Green manures may also be grown as cover crops with a view to conserving the soil moisture and bringing nutrients from the subsoil to the surface soil, but this does not as yet form a regular feature of the general farm practice in India, excepting in limited areas for plantation crops like tea, rubber and coffee.

Although a fairly large number of field experiments have been carried out in the different parts of India to assess the relative merit of green manure and other forms of bulky organic manures, like farmyard manure and compost, oilcakes and artificials, yet very little has so far been done in this country to ascertain the changes taking place in the nitrogen balance of the soil as a result of green manuring, or the ease with which the different plant materials decompose in the soil under varying soil, temperature, rainfall and irrigation conditions. The relative utility of legumes and non-legumes as green manures has also not been properly worked out. Again, the question of suitable rotations providing for natural recuperation of the soil nitrogen through the introduction of a leguminous crop in the rotation, has hardly ever been touched scientifically in any part of India. These are some of the most important factors which yet await elucidation—both under field and laboratory conditions. At present we have to depend almost entirely upon the results obtained by workers in other tropical and subtropical countries to glean whatever little knowledge that could be had on the scientific aspects of green manuring.

### *Some commonly used green manuring crops*

(a) *Sunn*. Sunn-hemp, sunn or *sanai* is a member of the genus *Crotalaria* and belongs to the natural order Leguminosae. With the exception of those areas which are apt to be waterlogged, sunn has been used as a green manure in practically all the States of India. The plant is of easy culture and reaches a height of 4 to 5 feet. It has erect growth with very little branching at the base. In addition to being a valuable green manure it furnishes fibre of fair strength. Its seeds are not suitable for human consumption but may be fed to cattle, although the plant itself is not relished by animals [Sornay, 1916].

Other varieties of *Crotalaria* are being used as green manure to a limited extent, specially in the South and Ceylon. In cocoanut gardens and in coffee estates plants like *Crotalaria striata* and

*Crotalaria trifoliata* are used. In Mysore and Ceylon *Crotalaria striata* is freely used as a mulch in tea, coffee and rubber estates. Rege [1935] reports a new introduction from Ceylon, viz. *C. anagyroides* which has been found to be very suitable for green manuring purposes.

(b) *Sesbanias*. Next in order of importance is probably *dhaincha* (*Sesbania aculeata*). According to Dobbs [1915] *dhaincha* is an ideal green manuring crop. It can withstand severe drought and will grow on badly drained land, and even on soils which are slightly saline. The crop hardly requires any irrigation if the germination has once started. Gadgil [1937] mentions *dhaincha* and another variety of this species *shevri* (*Sesbania aegyptica*), also called *jayanti* in Northern India, as suitable for green manuring in Bombay. These are also legumes, and being capable of growing under waterlogged conditions are used extensively in Bombay, Madras and Bengal as green manure for swamp rice and in Assam particularly for acid soils. These are reputed to be valuable as fodder and yield a fibre of medium strength [Sornay, 1916].

(c) *Phaseolus*. Many plants belonging to the species *Phaseolus* have been reported to be useful for green manuring purposes. Of the crops used as pulses in India, mention may be made of *moth* (*Phaseolus aconitifolius*), *urd* (*Phaseolus mungo*) and *mung* (*Phaseolus mungo radialis*), which are used as green manures, although the actual extent to which the plants are utilised for this purpose is not known. In Madras and Bombay another variety of this species, called locally *pillipesara* in Madras and *ran-mutki* in Gujrat, viz. *Phaseolus trilobus*, has recently found much favour [Ramiah 1935; Rege 1935].

(d) *Other leguminous plants*. Cowpea (*Vigna catjang*) and *Guar* (*Cyanopsis psoraliodes*) are also commonly used as green manures. Cowpea is suited to every soil and is a good fodder for livestock. *Guar* is also used for feeding purposes.

*Dolichos biflorus* called *kulthi* in Gujrati is being used in Bombay and *Tephrosia purpurea* or wild indigo in Madras. *Arhar* (*Cajanus indicus*) is used in both Punjabs and Sind (now in Pakistan).

In addition to above many wild leguminous plants like *Cassias* and weeds, e.g. *Desmodium*

*diffusum* (*patada shevra*) have been tried with success as green manuring plants by some workers.

(e) *Non-leguminous plants*. Amongst the non-legumes there is hardly any well established green manure plant, although Lander *et al.* [1923] found *bhang* (*Cannabis sativa*) to be somewhat useful in the Punjab and Bal [1937] reports using *kodogira* (*Vernonia cinerea*) in the Madhya Pradesh. Sun flower (*Helianthus annuus*), *jowar* (*Andropogon sorghum*) and maize (*Zea mays*) have similarly been tried by Mukherji [1938—1940] in the Uttar Pradesh.

#### Winter green manuring plants

The plants mentioned above are generally grown during the summer and rainy seasons (*kharif*) and only very few crops grown during the winter (*rabi*) are in actual practice ploughed in as green manure. Excepting *senji* (*Melilotus parviflora*) and pea (*Pisum sativum*) which are used to some extent in the Punjab and Sind in Pakistan as winter green manure, no other *rabi* green manuring crop has so far been reported in India. Berseem (*Trifolium alexandrinum*) stubbles are, however, used as green manure for cotton in Sind in Pakistan.

#### Crops suited to different tracts

In Madras black gram (*Phaseolus mungo*), green gram, *pillipesara* and *dhaincha* are used fairly extensively as green manures. In addition to the above Ramiah [1935] mentions sunn-hemp, indigo (*Indigophera anil*), wild indigo, horse gram (*Dolichos biflorus*) and cowpea, each being suitable under particular soil and climatic conditions. Ramiah [1935] specially refers to *pillipesara* which according to him is a recent introduction in the Godavari Delta. Its chief advantages are:

- (i) it can be sown in a standing crop of rice;
- (ii) it is a creeper with good vegetative growth and possesses little hard woody tissue;
- (iii) it is a valuable succulent fodder and hence a few cuttings could be fed to cattle—the remainder being puddled in;
- (iv) it decomposes easily when incorporated into the soil; and
- (v) the plant is not so delicate as sunn-hemp growing well on clayey soils with little irrigation during the summer and produce green matter weighing approximately 20,000 lb. per acre.

In the Madhya Pradesh, sunnhemp, *dhaincha* or *shevri*, *tarota* (*Cassia tora*) and *kodogira*, the first three legumes and the last a non-legume are frequently used as green manures [Bal, 1937].

At Pusa (Bihar), field trials conducted over a number of years with sunn, cowpea, *moth* and *guar* established the superiority of sunn over the rest.

*Dhaincha* and cowpea are advocated in Assam for acid soils and sunn and soybeans (*Glycine hispida*) for normal or limed soils.

In Bombay, *kulthi* and *niger* are used with conspicuous success for cane, paddy and maize, and *dhaincha*, and wild indigo are suggested specially for swamp rice. According to Gadgil [1937], *dhaincha* and *shevri* were best suited to water logged conditions who found the former to be specially efficient. For dry and irrigated lands he recommended *ran mulki* which produces 15,000 to 17,000 lb. per acre of easily decomposable green matter [Ramiah, 1935].

In the Punjab *senji* is recommended for improving alkaline soils and *guar* for poor lands—sunn, *urhar* and *dhaincha* being among the most commonly used green manuring crops there [Lander, 1937]. In Sind (now in Pakistan) according to Barakzai [1935] sunn and *guar* in the *kharif* and *matar* or peas in the *rabi* are the chief green manure crops. Cowpea is also used there to some extent.

Velvet beans (*Stizolobium deeringianum*) have proved to be a rapid growing and easily decomposable green manure in Mysore, and in estate practices *Crotalaria striata* and *Tephrosia candida* are used as mulches. In Travancore due to heavy rainfall (80 in. to 90 in.) growing of a green manure crop is not usually possible, and jungle growth and trees are cut and used for green manuring purposes along with *Tephrosia candida*, sunn and cowpeas which do well at some places.

Rege [1935] describing the most suitable green manuring crops for Bombay, states that *Crotalaria juncea*, *Crotalaria anagyroides* (a recent introduction from Ceylon), *Sesbania aculeata*, *Tephrosia purpurea*, *Phaseolus mungo*, *Dolichos biflorus* and *Vigna catias* could be used successfully in general farm practice. Recently summarising green manuring practices in sugarcane cultivation, Rege [1941], however, concludes that sunn is the only crop which has been studied in detail and which has become really popular. Nevertheless

green manuring sugarcane with cowpea is common in Jorhat (Assam), and in the Godavari Canal area *ran-mulki* compares favourably with sunn. At Pedagaon (Bombay-Deccan) a new species of leguminous weed called *patada shevra* (*Desmodium diffusum*) has been found to grow well, though slowly, and is ready for ploughing in a month later than sunn. It has been suggested that this may be as effective as sunn for sugarcane.

In Orissa experiments are in progress to utilize plants like *dhaincha*, cowpea, *biri* (*Phaseolus sp.*), *kulthi* and *mung*, and in Travancore leaves and tender twigs of many wild plants for manuring rice. The leaves used are of *vaha* (*Albizia lebbek*) *avarai* (*Cassia auriculata*), *pungu* (*Pongamia glabra*), *konnai* (*Cassia florida*), *margosa* (*Azadirachta indica*), *arukka* (*Caltropis gigantea*), *portia* (*Thespesia populnea*) and *nelli* (*Embelica officinalis*) [Sethi, 1940].

#### Legumes and non-legumes

The consensus of opinion is that both leguminous and non-leguminous crops could perhaps be utilised for green manuring. Legumes which are capable of fixing nitrogen from the atmosphere, supply nitrogen to the soil in addition to organic matter whereas, non-legumes supply mostly organic matter. Sahasrabudhe [1935] is inclined to believe that non-legumes are just as good as legumes on good soils, but on poor soils legumes may exert a better fertilising action. This view is shared by a number of workers in India and abroad. Not much experimental evidence in India, is, however, available on this point. In Madhya Pradesh where sunn, *dhaincha*, *tarota* and *kodogira* are used as green manures, the results obtained from *kodogira*, a member of the Compositae family, are observed to be somewhat similar to those from the three legumes [Bal, 1937]. However, there is not much experimental evidence to support this conclusion. Almost similar results have been obtained in the Uttar Pradesh by Mukerji [1937] by using sunn, *dhaincha*, *jayanti*, *javwar*, maize and sunflower on wheat, the difference in the yield of wheat being, statistically insignificant for legumes and non-legumes as green manures.

In the Punjab, Lander and associates [1923] found from their pot culture and field experiments extending over a period of five years that in the *barani* areas non-leguminous green manures like *bharg* were as effective as leguminous dressings. In the opinion of these authors, the main factor



responsible for the beneficial effect of green manuring being the improvement in the physical texture of soil, the utilization of non-legumes is just as effective as that of the legumes.

For paddy and garden crops green leaves from wild trees such as *vaha* (*Albizia lebbek*), *pungu* (*Pongamia glabra*), etc. are being used in Travancore [Narayan Iyer 1935, 1937]. For paddy a top dressing of some nitrogenous fertiliser like sulphate of ammonia or ammophos as a supplement to green manuring is considered there to be specially beneficial. In Madras, too, Ramiah [1935] reports using leaves for rice, the optimum dose being 4,000 to 5,000 lb. of leaf per acre. Higher doses like 6,000 to 8,000 lb. per acre on some poor soils have been found to depress the yield of rice unless used in conjunction with some phosphatic manure.

Sethi [1940] reports the use of leaves, specially those of *nelli* [*Embelica officinalis*] or tamarind in Madras for improving the alkaline condition of some soils.

Studying the influence of green manures on nitrogen fixation in the soil, Desai [1933] made the important observation that although the leguminous plants were much richer in nitrogen at the time of incorporation into the soil, the fermented tissues of non-legumes fixed much more atmospheric nitrogen than those of the leguminous plants [Allan, 1937; Hutchinson and Milligan, 1914]. It appears that the total nitrogen of the soil is, thus, ultimately raised to the same level in both the treatments. Joachim [1926, 1, 2; 1927], studying the nitrate accumulation in the soil as a result of green manuring, observed that the use of non-leguminous leafy material resulted in as great an accumulation as when leguminous plants were used. He, therefore, advocates the use of suitable non-leguminous material for green manuring, provided it is not grown on the field which is to be manured and is buried when it is tender.

#### *Composition of green manure plants*

Unfortunately, very little information is available on the chemical composition of some of the more important green manuring plants of India. Hardly any data exist indicating either the relative content of the fertilising constituents of these crops, or the changes in their chemical composition along with variations in the type of soil, the variety of seed and the stage of maturity. A few isolated figures found in the literature have been tabulated in Table I.

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Singh and Singh [1936] analysed sunn at the various stages of its growth, with a view to determine the period when the plant could yield the maximum amount of organic matter and contribute most to the fertility of the soil in terms of nitrogen content. The entire life period of the plant was divided into four distinct stages, viz.

- (i) juvenile or young stage (upto 30 days after germination),
- (ii) adolescent stage (upto 75 days),
- (iii) partial senescent stage (upto 90 days) and,
- (iv) senescent stage (upto 105 days).

The maximum output of organic and inorganic constituents was attained when the plant growth was at the partial senescent stage, i.e. 90 days after germination. The authors, however, remarked that the hard woody stems at that stage instead of leading to an improvement in the soil would actually cause great damage when ploughed in. On the other hand, the quantities of the majority of the fertilizing constituents of the leaves and roots attained their highest value only at the time of initiation of the first bud. They, therefore, concluded that green manuring either with the entire plant or with tops and roots alone, at a period coinciding with the initiation of buds, viz. 75 days after germination, should result in the maximum manurial value to the crop. The results of their analysis are given in Table II.

Regarding the relative manurial efficiency of the different parts of the plant as judged by chemical analysis, these authors further express the view that the leaf possesses the highest manurial efficiency, and next in order of importance are the roots and the stems. The fibre content, as shown by the percentage of cellulose, reaches a maximum when the plant is in its senescent stage; but the quality of the fibre is improved, if extracted, when the adolescent stage is reached. If both fibre production and green manuring are desired, the stem could be used for fibre when the plants are 75 days old, and the rest, viz. the leaves, tops and roots ploughed in as green manure. By this method it is assumed that the fertility of the soil remains practically the same as when the whole plants are buried.

Sethi *et al.* [1938] also conducted experiments in Uttar Pradesh for two years in properly replicated randomised blocks and the amount of nitrogen turned in per acre in pounds from sunn of different ages is given in Table III.

TABLE I  
Chemical composition of some of the green manure crops used in India

Serial No.	Botanical name	Common name	Vernacular name	On fresh basis							On dry basis						Reference		
				Moisture per cent	Ash per cent	Cellulose per cent	Fat per cent	Sugar per cent	Non-nitrogenous matter per cent	Nitrogenous matter per cent	Nitrogen per cent	Ash per cent	Cellulose per cent	Fat per cent	Sugar per cent	Non-nitrogenous matter per cent		Nitrogenous matter per cent	Nitrogen per cent
1	<i>Arachis hypogaea</i>	Groundnut	Mughali	80.4	1.59	6.05	1.23	1.37	8.51	2.74	0.44	8.4	29.70	5.50	6.4	38.50	13.30	2.10	Sornay (1916).
2	<i>Cajanus indicus</i>	Pigeon Pea	Arhar	70.0	2.64	10.72	1.65	..	7.88	7.11	1.12	..	..	..	..	..	..	..	Sornay (loc. cit.)
3	<i>Orotalaria juncea</i>	Sunn-hemp	Sanai	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	Pieters (1927).
4	<i>Orotalaria striata</i>	..	..	75.2	2.00	..	..	..	..	..	1.00	6.0	..	..	..	..	..	4.07	Joachim (1931).
5	<i>Orotalaria anagyroides</i>	..	..	72.8	1.80	..	..	..	..	..	1.32	6.5	..	..	..	..	..	4.84	Joachim (loc. cit.).
6	<i>Oyanopsis paoraloides</i>	Cluster beans	Guar (Hindi)	..	..	..	..	..	..	..	..	12.71	29.99	1.73	..	47.00	8.56	1.36	Sen (1938).
7	<i>Dolichos biflorus</i>	Horse gram	Kulthi (Bom.)	5.6	8.85	28.01	2.63	..	48.10	6.81	1.09	..	..	..	..	..	..	..	Leather quoted by Sornay (loc. cit.)
8	<i>Desmodium diffusum</i>	..	Palada Shevra (Bom.)	50.9	4.30	..	..	..	..	..	1.40	8.7	..	..	..	..	..	2.84	Joachim (loc. cit.)
9	<i>Indigophera anil</i>	Indigo	Neel (Vern.)	74.7	3.20	..	..	..	..	..	0.78	12.7	..	..	..	..	..	3.09	Joachim (loc. cit.)
10	<i>Melilotus parviflora</i>	..	Senji (U. P. and Punjab.)	34.4	2.26	4.13	0.38	..	6.16	2.49	0.43	9.5	31.62	1.47	..	41.95	15.46	2.50	Sen (loc. cit.)
11	<i>Phaseolus trilobus</i>	..	Pillipesera (Mad.)	11.2	6.50	7.75	0.39	..	69.44	24.52	3.92	..	..	..	..	..	..	..	Leather quoted by Sornay (loc. cit.)
		..	Ren Maki (Bom.)	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
12	<i>Phaseolus aconitifolius</i>	..	Moth (Bihar.)	9.94	4.02	4.60	0.86	..	56.21	22.37	3.58	..	..	..	..	..	..	..	Do.
13	<i>Phaseolus mungo</i>	Black gram	Urd (U. P.)	15.4	14.92	17.08	1.70	..	38.24	12.68	2.03	..	..	..	..	..	..	..	Do.
14	<i>Phaseolus mungo radiatum</i>	Green gram	Mung (U. P.)	13.3	14.29	18.65	2.52	..	39.67	11.56	1.85	..	..	..	..	..	..	..	Do.
5	<i>Pisum sativum</i>	Peas	Matar (Hindi)	12.2	2.50	48.50	1.20	..	29.00	5.60	..	3.9	22.60	2.40	..	54.42	16.69	2.66	Sen (loc. cit.)
16	<i>Sesbania aculeata</i>	..	Dhaincha	78.2	2.20	6.32	6.80	..	9.80	2.62	0.42	10.1	29.01	3.68	..	45.06	12.15	1.95	Mukerji (Unpublished.)
17	<i>Tephrosia candida</i>	..	..	13.4	4.80	13.65	8.50	..	25.80	33.27	..	..	..	..	..	..	..	..	Sornay (loc. cit.)
18	<i>Vigna catjung</i>	Cowpea	..	86.4	1.25	4.50	0.50	1.25	5.00	2.00	0.49	10.0	32.20	3.90	8.8	33.50	14.70	2.40	Sornay (loc. cit.)
	Do.	..	..	..	..	..	..	..	..	..	..	10.9	33.10	2.50	..	36.16	17.38	2.78	Sen (loc. cit.)

N.B.—Sen's (loc. cit.) figures for crude fibre and nitrogen free extract have been taken for cellulose and non-nitrogenous matter, respectively.

TABLE II

*Fertilising constituents incorporated by sunn-hemp in lb. per acre [Singh and Singh 1936]*

Age in days	Sample	Reducing sugars	Fata	Total carbohydrates	Sucrose	Cellulose	Nitrogen	Ash	Calcium	Potassium	Phosphorus	Magnesium	Sulphur
					<i>Juvenile stage</i>								
1	Tops and roots	0.60	1.08	1.6	0.26	0.36	0.54	0.62	0.16	0.05	0.03	0.03	0.12
	Entire plant	0.86	1.32	2.1	0.33	0.99	0.72	0.79	0.19	0.06	0.03	0.04	0.19
15	Tops and roots	1.47	2.67	5.44	0.92	2.11	1.58	1.98	0.46	0.28	0.11	0.08	0.62
	Entire plant	2.01	3.16	6.63	1.15	3.16	1.94	2.27	0.56	0.29	0.12	0.09	1.02
30	Tops and roots	18.0	30.3	69.9	12.04	13.3	22.9	32.7	9.30	3.97	1.44	0.86	10.39
	Entire plant	25.2	35.1	89.5	17.20	50.9	27.6	37.8	10.7	4.31	1.65	1.23	11.25
					<i>Adolescent stage</i>								
45	Tops and roots	51.8	46.1	227.1	47.8	59.7	81.2	108.5	42.0	22.8	2.79	3.39	28.11
	Entire plant	64.1	105.0	338.1	62.4	191.1	105.2	122.2	43.8	23.9	4.05	4.21	37.55
60	Tops and roots	175.7	457.4	1204.5	226.4	282.2	396.2	601.3	219.2	131.3	13.33	20.33	137.54
	Entire plant	207.9	676.3	2064.5	480.5	1376.9	683.8	962.5	332.9	202.52	21.32	21.25	168.11
75	Tops and roots	216.3	745.1	1667.1	417.7	489.2	473.0	840.6	276.1	188.30	15.71	35.88	178.04
	Entire plant	313.5	1055.2	2837.1	720.8	2153.1	781.1	1204.9	431.4	309.94	28.51	51.95	190.71
					<i>Partial senescent stage</i>								
90	Tops and roots	231.6	954.2	1649.6	362.3	433.3	447.3	573.8	232.7	197.67	15.94	40.46	130.00
	Entire plant	369.3	1607.8	3342.9	739.9	2863.3	783.9	1351.1	502.1	424.85	34.06	71.41	337.69
					<i>Senescent stage</i>								
105	Tops and roots	41.3	629.7	906.9	145.9	300.9	158.4	261.5	31.3	105.86	8.48	10.46	46.68
	Entire plant	151.9	2220.9	3055.8	509.5	3350.5	473.8	1264.2	170.6	455.43	31.91	43.59	169.52

TABLE III

*Quantity of green matter and amount of nitrogen turned in by ploughing sunn of different ages and different portions of the plant [Sethi, 1938]*

Age in days	Yield of green matter per acre (md.)	Nitrogen turned under (lb.)
30	183.4	51.5
40	236.3	56.7
50	285.6	73.6
60	302.9	70.8
(a) Whole sunn plants including roots	285.6	73.6
(b) Only top portion	252.6	59.3
(c) Roots alone	24.5	12.4

Comparing the above results obtained by Sethi [1938] with those obtained by Singh and Singh [1936] it will be noted that the latter workers claim to have secured nearly 680 lb. of nitrogen per acre by turning in sunn 60 days old and 780 lb. by that of 75 days old. These figures are apparently too high and have not yet been substantiated by other investigators. The work of Singh and Singh [1936], therefore, requires repetition and confirmation before any value could be attached to their figures.

### III. CULTURAL PRACTICES TO RAISE OR BURY GREEN MANURING CROPS

**T**HERE are practical difficulties in growing a green manuring crop, specially in those tracts where irrigation facilities do not exist and early rains in April or May are not received. In such areas green manures may be grown with the advent of the monsoon in fields which are well drained and not waterlogged. If it is intended to green manure paddy with sunn, and if sunn is sown along with paddy, it may not be possible to grow the former under the usual waterlogged conditions of the rice fields. This difficulty could be obviated either by growing an alternative green manure crop which may not be so susceptible to waterlogging, or else growing it in other fields, cutting and applying later on to paddy fields. The latter practice may not, however, be possible for an average cultivator having small and scattered holdings. In Madhya Pradesh plants like *Sesbanias* are grown on waste lands or along the *bunds* and are used as green manure for paddy [ Bal, 1937 ].

#### *Time of sowing*

Regarding the time of sowing, Howard and Howard [ 1915 ] expressed the view that under Pusa conditions the best time for putting in sunn was with the early rains in May. However, Sayer [ 1935 ], on the other hand, maintains that sowing of sunn for green manuring at the end of May or early in June is risky. It should be sown only at the actual break of the monsoon. In the irrigated areas of Madras, according to Ramiah [ 1935 ], it has been found practicable to sow a green manure crop for paddy as early as the middle of March and invert it in June. Another practice mentioned by the same author is to grow certain types of green manuring crops in the standing crop of paddy and keep it on until June, cutting it down in the meanwhile once or twice for feeding to cattle.

Sethi *et al.* [ 1938 ] summarising the practice followed in the Uttar Pradesh for sugarcane describe that the field is ploughed twice and *sanaï* seeds are sown by broadcasting at the rate of one maund per acre and then levelled off. It is useful to sow the seed as early as the end of May

or the beginning of June, if irrigation is available, but if the sowing is to depend entirely on rains it should be delayed till the arrival of the monsoon. In the former case the plants attain sufficient height to resist the effect of heavy monsoon showers, but if sown late in June the seedlings may be damaged by heavy rains in July\*\*.

#### *Time of burial*

The time at which a green manure crop is to be buried is also important, since the resultant beneficial effect depends amongst other things on this factor. Coleman, Iyengar and Sampatiengar [ 1912 ] working in Mysore found that the best time for ploughing in green manure was when it attained the flowering stage. Joshi [ 1922 ] finding that leaves alone were mostly responsible for the maximum manurial value, recommended that the plant could be allowed to grow fully to maturity and then buried under. Singh and Singh [ 1936 ], in view of their data on the composition of sunn at various stages of its growth, state that from the point of view of adding the optimum amount of fertilising constituents to the soil, the best period for burying in the crop would be the partial senescence or fully ripe stage. But considering the woody nature of the stems at this stage of its growth, which might delay decomposition, these authors conclude that the stage coinciding with the initiation of the buds, viz. 75 days after germination, should give the highest amount of easily decomposable manurial constituents. However, at Shahjahanpur the maximum amount of nitrogen was secured from sunn at 50 days growth followed by that of 60, 40 and 30 days [ Sethi *et al.* 1938 ]. Rege [ 1941 ] is of the opinion that the stage of growth and not the time factor should be taken into consideration, and in the Deccan the initial flowering stage is found to be the best period for inversion.

Hutchinson and Milligan [ 1914 ] conducted a series of experiments at Pusa on green manuring. Their observations showed that in the case of plants four and six weeks old, the amount of nitrate nitrogen formed was the same and nitrification in the soil was 67 and 50 per cent respectively.

\*\*At Padegon in order to see which crops would supply the maximum green matter and which months were favourable to sowing these crops six species of green manuring plants were sown during April, May, June, July and September for three years (1933-1936) in duplicate plots during the first year and single plots later. The results obtained as summarised by Rege [ 1941 ] showed that while sunn and *dhaincha* supplied maximum green matter, sunn was ready for ploughing in about three weeks earlier than *dhaincha*. Next to these two, in the matter of the quantity of green matter, was found to be *urd* which was even earlier than sunn. The best months for sowing, to secure maximum green matter, in the case of sunn, *dhaincha* and *urd* were found to be June and early July.

But with ten weeks old plants the nitrification recorded was only 34.5 per cent. They, therefore, concluded that although the total amount of nitrogen added in the latter case was much higher than in the former, the total amount of nitrates formed was greater in the former. Their results, after eight weeks of incubation, are given in Table IV.

TABLE IV

*Nitrogen and nitrate-nitrogen in the soil as a result of inverting green manures at various periods of their growth (Pusa)*

Age of plant	Nitrogen mg. per 100 gm. of the soil	Nitrate nitrogen per 100 gm. of the soil
4 week old . . .	12.0	9.8
6 week old . . .	17.4	9.3
10 week old . . .	22.2	8.7

Experience and experiment tend to show that although green manures when buried late add a greater amount of organic matter and nitrogen to the soil, the results on a succeeding crop may not be proportionately better. This may be due, as Sayer [1935] indicated, to the older plants depleting the soil moisture to a greater extent and leaving more undecomposed organic matter in the soil than the younger ones.

#### *Interval between burial and sowing of a succeeding crop*

Generally, it is accepted that the interval between burying a green manure crop and sowing the succeeding crop should not be too long. Howard [1913] considered a period of eight weeks to be the optimum for this purpose, and Hutchinson and Milligan [1914] have shown that a decrease in the nitrate content starts after the eighth week of burial. Howard (loc. cit.) in his experiments on green manuring tobacco observed loss of fertility if the interval between burial and transplanting was too long. Allan [1915] also considers approximately two months' interval between inversion and sowing of wheat and at least 12 in. to 16 in. of rain or irrigation water essential for successful results. Thus, according to him for green manuring wheat the crop must be inverted in August.

Regarding the effect of berseem stubbles used as green manure for cotton in Sind, according to Barakzai [1935], the stubbles are generally left in the soil after ploughing in for about two weeks for decomposition after which cotton is sown.

If a fallow intervenes considerable deterioration of nitrogen takes place, and the maximum benefit of legume cultivation may not be realized. However, there is lack of experimental data to support these important findings. Hutchinson and Milligan [loc. cit.] referring to such losses remarked that these could be avoided if the green manure crop was more mature and buried deeper. However, if rains fail the green matter may not decompose at all and this practice is therefore considered to be risky.

#### *Depth of burial*

The depth to which a green manure crop should be buried depends upon the soil, the green manure crop itself and its stage of maturity. It has been the general practice to bury a green manure crop deeper in light soils than in soils tending to be clayey. Older crops should be buried as near the surface as possible so as to provide more oxygen for decomposition [Hutchinson and Milligan loc. cit.]. According to Sayer [1935] the burial should be reasonably deep so as to provide a suitable cover for the ploughed in crop.

#### *Place of growth*

Rege [1935] from his experience in Bombay mentions that growing of a crop, at a place where it is to be ploughed in, is much more beneficial than bringing it from outside. The former practice also improves the tilth of the soil. Lander [1935], on the other hand, thinks that green manure carted from outside is a paying proposition, although increased yields are obtained if green manure is grown *in situ*. In Madhya Pradesh where for paddy well-drained areas are rare, monsoon starts late and irrigation facilities are absent, the green manuring crop is always brought from outside and puddled into the paddy fields [Bal, 1937].

There is ample evidence in the literature to show that green manure grown in one field and ploughed in another is more beneficial than that grown *in situ* [Grazia, 1907; Lohnis, 1926.] This seems to be due to the fact that the moisture with the green manure transferred from one field to another helps considerably the main crop, and this practice should be valuable for dry lands. The plant nutrients taken up by the green manure crop are also thus transferred to the soil which is manured.

#### *Sunn green manuring*

Gadgil [1937] has published a comprehensive note on sunn green manuring for the Deccan canal irrigated tracts, which deserves special

mention. Extracts from this note are given below :

(a) *Soil.* The sunn crop does well in light, medium black and heavy black soils of the Deccan. Maximum amount of green matter per acre is, however, obtained on medium black soils. Sunn crop may fail on very light shallow soils and very heavy stiff soils. On waterlogged and saline soils sunn does not germinate, but on soils which are only slightly saline, a medium crop may be obtained.

(b) *Climate.* The crop prefers a humid climate and in the Deccan Canal tract where the rainfall is 20 in. to 25 in. it grows well under irrigation. The rainfall should be evenly distributed. Hot winds and high temperature do not effect the crop unless it is in its very young stage.

(c) *Preparatory tillage.* The land should be ploughed up once at least and two harrowings given in order to bring the soil in good tilth for sowing.

(d) *Season and time of sowing.* Sunn is generally sown as a monsoon crop a week after the rains start. It could, however, be sown towards the end of the hot weather, i.e. between 15 May and 5 June when the vigour of growth would be excellent and more green weight may be obtained. It could be sown even earlier than this, i.e. in April, if no hot winds are prevalent ; but sunn crop sown in April is liable to attack by small caterpillars. Under Bombay conditions 15 May to 5 June is considered as the best period for sowing.

(e) *Seed rate and sowing.* Seed rate varies from 60 lb. to 80 lb. per acre, heavier soils requiring higher seed rate than the lighter types. Sowing is done cross-wise by a seed drill having coulter 10 in. to 15 in. apart. The field is first flooded till the land is fit for sowing operations.

(f) *Irrigation.* If the crop is sown in hot weather one irrigation is necessary a week after sowing. If monsoon starts, no further irrigation may be required excepting during long breaks. Three to five such additional waterings may be necessary. If the rainfall is evenly distributed no watering is required.

(g) *Cutting and burying.* The crop flowers  $2\frac{1}{2}$  to 3 months after sowing and should then be buried. One watering may be found necessary after burying if no late rains are expected.

#### *Green manure turned into compost*

Hutchinson [ 1916 ] was the first in India to have advocated on scientific grounds a preliminary

decomposition of the green manuring crops under artificial conditions before incorporating them into the soil, specially for regions with too low a rainfall to effect complete disintegration of the green material in the soil itself. He considered that negative results might be obtained from green manuring if the crop was not properly decomposed in the soil and organic nitrogen converted into nitrate nitrogen. Milligan, quoted by Hutchinson [ 1916 ] too supported the scientific aspect of this view and further stated that most of the *rabi* cereals required a sufficient amount of available nitrogenous matter at a very early stage of their growth for the maximum production of grain. The method of preliminary composting of green manures as given by Hutchinson [loc.cit.] is briefly as follows :

The green crop is cut, stacked in heaps, moistened with a little water and allowed to ferment for varying periods after which the rotted manure is applied to the soil. It was, at first found necessary to water the heaps occasionally to prevent drying out, but this was subsequently avoided by plastering the outside with clay, some water being added occasionally to prevent cracking of the latter.

Milligan, however, doubted the utility of this process on economic grounds. But, the method has distinct advantages for areas where autumn rains are not assured and will provide available nitrogen during the earlier stages of the growth of succeeding crops. Rege [ 1935 ] too emphasized the desirability of preliminary decomposition of green manures in heaps before application, specially for tracts with scarcity of water, and reported to have achieved good field results thereby. On black cotton soils in areas where the rainfall is less than 40 in. Allan [ 1937 ] considers composting of sunn more beneficial, giving the benefit of sunn stubbles in the soil to the next wheat crop.

Barakzai [ 1935 ] cites some instances of using sunn compost for potato and onion crops in Sind. The compost was applied to the potato crop one-and-a-half month old as a top dressing and to onion in the ordinary way before sowing. The results of these experiments conducted for a period of six years, showed that the crops receiving sunn compost gave always slightly more yield than the green manured ones.

#### *Green manure crops as inter-crops*

For those tracts where cultivators object to devoting land entirely to growing green manure crops, the practice of raising a green manure

in-between some cash crop and subsequently ploughing in the former seems quite workable. Jenkins [ 1935 ] refers to such a practice in Sind, where *guar*, is grown in between the rows of cotton and ploughed in just before the flowering of cotton. Roberts [ 1935 ], on the other hand, has found from experience of the Punjab that such interculture is harmful—the young plants of *guar* competing seriously in their early stage with cotton. He has also observed that white-fly which finds in some years a ready host in *guar*, subsequently starts damaging seriously the main crop of cotton. Patel [ 1935 ] reports having used *dhaincha* with success as an inter-crop with cotton on Surat Farm, and lays special stress on the shading effect of the crop on young cotton plants. He further mentions that cultivators in Bombay also grow a row of sunn or few rows of *urd* in between cotton for green manuring purposes.

Desai [ 1935 ] similarly reports using *guar* in-between cotton for experimental purposes in Sind, other crops like *mung*, sunn and soybeans being also tested side by side with *guar*. His observations are that *mung* gives better results than sunn. Next in order are soybeans and *guar*. Green manuring in-between rows could, according to Desai [ loc. cit. ] increase the yield of cotton by about 30 per cent, and in some cases as much as 60 per cent increase was obtained over the control. This practice is becoming very popular with the cultivators of Sind [ Thadani, 1937 ]. Experiments recently conducted at Surat and

reported by Patel [ 1937 ] show that the strip system of partial green manuring leads to an increase of 17 per cent in the yield of seed cotton over the control ; whereas, entire manuring before *jowar* gives an increase of 24 to 41 per cent and green manuring fallow increases the yield of the next cotton crop by 122 per cent.

As has been referred to by Allan [ 1937 ], in the western Uttar Pradesh the cultivators sometimes grow *metka* in-between rows of cotton and these are ploughed in after the cotton picking is over.

#### *Burning green manuring crops*

The practice of burning green manuring crops and applying the burnt residue is not at all prevalent in India. No experiments have been carried out anywhere to test the fertilising action of such a practice. The efficiency of burning a green manure crop ( pigeon-pea and sunn ) as compared with digging in has been the subject of several experiments at Yandev Agricultural Station, Benne Province (West Africa). The results of early experiments show that as regards fertility there is very little difference between burning and digging. But on a poor sandy soil, with pH 5-6 and which has been under cultivation for ten years, ploughing in has been found superior to burning. The physical condition of the soil seems also to have improved materially by the addition of organic matter as an aid to retention of moisture [ Briggs, 1938 ].

## IV. USE AND VALUE OF DIFFERENT GREEN MANURING CROPS

AS has been shown in Chapter II, a fairly large assortment of legumes and non-legumes constitutes the green manuring crops in India. The majority of these, however, consists of legumes ; different species of which are usually selected and grown to improve or maintain the fertility level of the soil. In deciding the agricultural utility of any particular green manuring crop due regard is generally paid to its suitability to fit into the cropping system of the tract, and its seed rate and habit of growth. There are, nevertheless, many tracts in India, specially in the South, where non-legumes are extensively used with success for green manuring purposes [ Ramiah, 1935 ; Bal, 1935 ; Narayan Iyer, 1937 ; Sethi, 1940 ]. Sahasrabudhe [ 1935 ] is of the opinion that non-legumes

are just as effective as legumes on good soils, but on poor soils legumes may exert a better fertilising action. More or less the same view is shared by a number of workers in other tropical and sub-tropical countries, specially in consideration of the carbon to nitrogen ratios of the green manuring materials and their rate of humification in the soil [ Lyon and Wilson, 1928 ; Eden, 1936 ; Roland McKeck, 1935 ].

Besides leguminous and non-leguminous crops and indigenous weeds, leaves, twigs and loppings from trees are generally used for green-manuring rice in Mysore and Travancore [ Coleman *et al.* 1912 ; Narayan Iyer, 1937 ]. For tea the use of leguminous trees like *sau* (*Albizzia stipulata*) [ Mann and Hutchinson, 1905, 1907 ], *dadap*

(*Erythrina lithosperma*) [ Wright, 1905 ; Holland, 1931 ] and a shrub *Rogamedelea* ( *Tephrosia candida*) [ Holland, loc. cit. and Mann and Hutchinson, loc. cit.] are also very common.

*Quantity of green matter and nitrogen added to the soil*

The beneficial effect of green manuring will depend mostly on the quantity of the green matter produced by the crop which is to be incorporated into the soil. The yield of green matter from particular green manure crop depends upon the nature of the crop, the condition of its growth, the stage of maturity and nutrient status of the soil. In Bombay Presidency, for medium soils the average yield of green matter varies from 20,000 lb. to 25,000 lb. per acre. In the Nira Right Bank Canal area where the soil is deficient in organic matter the yield obtained approximates to 18,000 lb. ; whereas, in the area commanded by the Nira Left Bank Canal where the soil is rich and has been manured continuously, the green weight goes up to as much as 69,800 lb. [ Gadgil, 1937 ].

Bal [ 1937 ] reports the average yield of green matter from three common green manuring crops

used in the rice, wheat or cotton tracts of the Madhya Pradesh. His figures are given in Table V. It is not clear whether the lower yields of green matter in the rice tract are due to early harvesting or the nature of the soil.

TABLE V  
*Yield of different green manuring crops in Madhya Pradesh*

Particulars	Green weight per acre (lb.)	
	Rice tract	Wheat or cotton tract
Sunn	4,000 to 10,000	15,000 to 22,000
<i>Sewri</i> or <i>dhaincha</i>	3,000 to 3,000	10,000 to 20,000
Cowpea	3,000 to 7,000	12,000 to 16,000

Mukerji [ 1939-42 ] recorded at Kanpur the following yields of green matter per acre from six leguminous and non-leguminous crops which were used as green manure. The experiment was conducted on properly randomised blocks for three years.

TABLE VI  
*Yield of green manuring crops at Kanpur*  
(Green matter in lb. per acre)

Year	Sown on	Harvested on	Sunn	<i>Dhaincha</i>	<i>Jayanti</i>	Maize	<i>Jowar</i>	Sun flower
1939-40	1-7-39	25-8-39	15,900	12,080	500	12,060	14,700	9,800
1940-41	8-6-40	14-8-40	15,340	8,980	420	11,100	21,900	13,140
1941-42	15-6-41	13-8-41	17,950	1,300	370	8,850	13,250	7,810

It may be observed from the Table that *Jayanti* (*Sebania aegyptica*) does not grow quickly under Kanpur conditions.

Sethi [ 1938 ] studied this problem at Shahjahanpur (U. P.). In experiments conducted for two years in properly randomized blocks, the yield of sunn at different ages was determined. The amount of nitrogen turned under was also estimated. The results obtained have already been given in Table III.

The quantity of nitrogen turned in was clearly reflected in the crop yield experiments at Shahjahanpur during 1936-37. The heaviest yield of sugarcane (Co. 313) was obtained by ploughing in sunn 50 days old. The results obtained are tabulated below [ Mitra, private communication ]

TABLE VII  
*Yield of sugarcane by turning in sunn of different ages*  
(Shahjahanpur)

Age of crop in days	Yield of cane per acre in md.
30	665.09
40	699.99
50	733.33
60	690.39

The amount of nitrogen added to the soil depends upon the stage of maturity. However, in the case of sunn it has been assumed that a crop about ten weeks old under normal conditions adds approximately 60 lb. nitrogen per acre if inverted early in September [ Allan, 1935 ].



Allan (loc. cit.) further came to the conclusion that after making due allowance for a poor crop of sunn under abnormal conditions, it may be taken to add roughly 45 to 50 lb. of nitrogen per acre. Information on this important point for the other green manuring crops is particularly absent and requires investigation.

#### *Application of different green manures to crops*

The increase in the yield of a subsequent crop due to green manuring varies with the locality. In general it has been estimated by Ramiah [1935] that in soils above the average level of fertility it may amount to about 8 to 10 per cent, whereas, on poor soils and lands of average fertility the increase may extend to 20 or 25 per cent. The beneficial effect of green manuring becomes strikingly evident during bad seasons. In Madhya Pradesh sunn has been shown to add roughly 16 per cent to the yield of paddy [Bal, 1935].

There are three principal crops for which green manuring as a practice has been adopted in India, viz.

- (a) for transplanted paddy in areas where early monsoon showers are received or irrigation facilities are available;
- (b) for sugarcane in tracts where it was customary to have a cultivated fallow, and
- (c) for wheat under conditions where it is possible to bury the crop by the middle of August and irrigation water for decomposition is available later.

There is, however, some scattered evidence of the use of green manure for crops other than those mentioned above.

(a) *Paddy*. Dobbs [1915] mentioned that on the heavy delta soils at Manganallur (Madras) the application of a green manure crop in the ordinary way resulted in a failure of paddy due to bad drainage; whereas, at Samalkota (Madras) in 1909 increased yields of straw were obtained as a result of heavy dressing of green manure. Thomas and Raju [1914-18] reported an increase of 474 lb. per acre during 1915 and 426 lb. during 1916 as a result of green manuring rice at Palur Experimental Station in Madras. The green manure was, however, supplemented with bone-meal and potash. All these experiments were done on unreplicated plots. In South India, Molegode [1918] similarly obtained 70 per cent increase in the yield of rice as a result of sunn green manuring. Table VIII records the yield of paddy after green manuring at Marthur Farm Rao, 1923].

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TABLE VIII

*Yield of paddy at Marthur Farm as a result of green manuring*

Treatment	Grains lb. per acre	Straw lb. per acre
Control	1,360	1,840
Green manuring with sunn	1,840	2,650
Green manuring with cowpea	2,120	2,520

Ramiah [1935] points out that the value of green manures on rice is doubtful on soils of good fertility giving about 3,000 lb. of grain per acre, but on soils of ordinary fertility the value becomes apparent. He has given illustrations in support of this statement from his experience in Madras Presidency. On Coimbatore wet lands the yield of rice increased from 2,000 to 4,000 lb. per acre as a result of systematic growing of a green manure crop in rotation with rice. Similarly, in Hospect area of Bellary district the average yield of rice as a result of green manuring has always been above 3,000 lb. per acre. The results of soil analysis for these areas are, however, not available.

In Madhya Pradesh similar beneficial effect of green manuring has been observed with transplanted paddy in tracts where irrigation facilities are available. But if sown *in situ* with the rains the green manuring crop generally suffers from waterlogging. As pointed out by Allan [1937] green manuring for broadcast paddy is not feasible unless the green manuring crop is sown in March or early in April and ploughed in before broadcasting is done. This is a condition which can hardly be realised in practice, specially in regions where irrigation facilities do not exist. A partial effect may, however, be secured by sowing a mixture of paddy and sunn, uprooting the latter and puddling into the field after about six weeks' growth. The green manure crop in that case is also apt to suffer from waterlogging; hence this suggestion of Allan has not been found practicable in Madhya Pradesh. This difficulty may be solved by sowing on the *bunds* indigenous weeds or crops like *sesbanias*, cutting and puddling them as manure [Bal, 1937]. Allan [1937], on the other hand, does not consider this to be a practical proposition. The alternative of growing a green-manuring crop like sunn on well-drained areas, cutting and transferring to paddy fields has also never been popular with the cultivators, chiefly because the scattered nature of the holdings reacts adversely against this practice. For

transplanted paddy it is rather difficult to secure a good growth of the green manuring crop *in situ* before the paddy seedlings are ready for transplantation. But according to Allan [*ibid*] if the puddling of the green manure is done even a week earlier than transplanting no ill-effect is noticeable and an increase of about 16 per cent may be taken as a rough addition to be obtained in the yield of paddy.

As stated by Bal [1937] and Sethi [1940] the difficulty of green manuring paddy is much less in evidence in Madras, Bengal and Uttar Pradesh.

The experiments conducted at the Rice Research Station, Nagina (U.P.), as described by Sethi [1940] indicated that of all the green manures tried for paddy during 1932 to 1937 sunn alone showed consistently the best results. Sunn grown *in situ* was ploughed in after nine weeks and allowed to rot for two weeks before sowing paddy. During 1934-1935 when the green manure was brought from outside and ploughed in, no response was indicated.

In Orissa (1933 to 1938), the effect of different green manuring crops on paddy was studied on light and heavy clayey loams. *Dhaincha* seems to be best suited for paddy in that province.

(b) *Sugarcane*.—Green manuring for sugarcane is probably the easiest and could be done as late as September. This is established as a sound practice on any class of soil varying from alluvial to black or red soils. The advantage of green manuring over no manure has been demonstrated at Shahjahanpur

where an increase of 43.4 per cent was reported by using sunn. The percentage of sucrose was, however, found to be low for green manured plots. The results are given below (Sethi *et al.* 1938).

TABLE IX

Comparison between green manuring and no manuring sugarcane (Shahjahanpur)

Particulars	Green manured	Non-manured
Yield of cane per acre in md.	891.66	621.74
Percentage sucrose in juice	14.41	15.29

At Jorhat cowpea as a green manure for sugarcane during 1937-38 gave only a slight increase in yield over no manure. At Kopargaon Farm on the Godavari Canal, *ran-mulki* has been found to give practically the same effect as sunn. [Rege, 1941]

(c) *Wheat*. For wheat sufficient interval (approximately two months) between inversion and sowing and enough moisture usually 12 in. to 16 in. of rain or irrigation water for decomposition are considered essential by Allan [1915]. Green manuring wheat is thus restricted to alluvial soils having irrigation facilities and is not considered safe on heavy black soils under dry *rabi* crop conditions. Allan [1915] however, has recorded an increased yield of 223 lb. of grain (wheat) after sunn and 203 lb. after *sewri* as a result of three years' trials in Madhya Pradesh. In an experiment conducted by Mukerji [1938 to 1940] at Kanpur on the comparative effect of five green manure crops on wheat, the following results were obtained.

TABLE X

Yield of wheat as a result of green manuring (Kanpur)

(lb. per acre)

(6 × 5 randomized blocks)

Year	Sunn		<i>Dhaincha</i>		Control		Maize		<i>Jowar</i>		Sun flower	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
1939-40	2,325	5,415	2,350	5,360	2,435	5,705	2,403	5,207	2,359	5,538	2,485	5,508
1940-41	2,877	5,064	2,571	4,559	2,599	4,361	2,358	3,965	2,130	3,548	2,417	4,316

The results have so far shown that the differences in the yield of grain from the six treatments are not significant.

(d) *Other crops*. At Lyallpur in 1932, Lander [1935] got statistically significant increase in the yield of cotton by using *senji*

as a green manure. The value of different leguminous crops when grown in rotation with cotton in Sind has been reported by Barakzai [1935] and Desai [1935]. The value of berseem stubbles as soil fertiliser has been recognised in

that province. Table XI gives the results of a trial conducted during 1934-35 and quoted by Desai [loc. cit.] on the relative value of different leguminous crops as judged by the yield of seed cotton, for bringing about recuperation of nitrogen in the soil :

TABLE XI

*Yield of cotton grown after leguminous crops and jowar in Sind*

Previous crop	Succeeding crop cotton seed in lb. upto 31-12-34	Remarks
1. <i>Mung</i>	1,400	The last picking was not over.
2. Soybeans	1,287	
3. <i>Guar</i>	1,147	
4. Groundnut	1,064	
5. Fodder jowar	921	

Sahasrabudhe [1934] describing manurial experiments conducted in the Bombay Presidency during 1896 to 1931 reports that for maize, when *niger*, sunn and *kulthi* were compared as green manures against fallow or with each other, sunn was found to be the best. In Africa the results of three years' experiments have shown that sunn gives a considerable increase in the yield of maize ; whereas, weeds alone as green manure do not increase the fertility of the land [Fuggles-Conchman, 1939].

Green manuring does not show any effect on the yield of *jowar* and potatoes in the Bombay Presidency ; whereas, on tobacco it was found better than farmyard manure [Sahasrabudhe, 1934]. Definite depletion in the yield of *arhar* under the influence of green manure, even in conjunction with superphosphates has been observed at Pusa (1929) in long term experiments laid out on duplicate plots, and it has been suggested that green manuring leguminous crops is harmful.

At Pusa *C. mujassi* has been found to be the best for oats [Iyer, 1939]. For tobacco, sunn, cowpea and *dhaincha* were found almost equally useful [Dobbs, 1915]. For jute at Mymensingh sunn is reported to bring about an increased yield. Since it never gets very cold there it is possible to grow sunn in October and bury it in December.

(e) *Garden crops.* Green manuring as practised in India for plantation crops and fruits has been

reported only by a few workers. In their bulletin on tea plantations Mann and Hutchinson [1906] have described all the experiments on green manuring tea, carried out in Assam up to that date. The results on record afford ample evidence to prove the beneficial effect of green manuring on tea. For tea reference has already been made to trees like *sau*. The use of *Tephrosia candida* (*boga medelea*), a shrubby plant, *arhar*, *dhaincha* and cowpea generally leads to increased yield of tea. Besides the above *mati-kalai* (*Phaselous mungo*) is also grown for green manuring in the tea gardens in Assam. A significant fact, however, is that no benefit to tea occurs whilst the legumes are growing among tea, but following burial or loppings, and specially after the leaves have rotted in the soil, the yield of tea is markedly increased.

Green manuring is also reported as an aid to fertility in cocoanut gardens, and is used effectively for yam and betel vines. On coffee estates it is now a regular feature to grow *Crotalaria striata* and *Crotalaria trifoliata*, etc. and to cut and apply these as mulches. Ramiah [1935] in describing the importance of green manuring for cocoanut mentions that a crop of cowpea grown under the trees during the monsoon and inverted after the rains brings about on an average an increase in the yield of the fruits by 10 per cent.

It is generally recognized that in newly planted orchards green manuring by sunn considerably improves the yield of fruits. Even for old orchards of citrus in the Agra district of Uttar Pradesh green manuring with sunn in between the rows of the trees is found very useful both for growth and bearing. But it is now reported from the Punjab ; [Punjab Department of Agriculture, private communication, 1941] that although *guar* has proved to be a very useful green manure for ordinary crops yet it has given either negative results or proved even detrimental to the growth and productivity of citrus trees. The reason adduced is that the water and plant food requirements of both *guar* and citrus being at their maximum in the summer, a competition is set up between the *guar* and citrus roots. Although no experimental evidence is yet available, it is presumed that this competition could be avoided by using a winter legume like *senji* as green manure.

#### *Different parts of green manuring crops*

Attempts have been made to study the relative fertilising value of different parts of green manuring crops. Sunn has so far received most attention in this direction. Joshi [1922] was probably the

first to have studied this problem scientifically and has done considerable work on this subject. He found that roots and stems of green manures were of little immediate value to the succeeding crop which benefits chiefly through the decomposition of leaves. With a view to test these points further pot experiments were carried out simultaneously with field experiments for three years at Pusa. The chief observations recorded for six different green manure crops were :

- (a) The application of leaves alone of all the plants used as green manures gave high yield of oats.
- (b) Burying the whole plant resulted in lower yields than those obtained by adding leaves alone.
- (c) The use of stems and roots had an injurious effect on the succeeding crop.

According to the above author these results are applicable only to the Gangetic alluvial soil and not to black cotton soil in which cellulose material may decompose easily and the decomposition of leaves may not be rapid enough. Bal [1923] has, however, shown that the more tender the plant is the better is its decomposition in black cotton soils, which is a conclusion contrary to the above assumption of Joshi [1922].

Lander, Wilsdon and Lal [1923] while studying the comparative value of a number of green manure crops in the Punjab, observed that the removal of the above-ground portion of a leguminous crop caused a depression in the yield of the subsequent crop. These observations of Joshi, and Lander *et al.* are not found to hold good in the case of berseem stubbles which have shown considerable fertilising action on cotton in Sind. Barakzai [1937] from his experience in Sind has reported marked increase in the yield of cotton after the berseem stubbles are buried in the soil and left over a period of two weeks for decomposition. He advances the hypothesis that since the underground portions of such leguminous crops are

tender and easily decomposable, they add a considerable amount of humus and nitrogen to the soil. Mukerji's work [1937-41] on the effect of growing berseem and ploughing in the stubbles after the last cutting is over on the yield of subsequent crops of *jowar* and cotton under Kanpur conditions has, however, failed to substantiate the claims of the Sind workers. No statistically significant increase in the yield of cotton lint or *jowar* fodder was obtained as a result of berseem cultivation. Singh and Singh [1936] set out to analyse chemically the sunn plant at various stages of its growth and concluded that the greatest manurial efficiency could be attributed to the leaf, the stem being less useful in this direction. The root, on the other hand, stood midway between the leaf and the stem. It has accordingly been suggested by the above authors that the leaves and roots should be ploughed in for green manuring and the stem used for fibre production. No field data on crop yields have, however, been cited to lend support to these observations.

Sethi [1938] studied this problem at Shahjahanpur. The results of experiments conducted for two years in properly randomized and replicated blocks afford quantitative data on the yields of green matter and the amount of nitrogen turned under in lb. per acre for the different parts of sunn and the whole plant. The results have been summarised in Table III (p.7).

The total nitrogen per cent in the soil as a result of ploughing in the different portions of sunn was studied at the same station throughout the season in 1935-36 and the highest nitrogen accumulation was observed in the treatment receiving whole sunn plants, followed by those receiving tops and roots. Actual crop yield data during the three years, 1936 to 1939, also showed the same trend. Whole sunn plants consistently led to the best results followed by tops and roots. The yield figures for each of the three years are given in Table XII (Mitra, private communication).

TABLE XII  
Manurial value of different portions of sunn (Shahjahanpur)  
(4 × 4 randomised blocks during 1936-38 and 4 × 8 during 1938-39)

Treatments	1936-37				1937-38				1938-39			
	Yield of cane lb. per acre	Percentage over control	Sucrose per cent	Purity per cent	Yield of cane lb. per acre	Percentage over control	Sucrose per cent	Purity per cent	Yield of cane lb. per acre	Percentage over control	Sucrose per cent	Purity per cent
1. Control . . . . .	33,235	100.0	19.93	90.90	34,049	100.0	18.82	89.58	49,861	100.0	20.32	93.11
2. Sunn tops only . . . . .	41,774	125.7	20.03	90.50	37,038	108.8	18.05	90.42	51,989	104.2	19.72	90.61
3. Sunn roots only . . . . .	42,048	126.5	20.18	91.40	33,002	96.9	18.67	90.78	51,280	103.2	19.48	89.59
4. Sunn whole plants . . . . .	50,163	150.9	20.06	91.45	36,501	107.2	18.68	89.52	53,406	107.1	19.36	90.10
S. E. . . . .	2,244	6.7	..	..	1,549	4.5	..	..	1,637	3.3	..	..

It will be noted from the above Table that removing stems from the whole plant and ploughing in only the tops does not diminish the fertilising value of sunn to a very great extent. A similar view has been expressed by a number of other workers in India and it has even been suggested that the profit accruing out of the sale of the fibre from the stems will more than balance the slight fall in crop yield due to the stems being excluded for green manuring purposes.

#### *Green manuring plants for dual purposes*

In view of the finding that the removal of hard woody stems from a green manuring plant does not influence its manurial value to a great extent, attempts have not infrequently been made to utilise a green manure crop for dual purposes, viz. a part being used as manure and the rest either fed to cattle or utilised for production of fibre. Thus, as indicated by Joshi [1922], the stalks of cowpeas could serve as a fodder for cattle and considerable extra benefit might be obtained by diverting even half of the crop to that end. *Guar* stalks also could similarly be fed to cattle. According to Joshi [*ibid*] better yield of a succeeding crop is obtained if the hard woody stalks of sunn are removed and utilised for fibre production. *Dhaincha*, unfortunately, can not afford this dual purpose [Dobbs, 1916]; but Sornay [1918] mentions that a fibre of fair strength could be extracted from this crop too. This requires further investigation.

Sayer [1935] conducted an experiment at Pusa in which the sunn crop was allowed to grow a

little longer and the tops and roots were ploughed in—the stem being used for fibre production. The effect of this treatment on wheat was compared against that of burying the whole plant. The average of two years' yield showed that with a slight decrease in the outturn of the wheat grain, it was possible to get about 665 lb. of sunn fibre. The economics of the two treatments showed a slightly more profit in the case when fibre extraction was resorted to. For a similar experiment on paddy conducted at Nagina (U.P.) Sethi [1940] records that green manuring with the whole plant showed a net profit of Rs. 53 as. 2 per acre; whereas, tops, leaves and roots gave only a very low margin of profit even after taking into account the sale proceeds of the fibre. Bal [1937] considers that even if a sunn crop was grown exclusively for fibre production it would prove beneficial to the succeeding cotton crop, as the leaves falling on the ground and the root residues left therein would improve the soil fertility.

The dual use of sunn referred to above, may not be feasible for crops like wheat and paddy, since the burial of the green manure can not be delayed too much in such cases; but for sugarcane under irrigation the ploughing in of manures could be postponed for some time and the mature stems of sunn utilized for fibre production. The Department of Agriculture, Uttar Pradesh, have done considerable work on this aspect of green manuring sugarcane and the main results obtained are briefly given in Table XIII.

TABLE XIII

*Green manuring sugarcane (Co. 312) by sunn of different ages in Uttar Pradesh (Yield of cane in lb. per acre)*

(4 × 4 randomized blocks)

Serial No.	Locality	Year	Sunn ploughed in 60 days after germination	Sunn ploughed in 75 days after germination	Sunn cut for fibre 75 days after germination, and roots and tops ploughed in	Sunn cut for fibre 90 days after germination and roots and tops ploughed in
1	Mainpuri Farm	1938-39	97,619	92,448	91,400	87,290
		1939-40	79,076	79,063	78,816	76,991
		1940-41	67,829	63,728	66,099	64,811
2	Kalai Farm (Aligarh)	1937-38	72,301	72,411	70,492	71,576
		1938-39	72,169	77,387	73,954	71,482
3	Kalianpur Farm (Kanpur)	1937-38	3,518	3,518	3,500	3,432*
		1938-39	0,742	3,887	3,790	3,839*
		1939-40	3,644	3,786	3,692	3,590*
4	Atarra Farm (Banda)	1940-41	59,450	62,216	65,190	63,622

From the above results it is evident that harvesting sunn for fibre 90 days after germination and ploughing in roots and tops, has in most cases given a lower yield of cane than in the corresponding treatment 75 days after germination. Similarly, the yield of cane obtained with the whole plants being ploughed in has in general been somewhat greater than when the stems were removed for fibre production 75 days after germination. There are *a priori* reasons to believe, however, that this slight depression in the yield as a result of not burying the stems may not affect the total net profit; since additional income is apt to come through the sale of the sunn fibre. The economics of this practice as worked out in the Uttar Pradesh and elsewhere will be discussed in a subsequent section.

#### *Residual effect of green manuring*

Although in general the utility and value of green manuring have been realised, yet there is lack of evidence to prove the extent of the residual effect it leaves in the soil. On Pusa soils sunn as a main source of nitrogen appears insufficient in a two year four-course rotation of maize, *arhar* and oats. Experience in the Punjab, however, shows that increased yields of crops may be obtained as far as five years after the original application. Khan [1923] found that the beneficial effect of green manuring sugarcane with *bhang* (*Cannabis sativa*) lasted for four years. The results of field experiments at Rothamsted from 1899 to 1923, as cited by Nicol [1933], show that legumes exert a considerable residual value over a period of several years as evinced by increased grain yields. Joachim [1931], however, states that under tropical conditions the effect of green manuring may be expected to last for only about six months so far as the soil nitrogen is concerned. Similarly, it has been reported by Fuggles-Conchman [1939] that in Morogoro (East Africa) the beneficial effect of green manuring with sunn remains in evidence only for one year. These differences are probably due to different soil and climatic conditions, and the problem requires much further investigation.

#### *Relative value of green manuring and farmyard manure*

Not much work on scientific lines has been done in India to compare the relative efficiency of green manuring and farmyard manure when used as organic manures. Since farmyard manure still happens to be the chief indigenous source of orga-

nic matter and nitrogen to the soil, any change from the existing system of manuring requires careful studies. Rege [1941] has summarised in detail recent experiments done on sugarcane in which green manures have been compared with farmyard manure. It seems that many systematic investigations on this problem are not on record.

In Bihar at two stations, viz. Sepaya and Musherri, in experiments conducted over a number of years, sunn (green manure) and farmyard manure were applied on the basis of 40 lb. nitrogen and 20 lb. phosphoric acid with and without top dressing at Sepaya during 1932 to 1936 and on equal quantity basis at Musherri during 1933 and 1934. In general it has been mentioned by Rege [loc. cit.] that farmyard manure gave better yield of cane than sunn green manuring in these experiments, although juice richer in sucrose was obtained through the latter. In the *Annual Report on Experimental Farms in Bihar and Orissa* for the year 1934-35, it has, however, been mentioned that 'the fact that green manure is better than farmyard manure as an organic manure has been confirmed.'

At Padegaon an experiment was conducted for two seasons (1936 to 1938) in which three basal manures—sunn (green manure), farmyard manure and groundnut cake—with two levels of top dressings at 150 lb. nitrogen and 225 lb. nitrogen per acre were compared for sugarcane. The results obtained, as given by Rege [loc. cit.] are presented in Table XIV.

Comparing the results obtained through farmyard manure with those obtained through green manure, it seems that, although the differences in the yield of cane by using these two manures are not statistically significant, farmyard manure with 150 lb. nitrogen has given, in both years, lower yield of cane than green manure. With higher nitrogenous top dressing the yields become more or less the same. The sucrose percentage figures tend to show better availability of nitrogen in the case of green manure.

At Kanpur during 1940-41 a similar experiment was laid out by Mukerji [1940 to 1942] in which sunn green manuring was compared with farmyard manure and compost as basal manures for sugarcane. The experiment was conducted on a split-plot factorial ( $7 \times 4 \times 3$ ) design in which the basal manures constituted the whole plot treatments and mixtures of inorganic and organic nitrogenous manures as sub-plot treatments. The results obtained for the whole plot

TABLE XIV

Comparison of sunn green manure, farmyard manure and groundnut cake as basal manures, Padegaon 1936-38

Treatments	(Lay out 6×4 randomized blocks)							
	1936-37				1937-38			
	Yield of cane lb per acre	On percentage basis	Sucrose percent	Purity per cent	Yield of cane lb. per acre	On percentage basis	Sucrose percent	Purity per cent
150 lb. N per acre	78,064	100.0	18.99	<i>Sunn as basal</i>		100.0	20.53	92.55
225 lb. N per acre	99,098	126.9	20.16	89.32	62,944	128.8	19.78	92.76
				90.67	81,088			
150 lb. N per acre	74,547	95.5	20.49	<i>Farmyard manure as basal</i>		96.8	21.05	92.76
225 lb. N per acre	100,150	128.3	20.45	89.08	58,688	130.2	18.58	88.55
				90.18	81,984			
150 lb. N per acre	101,517	130.0	19.66	<i>Groundnut cake as basal</i>		135.9	19.86	90.93
225 lb. N per acre	108,102	138.5	19.82	90.80	85,588	149.1	18.93	90.20
S.E.	5,398	6.9	..	89.82	93,856	5.3	..	..
				..	3,337			

treatments for the year 1940-41 showed no significant difference in the yield of cane between sunn green manuring, compost and farmyard manure treatments. Almost identical results were obtained for wheat in the previous year at the same station.

In the black cotton soils of the Surat tract, experiments have been conducted for a number of years in which the relative manurial value of farmyard manure and green manuring with *dhaincha* has been compared on cotton and *jowar*. These

experiments are described by Patel [1937] and clearly show the beneficial effect of green manuring as compared with farmyard manure.

*Dhaincha* was grown in strips between two rows of cotton and was buried after a month's or six weeks' growth when it was nearly one foot high. The yield of green matter thus incorporated in the soil was never very high (about 7,000 lb. per acre) but the results obtained clearly show the superiority of green manuring as compared to farmyard manure at five cartloads per acre. The data of the experimental results are given in Table XV.

TABLE XV

Cotton green manuring experiment, Surat (1934-39)

(4 × 4 latin square)

Treatments	1934-35		1935-36		1936-37		1937-38		1938-39	
	Yield of cotton lb. per acre	Per cent increase over control	Yield of cotton lb. per acre	Per cent increase over control	Yield of cotton lb. per acre	Per cent increase over control	Yield of cotton lb. per acre	Per cent increase over control	Yield of cotton lb. per acre	Per cent increase over control
1. No manure	593.4	..	554.6	..	450.1	..	382.7	..	522.7	..
2. Farmyard manure at five cart loads per acre.	651.0	9.71	584.0	5.30	480.6	6.8	382.2	0.1	566.2	8.23
3. <i>Dhaincha</i> plus farmyard manure at five cartloads.	647.4	9.09	658.0	18.63	587.2	30.5	237.3	37.9	646.1	23.6
4. <i>Dhaincha</i> alone	640.1	7.87	684.9	23.5	546.2	21.4	215.0	43.8	578.0	10.7

It will be observed that, if the results obtained during 1934-35 are not taken into consideration, during the remaining years the superiority of *dhaincha* green manuring over farmyard manure

is clearly shown. However, it may be mentioned that in adding farmyard manure the nitrogen content was not taken into consideration. The treatment in which both *dhaincha* and farmyard manure

were used has given the best results evidently due to the double quantity of nitrogen which it received from both farmyard manure and *dhaincha*.

Similar experiments were laid out for *kharif jowar* during 1934 to 1939 and the superiority of *dhaincha* green manuring over farmyard manure at five cartloads per acre was also indicated in these experiments. An increase of 36.93 per cent and 9.41 per cent in the yield of *jowar* grains over control with *dhaincha* green manuring was secured as against 5.36 per cent and 0.34 per cent with farmyard manure alone during 1934-35 and 1938-39 respectively. The yields of *jowar* grain obtained during the remaining years were not favourable owing to deficiency of rains and in one year two varieties of *jowar* were sown in different treatments.

The results for those years are, therefore, not comparable.

At the same station the residual effect of *dhaincha* green manuring and farmyard manure was compared on the next *jowar* crop in the case of cotton green manuring experiments described above ; and on next cotton crop in the case of *kharif jowar* green manuring experiments. In general *dhaincha* gave significantly greater residual effect than farmyard manure.

From the results available, so far, it may be concluded that the superiority of green manure over farmyard manure has been indicated in some of the provinces where such investigations have been carried out.

## V. GREEN MANURING IN CONJUNCTION WITH ARTIFICIALS

### *Application of fertilizers to the green manuring crop*

One of the main objects of growing a green manuring crop being to provide as much of organic matter as possible, it is natural that every effort should be made to secure the maximum yield of green material. On very poor soils the outturn of a green manure crop is likely to be very meagre ; hence, the benefit from the crop may be much below expectation. The addition of nitrogen to a leguminous crop is not usually necessary since the legume is capable of collecting nitrogen by itself ; but an application of phosphatic and potassic fertilizers often stimulates the growth of the crop, and thus enables the cultivator to obtain within a comparatively short period a large quantity of green material and nitrogen. Moreover, the fertilizers added serve the dual purpose of increasing directly the yield of the green manuring crop as well as that of the succeeding crop by being available after the inversion of the green material into

the soil. The addition of fertilisers affords an additional advantage of hastening the growth of the green manuring crop ; thereby reducing the period over which the crop otherwise would have occupied the land.

Some notable work on a quantitative basis has in this connection been carried out in the Bombay Presidency in recent years. The necessity for increasing the bulk of the green manuring crops is now felt somewhat acutely in the Bombay-Deccan where owing to a large increase in the acreage under sugarcane in the canal commanded areas, the demand for organic manures has far exceeded the available scanty supply of cattle dung.

An experiment was started in 1937-38 at Padegaon (Bombay) to test whether any system of manuring could bring about an increase in the yield of sunn. The results as summarised by Rege [1941] are given in Table XVI.

TABLE XVI  
*Fertilising sunn crop, Padegaon, 1937-38*  
Layout 8×4 randomized blocks

Treatment	No basal manure		F.Y.M. 10,000 lb. per acre	
	Yield of green matter in lb. per acre	Percent over no-manure	Yield of green matter in lb. per acre	Per cent over no-manure
1. No manure . . . . .	16,775	100	18,125	108.0
2. 20 lb. N alone . . . . .	17,375	103.6	17,775	105.9
3. 50 lb. P <sub>2</sub> O <sub>5</sub> alone . . . . .	18,200	108.5	17,575	104.8
4. 20 lb. N+50 lb.P <sub>2</sub> O <sub>5</sub> . . . . .	18,475	110.1	18,525	110.4
S.E. . . . .	558.3	3.3	558.3	3.3



It would be noted that the treatment where both nitrogen and phosphates were used has given maximum yields both with and without any basal dressing. Next in order of importance comes phosphate alone. The other treatments do not record any appreciable increase. Padegaon soil is deficient in phosphates, and this addition, therefore, seems to benefit the green manuring crop. It may be observed that the increase in the yield has been rather slight (10 per cent), and as the economics of this practice have not been worked out, any general recommendation would be risky unless the problem is studied in a much more extensive form.

It has been observed in Assam (Borbhetta) that cowpeas, *dhaincha* and *mati-kalai* hardly grow without some phosphate, but give excellent crop with basic slag at 600 lb. per acre [Mitra, 1935].

Arnold [1931] carried out in Rhodesia an experiment to study whether it was more profitable to apply phosphatic fertilizers direct to a maize crop after ploughing under an unfertilised green manure crop or to the green manure crop itself which was to be followed by maize. A difference of only 3.00 'bags' resulted in favour of phosphates being applied to the green manure crop in the case of raw phosphatic rock and only 0.57 'bags' in the case of bone-meal and super.

TABLE XVII

*Difference in the yield of 'bags' of maize as a result of applying phosphatic fertilizers (Arnold)*

Treatment	Applied to green manure crop	Applied to green manure maize
1. Raw phosphatic rock	+14.11	11.11
2. Bone-meal and super	+11.48	10.91

Rao [1923] in Ceylon found superphosphates added to sunn at the time of sowing to be beneficial to the succeeding crop of paddy. This was, however, not found to be the case when sunn was replaced by cowpea. This is attributed to the rapid growth of the cowpeas brought about by superphosphate and thus involving the inversion of mature stems, the nitrification of which proceeds too slowly in the soil to keep pace with the nitrogen requirement of the succeeding crop. The results obtained are given in Table XVIII.

It may be noted from Table XVIII that the growth of sunn in the unmanured treatment being very poor the observed response to the addition of phosphates is specially striking. Bal [1936] also maintains, in view of the work carried out by him

TABLE XVIII

*Yield of paddy with super phosphate in conjunction with sunn and cowpea (Marthur Farm 1923) lb. per acre.*

Treatments	Green matter	Paddy grain	Paddy straw
1. Control	..	1,360	1,840
2. Sunn	2,920	1,840	2,560
3. Sunn stimulated by super @ 240 lb. per acre.	15,680	2,520	3,400
4. Cowpea	1,640	2,120	2,520
5. Cowpea stimulated by super @ 240 lb. per acre.	3,560	2,080	2,680

in Madhya Pradesh, that phosphatic fertilisers applied at the time of sowing green manures considerably intensify the beneficial effect of the latter and even increase the phosphate content of the paddy grains.

#### *Fertilizing effect of artificia's with green manuring*

The use of green manures in conjunction with artificials has been studied in India mainly for paddy and sugarcane, and the available data have been classified below according to the nature of the artificial used.

(a) *Nitrogenous artificials.* Harrison and Aiyer [1916] suggested using green manures in conjunction with cyanamide for paddy under South Indian conditions. They believed that as cyanamide on decomposition furnished ammonia which could be utilised by the rice plant, the use of this could produce better effect than any other artificial. The addition of some ammonium sulphate to any form of green manure at the time of inversion has resulted in material increase in the yield of paddy in Mysore. Narayan Iyer [1937] reported a pot culture experiment in which an increase in the yield of paddy was obtained with ammonium sulphate used in conjunction with green manure. His results are given in Table XIX.

TABLE XIX

*Yield of paddy with sulphate of ammonia and green manure (pot-culture trial, Mysore)*

Treatment	Per cent yield
1. No manure	100
2. Green manure alone	127
3. Green manure + S.A. applied simultaneously	204
4. Green manure + S.A. three weeks later	190

The application of sulphate of ammonia at the time of burial has practically doubled the yield. No field data are, however, available in this connection.

The results obtained at Shahjahanpur have been summarised by Sethi *et al.* [1938] and the average yields for three years are given in Table XX along with the sucrose percentage and purity coefficient.

TABLE XX

*Manurial trials with sugarcane at Shahjahanpur*

(4 × 4 randomized blocks during 1933-35 and latin square during 1935-36)

Treatment	1933-34				1934-35				1935-36			
	Yield of cane lb. per acre	Per cent over green manure alone	Sucrose per cent	Purity per cent	Yield of cane lb. per acre	Per cent over green manure alone	Sucrose per cent	Purity per cent	Yield of cane lb. per acre	Per cent over green manure alone	Sucrose per cent	Purity per cent
1. Green manure	69,550	100.0	17.26	88.82	74,809	100.0	17.06	89.78	54,671	100.0	17.32	87.37
2. Green manure + S.A. (Total 120 lb. N).	75,022	107.9	16.82	87.84	85,526	114.3	16.86	89.25	65,207	119.8	17.14	86.99
3. Green manure + castor cake (total 120 lb. N)	73,644	105.9	16.72	87.81	83,386	111.5	16.84	84.43	65,719	120.2	17.21	86.64
4. Green manure + Farmyard manure (total 120 lb. N).	75,122	106.6	17.06	87.53	84,509	112.9	18.22	88.53	65,904	120.5	17.39	87.57
S.E.	1,283	1.8	..	..	1,659	2.2	..	..	1,000	1.8	..	..

It will be seen from Table XX that the increase in the yield obtained with either sulphate of ammonia, castor cake or farmyard manure over green manure alone is significant, although differences between the three top dressings are not very remarkable.

Results of field experiments recently available at Kanpur [Mukerji, unpublished], both for wheat and sugarcane, are summarised in Tables XXI and XXII.

TABLE XXI

*Manurial trials with wheat (C 13) at Kanpur*  
(7 × 4 × 3 split plot design)

Treatment	Yield of wheat grain in lb. per acre	Per cent over green manure alone
1. Green manure (sun) alone	1242.0	100
2. G. M. + castor cake at 50 lb. N per acre	1530.0	123
3. G. M. + rape cake at 50 lb. N per acre.	1478.4	119
4. G. M. + groundnut cake at 50 lb. N per acre.	1555.2	125
5. G. M. + sulphate of ammonia at 50 lb. N per acre	1520.0	122

It appears that addition of oil-cakes or sulphate of ammonia to green manure leads to very marked increase in the yield of wheat as compared with green manure alone. As a supplement groundnut cake seems to be the most effective followed by castor cake and sulphate of ammonia.

TABLE XXII

*Manurial trials with sugarcane (Co. 312) at Kanpur*  
7 × 4 × 3 split plot design

Treatment	Yield of cane lb. per acre	Sucrose per cent	Per cent over green manuring alone
1. Green manure (sun) alone	56,040	14.88	100
2. G. M. + castor cake at 100 lb. N per acre	76,648	14.65	137
3. G. M. + rape cake at 100 lb. N per acre	78,104	15.09	139
4. G. M. + groundnut cake at 100 lb. N per acre	58,296	14.40	104
5. G. M. + sulphate of ammonia at 100 lb. N per acre	61,736	14.90	110

Very significant increase in the yield of cane has been obtained by supplementing green manure with castor cake and rape cake. It is also interesting to note that the increased yields secured with both sulphate of ammonia and groundnut cake applied in conjunction with green manure are not very striking.

From the results recorded in Tables XX, XXI, and XXII it would appear that for wheat as well as for sugarcane, under the conditions prevailing in Uttar Pradesh, the addition of oil-cakes to green manure brings about a marked increase in the yield. The economic aspects of this practice require further investigation.

(b) *Phosphatic artificials.* Viswanath [1937] has scrutinised the results of 257 experiments conducted all over India and reported in various Journals, Bulletins or Reports. He has found that out of ten experiments conducted with green manures and phosphates eight gave significant increase in yield; and that out of eighteen such experiments on green manure with nitrogen and phosphates ten gave significant increase in the yield and in the case of the remaining eight the yields were not significantly higher than that with green manure alone. There are thus *a priori* reasons to believe that the use of phosphatic fertiliser as a supplement to green manures is evidently beneficial, and the most responsive crop in this connection is found to be paddy.

There is ample evidence of the beneficial effect of adding phosphates to green manures for paddy in the Madhya Pradesh, Madras, Bombay and the tract bordering the Bay of Bengal. The only exceptions on record where such additions have not increased the yield to a great extent are Nagina in the western Uttar Pradesh and three stations in Madras (Aduturai, Smalketa and Palur). During 1935 to 1938 at Nagina the addition of superphosphates slightly increased the yield of paddy and the results obtained are detailed in Table XXIII (Mitra, private communication).

TABLE XXIII

Yield of paddy in lb. per acre (Nagina, U. P.)

Treatment	1935	1936	1937	1938	Average	Per cent increase
1. Control	2,574	1,320	1,350	1,629	1,718	100
2. Green manure	2,657	2,619	3,701	1,913	2,723	158
3. Green manure + super-phosphate	2,890	2,385	3,736	2,045	2,764	161

Since at Nagina the addition of superphosphate increases the yield only very slightly, as compared with green manure alone, the extra profit is not at all found to be commensurate with the cost of the fertiliser used.

Sethi [1941] in his monograph on 'Manuring of Paddy' has given a brief account of the experiments conducted at various experimental stations where the addition of phosphates to green manures at the time of inversion has been tested. At Gaya (Bihar) during 1936-37 increasing the dose of superphosphate resulted in better yields of both

straw and grain. The results are reproduced in Table XXIV.

TABLE XXIV

Green manuring with superphosphate—Paddy experiments (Gaya, Bihar)

Treatment	Increase in output		Net profit lb.
	Grain lb. per acre	Straw lb. per acre	
1. Green manures at 125 md. + super at 20 lb. per acre	1936		Rs. As. 13 8
	630	371	
2. Green manure at 125 md. + super at 40 lb. per acre	1937		17 13
	869	457	
1. Green manure at 125 md. + super at 20 lb. per acre	676	427	14 0
	830	513	17 4

At Richhai (M. P.) during 1930 to 1935 significantly higher yields of paddy were obtained through the use of green manures in conjunction with superphosphates. Similar results have been reported from Dacca (now in Pakistan), Berhampur (Orissa) and Cochin.

For other crops, too, long term work done on duplicate plots at Pusa and reported by Sayer [1935] shows green manuring with superphosphates to be more effective than green manuring alone, except for *arhar* which gave negative results with green manuring. The data are summarized in Table XXV.

TABLE XXV

Green manuring alone and with superphosphates at Pusa

Treatments	Maize	Oats	Arhar
	(lb. per acre)		
1. No manure	578.0	509.0	836.5
2. Green manure (sunh)	893.0	659.0	652.0
3. Green manure + super-phosphates	1301.0	1405.0	679.0

It seems that for *arhar* green manuring even with superphosphates brings about a depletion in the yield of grains. A reference to this has already been made in Chapter IV.

Mukerji [1923-24] from his studies on the effect of superphosphates in conjunction with green manures on Pusa soils showed that the addition

of phosphates helped the decomposition of green manures. It was also suggested by him that phosphates in organic combination being more beneficial to plants, increased crop yields could be obtained by using green manures in conjunction with phosphatic fertilisers. Benton [ 1927 ] in India and Heintze [1909] in Germany have also supported the above assumption. Recently Rege [ 1935 ] has expressed similar views. He suggests that the application of superphosphates with green manures makes phosphates more available to crops, specially in soils deficient in that ingredient.

(c) *Lime*. According to Joachim [1926, 1927, 1928] the addition of lime hastens the decomposition of green manures in Ceylon. Increased yields following the application of lime to green manure have also been reported from Mysore (1919-20). Lime added to green manures, according to most foreign writers, increases the yield of the

ucceeding crops, but there is lack of experimental evidence to support this statement. The quantitative data furnished by McCall [ 1924 ] on the effect of lime in conjunction with green manure on wheat and corn are given in Table XXVI.

TABLE XXVI

*Effect of lime applied with green manures on the yields of wheat and corn. McCall [1924]*

Treatment	Yield in bushels per acre	
	Wheat	Corn
1. Control . . . . .	14.0	20.3
2. Lime alone . . . . .	19.6	31.3
3. Green manure alone . . . . .	14.4	25.8
4. Lime + green manure . . . . .	21.8	37.8

It will be seen from Table XXVI that lime used in conjunction with green manure has been found beneficial to wheat and corn. Lime will particularly be needed in acid soils.

## VI. GREEN MANURING AND ROTATION OF CROPS

ONE of the most important factors controlling the adoption of green manuring in actual practice is the possibility of having as an alternative a definitely remunerative crop in the *kharif* specially when the green manures are meant for *rabi* crops. There a *rabi* crop is preceded by a fallow, green manuring may not be difficult to introduce; or even a green manure crop may be grown in the rotation, and a part after harvesting buried under.

In the Madhya Pradesh it has been found that cotton yields are better if followed by sunn or groundnut; whereas, the yield of wheat could be better maintained after *lakh* than after gram [ Bal, 1937 ]. The marked value of groundnut as a recuperating crop has also been noted in Madras.

### *Legumes in rotation*

In Bombay (*Annual Reports 1932-33*) it was found that *bajri* after *kulthi* yielded 25 per cent more than *bajri* after *bajri*; but economically *bajri* after *bajri* proved to be a more paying rotation.

Lander [ 1935 ] describes a few rotations followed in the Punjab where leguminous crops are interposed in order to increase the fertility of the soil.

It is considered that a detailed investigation to assess the relative merit of the above rotations as affecting the soil fertility may yield very valuable results.

Ramiah [ 1935 ] summarising the results of rotational experiments carried out in Madras indicates that if a green manure crop is grown between rice and sugarcane in a two-year rotation, the yield of rice could always be maintained at a high level in spite of sugarcane being an exhaustive crop. He further mentions that in the black cotton soil tracts of the former ceded districts the usual two-crop rotation of cotton and sorghum has been improved by the introduction of a leguminous crop of groundnut in rotation. The yield of cotton is also increased by this practice. The beneficial effect of legume cultivation could also be secured by growing a mixture of a cereal and a pulse.

Ramiah [ 1936-37 ] further refers to the harmful effect of sorghum on cotton and mentions that cotton after *cumbu* (*Pennisetum typhoidum*) gives 15 per cent more yield than cotton after sorghum. Similar results were obtained for groundnut at Palakuppam (Madras) where groundnut gave better yield after *cumbu* than after sorghum. Even as a mixed crop groundnut fares better when grown mixed with *cumbu* than with sorghum.

With a view to study the role of green manuring in crop rotation, experiments were conducted at Surat (Bombay) on the yield of cotton and *jowar* after green manuring with *dhaincha* in the rotation. The results obtained have been summarised by Patel [ 1937 ] and are given in details in the *Annual Reports of the Department of the Agriculture, Bombay Presidency 1939-40*. There were eight treatments in properly randomised blocks and green manuring was done once in a cycle of six years. The residual effect was studied on the next *jowar* crop. Two treatments, viz. (G) and (H) were used as control where no green manuring was done. Farmyard manure at the rate of ten cart-loads per acre was given to the whole series once in 1933-34.

The average results for the years 1935 to 1939 are given in Table XXVII.

TABLE XXVII  
*Rotational experiments at Surat (1935-1939)*  
layout 8 × 5 randomised blocks

Treatments	Average yield of seed cotton		Average yield of <i>jowar</i> grains	
	lb. per acre	Percent over control	lb. per acre	Per cent over control
(A) Green manuring fallow (1st year)	..	..	..	..
(B) Cotton after green manuring (2nd year)	1136.4	230.1	..	..
(C) <i>Jowar</i> after cotton (3rd year).	..	..	1035.0	116.8
(D) Cotton after <i>jowar</i> (4th year).	529.9	105.9	..	..
(E) <i>Jowar</i> after cotton (5th year).	..	..	927.5	104.6
(F) Cotton after <i>jowar</i> (6th year).	479.2	97.1	..	..
(G) Cotton after <i>jowar</i> Control.	493.7	100.0	..	..
(H) <i>Jowar</i> after cotton control.	..	..	886.7	100.0

It will be seen that the rotation cotton after green manuring gave more than double the yield of seed cotton than cotton after *jowar*. The residual effect of green manuring in the rotation was observed to last even upto the third year when higher yields of *jowar* grain were obtained as compared to *jowar* after cotton without green manuring. These results are of considerable interest to the cotton growing tracts of the Bombay Presidency.

Results obtained at Sakrand (Pakistan) as reported by Barakzai [ 1935 ] show that in rice tracts *matar* (chikling vetch) occupies an important

position as a crop growing in rice fields, and that in light soils gram could easily replace *matar*. Berseem crops ( *Fahal* variety) could advantageously grow in rotation with rice, the crop being turned in after taking one cutting. The same author further reports [ 1935 ] that berseem cultivation in the immediately preceding *rabi* season invariably results in higher yields for seed cotton. The stubbles left after the last cutting of berseem could be buried under *Sunn* and *guar* sown thickly in *kharif* season stand next to berseem. Pulses like *moong*, soybean and *mata* rank third as rotational crops useful for cotton. Barakzai [ loc. cit. ], however, mentions that if a fallow intervenes considerable loss of nitrogen takes place and the beneficial effect of legume cultivation is not fully realised.

During 1916 to 1927 an experiment was conducted at Pusa over an area of 413 acres with a three year six course rotation. The scheme as detailed by Sayer [ 1935 ] is summarised in Table XXVIII.

TABLE XXVIII

*Rotation studies at Pusa [ Sayer, 1935 ]*

Particulars	1st year	2nd year	3rd year
Monsoon crop	Maize for silage and fodder	Maize for corn	Leguminous crops
Winter crop	Oats	<i>Arhar</i>	Oats

Steady increase in the yield of oats in the area where leguminous crops were grown was observed, showing that the soil fertility was thereby considerably improved.

#### *Rotations for sugarcane*

With regard to rotations best fitted for sugarcane cultivation, the experiments conducted by Sayer [ 1935 ] at Pusa show that the yield of cane is considerably increased if three green pulses intervene instead of two in a four year rotation. The two rotations tried were as follows :

	1st year	2nd year	3rd year	4th year
I	Sugarcane	Maize + pulses	Green pulse	
	Do.	Oats	Fallow	Pulses
II	Sugarcane	Pulses	Maize	
	Do.	Oats	Berseem	Fallow

Mitra [ 1935 ] reports that on Jorhat Farm, Assam, the following rotational system has proved very successful for sugarcane :

In a four year rotation a green manure crop is grown in the third year (after two years of plant and ratoon cane) and this is ploughed in and followed by a winter crop. In the fourth year another green manure crop is grown in *kharif* and the land is kept fallow in the *rabi* when it is ready for cane plantation.

The usual rotation followed in Bihar is : sugarcane—monsoon crop for fodder or seed (*rabi*)—green manure—cane. Thus green manuring is done once in three years. Maclean [ 1937 ] has described the results of an experiment in Bihar in which cane was grown after green manuring, after maize and after fallow. It is interesting to note that the yield of cane after green manuring was found to be lower than that after fallow. The results of three years' trials on two different places clearly showed that the practice of green manuring sugarcane was harmful as compared to having cane after fallow, and Maclean suggests changing the usual rotation, green manure—sugarcane—fallow—wheat to green manure—wheat—fallow—sugarcane. This is rather an important observation and these two rotations require very careful study before attempting any general recommendation.

Rege [ 1941 ] rightly considers that securing an intermediate fodder crop during the interval between the ploughing in of green manure and planting of sugarcane would be definitely harmful and might even result in lowering the cane yield. At Muzaffarnagar (U. P.) sunn green manuring of sugarcane has been compared with having cotton in the *kharif* for two seasons ( 1935 to 1937 ) with and without top dressings. It seems that the outturn of cane after cotton is slightly less than that of cane after green manuring ; but this difference is eliminated on applying a top dressing of farmyard manure. In the case of ratoon crops cotton appears to lower the yield of cane still further.

During 1937-39 these experiments were repeated with modifications at Muzaffarnagar. There were three treatments of sunn green manuring, viz. sunn buried as such, sunn buried after taking fibre and sunn buried after taking seed and fibre. These were compared amongst themselves and

with having cotton-pea, cotton-*me'ha* and cotton-fallow in rotation. The results obtained are given in Table XXIX (Mitra, private communication).

TABLE XXIX

*Rotational trials at Muzaffarnagar (Plant Cane)*  
( 6 × 4 randomised block )

Treatments	Yield of cane in md. per acre	
	1937-38	1938-39
1. Sunn buried in . . . . .	728	1,118
2. Sunn fibre taken . . . . .	727	1,112
3. Sunn seed and fibre taken . . . . .	658	996
4. Cotton— <i>me'ha</i> . . . . .	643	865
5. Cotton—pea . . . . .	641	772
6. Cotton—fallow . . . . .	625	827
7. Critical difference . . . . .	78.7	101.6

It will be observed from above that there is practically no difference in the yield of cane when fibre is taken from sunn and when the whole plants are buried ; but that cotton in the *kharif* is definitely harmful and lowers the yields.

All the three methods of green manuring also proved superior to cotton treatments with ratoon crop. The results obtained during 1938-39 are given in Table XXX.

TABLE XXX

*Rotational experiments at Muzaffarnagar (Ratoon cane)*

(6 × 4 randomized blocks)

Treatments	Yield of cane in md. per acre
1. Sunn buried in . . . . .	504
2. Sunn fibre taken . . . . .	513
3. Sunn seed and fibre taken . . . . .	509
4. Cotton— <i>me'ha</i> . . . . .	483
5. Cotton—pea . . . . .	435
6. Cotton—fallow . . . . .	396
7. Critical difference . . . . .	58.5

At Padegaon, the effect of a variety of *kharif* money crops has been tested against fallow and green manuring with *patala shevra* and sunn on the succeeding crop of sugarcane during 1937-38. The results as described by Rege [1941] are given in Table XXXI.

TABLE XXXI

Effect of kharif crops, fallow and green manuring on sugarcane ( Padegaon 1937-38 )

(6 × 4 randomized blocks)

Previous treatment	Average yield per acre in lb.	Expressed on per cent basis	Sucrose per cent	Purity per cent
Sunn	73·194	100·0	20·40	90·7
Cotton (N.R.)	64·631	83·3	20·36	89·3
Groundnut (big Japan)	54·481	74·4	20·18	92·0
Jowar (fodder)	59·935	81·9	20·40	91·5
Fallow	68·063	92·9	20·66	91·8
Palada sheeta	76·761	104·9	20·45	92·1
S. E.	3·203	4·4	..	..

It may be noted that green manuring stands first followed by fallow, cotton, jowar and groundnut. The behaviour of groundnut is peculiar

in as much as it contradicts the general opinion about its recuperative effect on the soil [Ramiah, 1935 ; Bal, 1937].

## VII. ECONOMICS OF GREEN MANURING

IN practically every tract the sole objection on the part of cultivators to growing green manure crops is that these occupy the land which would otherwise be utilised for growing kharif money crops like jowar or groundnut. Where the land is left fallow in the kharif green manuring may not be difficult to introduce. Allan [1937] stated from his experience in Uttar Pradesh and Baroda that cultivators grew green manure only when they had no alternative crop to sow. In Sind, however, this difficulty about kharif green manuring is felt much less ; since no assessment is levied there by Government on the cultivation of a green manure crop, provided notice is given ahead to the authorities of the intention of using land for such purposes [Barakzai, 1935].

According to Rege [1935] the actual replacement of a paying crop by green manure crop can hardly be economical unless the green manure is specifically meant for sugarcane. Lander [1937], however, observes that taking into consideration the residual effect, green manuring has in all cases been found economical in the Punjab. There seems to be a net saving of Rs. 50 to Rs. 70 on manuring sugarcane in the Deccan Canal area if sunn green manure is used [Gadgil, 1937]. Similarly, from the Uttar Pradesh a net saving of Rs. 80 to Rs. 90 is reported in favour of green manuring with sunn. Moreover, it may be mentioned that the usual method of costing on the basis of nitrogen only can hardly be

justified in view of the cumulative and other benefits derived from green manures. With the increase in the cost of farmyard manure in Bombay, Gadgil [1937] considers green manuring to be the cheapest source of supplying organic matter and nitrogen to the soil.

### Cost of green manures

Allan [1935] has calculated the price per lb. of nitrogen in different nitrogenous manures commonly used for sugarcane and paddy in Uttar Pradesh. (see Table XXXII, p. 28) He finds green manuring with sunn (assuming it to add roughly 45 lb. of nitrogen per acre) to be the cheapest [Sethi, 1940].

According to Allan [1935] the extra cost involved for preparing the land for green manure may be considered to be negligible, since the number of ploughings and turnings upto the time of sowing the sunn seeds would be about the same as in the case of land not to be green manured. Sunn will, moreover, stand for two months in the field and the saving on ploughings that would otherwise have to be given to fallow land during this period should compensate for the extra ploughings at the time of burying the crop of sunn.

The unit values of nitrogen from sunn green manuring and farmyard manure for the Deccan Canal area, as calculated by Gadgil [1937] are given in Table XXXIII.

TABLE XXXII

Price per lb. of nitrogen in different nitrogenous manures [Allan, 1935]

Sl. No.	Manure	Current rate (1935)	Per cent N	Total N contained in col. 3	Annas per lb. of N
1	Castor cake	Rs. 1-1-6 per md.	4.0	lb. 3.29	5.32
2	Neem cake	Rs. 1-4 per md.	6.0	4.92	4.06
3	Ammonium sulphate	Rs. 4-11 per bag, of 78 lb.	20.6	16.07	4.67
4	Farmyard manure	Rs. 1-4 per cart of 15 md.	0.46	5.68	3.52
5	Green manuring with sunn	Rs. 2-8 for 1 md. of seed required for an acre	..	45.00	0.88

TABLE XXXIII

Cost of green manuring with sunn in the Deccan Canal area [Gadgil, 1937]

Particulars	Cost
1. One ploughing	6 0
2. Two harrowings	3 4
3. Seed 60-80 lb.	1 4
4. Sowing	0 8
5. Irrigation labour	3 0
6. Irrigation cost	2 8
7. Cutting sunn crop	7 0
8. Ploughing in sunn	
Total	26 0
9. Rent of sugarcane land	15 0
10. Interest on Rs. 26 @ 9 per cent	2 0
11. Yield of sunn per acre 20,000-25,000 lb. of green matter	43 0
12. At 0.45 per cent N one acre of sunn will give 101.2 lb. N (approximate)	
13. 101.2 lb. N costs Rs. 43	
14. Therefore, one lb. N. costs Rs. $\frac{43}{101.2}$	

as. 6 pies 9.

One cart-load of farmyard manure (about 800 lb.) having 0.5 per cent nitrogen and costing Rs. 2-8-0 gives the unit value of nitrogen at 10 annas per lb.

From the above it will be seen that in the Bombay-Deccan sunn green manuring is cheaper than farmyard manure. Roberts [1937], however, suggests that while assessing the nitrogen unit value of green manuring crops, apart from the cost of seed, ploughing, irrigation, etc. one has also to consider the value of an alternative leguminous fodder crop. Gadgil [1937] has taken into account even this aspect of an alternative *kharif* fodder crop and his figures are given in Table XXXIV (p. 29)

Adding Rs. 22, the average of these two, to Rs. 43 already worked out above, sunn green manuring involves a total cost of Rs. 65, which gives unit value of nitrogen at 10 annas 4 pies per lb. This is slightly more than the calculated unit value of nitrogen per lb. from farmyard manure in the Bombay-Deccan.

Gadgil [1937], however, considers this economical as 'the sum arrived at is less than Rs. 75, the cost of 30 cartloads of farmyard manure'. Much further data are certainly necessary to arrive at definite conclusions on this important economic aspect of green manuring.

#### Green manuring paddy

Sahashrabudhe [1934] summarising the results of green manuring in the Bombay Presidency has reported that green manuring has been found to be economically satisfactory for paddy at Deohad, Karjat, Kumta and Ratnagiri. Similarly Ramiah [1935] found green manuring to be the most economical method of fertilising rice fields in Madras.

Sethi [1940] worked out the economics of green manuring paddy at the Rice Research Station, Nagina in the Uttar Pradesh. If the crop was grown *in situ* there was a net profit of Rs. 53; whereas, if brought from outside and ploughed in the net profit fell to Rs. 37 only. At the same station during 1937-38 green manuring alone gave a profit of Rs. 62; but when it was used in conjunction with superphosphates the profit was reduced to Rs. 53 per acre.

At Nagina the effect of sunn manuring was compared with artificials during 1935 to 1938, and the economics of the various treatments also worked out (Mitra, private communication). It was observed that sunn alone proved most profitable followed by sunn *plus* superphosphates. The figures are given in Table XXXV (p. 29).



TABLE XXXIV

Net profit obtained by growing an alternative kharif crop in place of green manures [ Gadgil, 1937]

Crop	Cost of cultivation per acre	Value of yield	Net profit
<i>Niloha (jowar)</i>	Rs. 40	Rs. 60 for 6,000 lb. dry fodder @ 100 lb. a rupee	Rs. 20
Groundnut	50	Rs. 75 for 2½ <i>khandis</i> @ Rs. 30 a <i>khandi</i>	25

TABLE XXXV

Economics of sunn and other artificials for manuring paddy, Nagina (Average for the years 1935-38)

(50 lb. N and 50 lb P<sub>2</sub>O<sub>5</sub> per acre)

Treatments	Total manuring charges		Yield per acre		Difference in yield over control	Value of increased yield @ Rs. 2-12 a md.		Total profit or loss	
	Rs.	as.	lb.	lb.		Rs.	as.	Rs.	as.
1. No manure	..		1718	..	..		..		..
2. Ammonium sulphate	16	11	2106	388	13	1	3-10		loss
3. Green manure	10	0	2723	1005	33	11	23-11		profit
4. Niciphos	21	15	2195	477	16	1	5-14		
5. Green manure plus superphosphate	10	0							
	+	9 15							
	19	15	2764	1046	35	3	15-4		profit
6. Superphosphate	9	15	1842	124	4	2	5-13		loss

(N.B.—Cost of growing, ploughing, etc. of green manure has been taken at Rs. 10 per acre).

In Bihar the advantages of green manuring the paddy crop has been well established, and an extra profit of Rs. 10 to Rs. 15 per acre achieved at two stations, viz. Sabour and Gaya [Sethi, 1940]. At the latter station during 1936-37 the economics of the effect of phosphate supplements to green manures and farmyard manure was also worked out. The addition of superphosphate to green manure (*dhaincha*) increased the net profit from Rs. 14 to Rs. 17 per acre against the control. This result is contradictory to that obtained at Nagina with sunn and superphosphate. The table containing the results of the above experiment at Gaya, as given by Sethi [loc. cit.], is reproduced in Table XXXVI (p. 30).

#### Green manuring sugarcane

Sahasrabudhe [1935] has mentioned that green manuring has been found to be economically profitable for sugarcane at Manjri and Kapargaon in the Bombay Presidency. Gadgil [1937] also reports

sunn green manuring to be the cheapest for sugarcane, and a net saving of Rs. 50 to Rs. 70 may be expected through green manuring sugarcane in the Deccan Canal tract.

At Shahjahanpur during 1933-34 an experiment was laid out in which the profit accruing from the use of sunn as green manure for sugarcane was carefully worked out. The results of this trial, as reported by Sethi *et al.* [1938], are given in Table XXXVII (p. 30).

It will be seen from Table XXXVII that at Shahjahanpur an additional profit of nearly Rs. 69 per acre has resulted by green manuring cane with sunn.

#### Green manuring other crops

Barakzai [1935] has calculated the average expenditure per acre on green manuring—for potato and onion crops from the data recorded in Sind for

TABLE XXXVI  
Economics of green manuring paddy at Gaya (1936-37)

Treatments per acre	Year	Cost of manuring	Increased outturn over control in lb. per acre		Sale price of increased outturn per acre		Total	Net profit
			Grain	Straw	Grain	Straw		
F. Y. M. @ 100 md.	1936	Rs. 9 4	577	280	Rs. 14 6 9	0 14 0	Rs. 15 4 9	Rs. 6 0 9
	1937	9 4	404	310	10 1 7	0 15 6	11 1 1	1 13 0
G. M. @ 125 md. and 20 lb. super	1936	4 9	630	371	15 12 0	2 5 0	18 1 0	13 8 0
	1937	4 9	676	427	16 14 0	2 10 0	19 8 0	14 15 0
F. Y. M. at 100 md. and 40 lb. super	1936	11 6	607	280	15 2 9	0 14 0	16 0 9	4 10 9
	1937	11 6	594	361	14 10 0	1 2 0	15 12 0	4 6 0
G. M. at 125 md. and 40 lb. super	1936	6 11	869	457	21 11 0	2 13 0	24 8 0	17 13 0
	1937	6 11	830	513	20 12 0	3 3 0	23 15 0	17 4 0

## Basis of calculation

1. F. Y. M. at Rs. 1-4-0 per cart of 12 to 15 md.
2. Cost of sowing and raising dhaincha Rs. 3-8-0 per acre.
3. Super phosphate at Rs. 4-4-0 per 80 lb.
4. Paddy at Rs. 2 per 80 lb.
5. Straw at as. 4 per 80 lb.

TABLE XXXVII

Showing comparative data of cost and profit as a result of green manuring (Shahjahanpur, 1934)

Particulars	Green manured	Not green manured
1. Yield of cane per acre md.	891.66	621.74
2. Total yield of sugar (md.)	55.28	38.61
3. Total price of sugar (Rs.)	400.52	279.89
4. Total cost of producing cane and manufacturing sugar (Rs.)	258.13	206.42
5. Profit (Rs.)	142.39	73.47
6. Extra profit by the use of green manuring (Rs.)	68.92	..

a period of six years. He has compared the cost of green manuring with that of manuring these crops with cattle manure and finds that under Sakrand conditions the gain in favour of green manure is Rs. 9-4-0 per acre. The actual details are shown in Table XXXVIII.

TABLE XXXVIII

Cost of green manuring potato or onion crop as compared with farmyard manure (Sakrand-Sind)

Particulars	Cost
	Rs. as.
1. Soaking dose (one man for half day)	0 4
2. Ploughing, sowing and, levelling (3 men for a day and 4 bullocks.)	3 12
3. Cost of 80 lb. seed at Rs. 3 a md.	3 0
4. Two subsequent irrigations (one man)	0 8
5. Cutting (four men for a day)	2 0
6. Burying and levelling (4 men for a day and 4 bullocks)	3 8
7. Subsequent irrigation for decomposition (one man for half day)	0 4
<b>Total</b>	<b>13 4</b>
N.B.—Wages at arnas 8 per man and cost of bullock annas 6 per bullock.	
<i>For Cattle manure</i>	
1. 30 carts of manure @ 8 as. a cart	15 0
2. Cartage @ 4 as. a cart	7 8
	<b>22 8</b>

## Green manuring for dual purposes

*Wheat.* With a view to find out the profit resulting from the practice of growing sunn for the dual purpose of green manuring and fibre production, experiments were laid out at Pusa by Sayar [1935]. His results showed that although by burying the roots and tops and removing stems for fibre, the yield of wheat went down slightly in comparison to burying the whole plant four to five weeks earlier, the difference in the net profit for the average of two years was Rs. 3-14-11 more for the treatment where fibre production was resorted to. His results are summarised in Table XXXIX (p. 31).

The results given therein may be accepted with some reserve since during 1932 the treatment where fibre was extracted yielded less profit than during 1933 when the profit was more in comparison. However, taking the average for both the years the profit from treatment T<sub>5</sub> was more than that from T<sub>4</sub>.

Sayer [loc. cit.] further remarks that in both the seasons there was sufficient autumn rains to decompose late buried sunn tops and that on an average

143 coolies were required for cutting, rotting and extracting sunn fibre from one acre in T<sub>5</sub>.

*Paddy.* Sethi [loc. cit.] reports that green manuring with tops, roots and leaves alone (stems for fibre) gave always a lower margin of profit in experiments laid out at Nagina on paddy during 1936 to 1938 as compared with burying the whole plant. The expenditure on stripping and fibre extraction goes very high, and the extra

TABLE XXXIX  
*Economics of green manuring for dual purpose*

Treatments.	Year	Wheat grain per acre in lb.	Fibre per acre in lb.	Cost of produce	Cost of cultivation.	Profit	Total profit
T <sub>4</sub>	1932	1340.4	..	Rs. a. p. 66 5 0	Rs. a. p. 31 0 3	Rs. a. p. 35 4 9	75 6 11
(whole plant)	1933	1406.5	..	71 0 9	30 14 7	40 2 2	
T <sub>5</sub>	1932	963.2	611.3	94 5 7	63 13 4	30 8 3	79 5 10.
Tops and roots and as G.M. and stems for fibre	1933	1187.8	720.1	111 0 4	62 2 9	48 15 7	

profit obtained through the sale of fibre does not balance the cost. The economics of fibre extraction in the case of paddy is worked out in Table XL (Mitra, private communication).

TABLE XL  
*Economics of fibre extraction from sunn in the case of green manuring paddy (Nagina 1936 to 1938).*

Treatments.	Total expenditure	Increase in yield over control (average of 3 years) in lb.	Value of increased yield and fibre	Net profit	Remarks.
1. Whole Plants	Rs. as. 10 0	1638	Rs. as. 55 0	Rs. as. 45 0	Cost of green manuring with sunn @ Rs. 10 per acre.
2. Tops only	10 0	1475	49 8	39 8	
3. Leaves, tops and roots	69 8	1393	46 12 29 8* 3 0†	9 12	Cost of extracting fibre Rs. 59 av. 8.

\* for fibre  
† for sticks

*Sugarcane.* As mentioned in Chapter IV, a large amount of work has been done in the Uttar Pradesh to ascertain the relative manurial value of sunn whole plants and tops and roots at different ages, with a view to utilising the stems for fibre production. The results in general indicate that the yield of sugarcane is not much affected if the stems are removed and only the tops and roots are ploughed in. However, the economics of this project requires a careful study and at Shahjahanpur during 1937 to 1939 experiments were laid out in which the expenditure and the income derived from all the products were calculated. The results of this investigation are detailed in Tables XLI and XLII (pp. 34, 35) (Mitra private communication).

It will be noted that during 1937-38 in the treatment in which whole sunn plants 75 days old were buried the increased profit, over the control, amounted to Rs. 42; but if fibre was extracted and only tops and roots were ploughed in the profit increased to Rs. 55. Similarly, an increased profit has been observed with sunn plants 90 days old in which fibre extraction was resorted to. Much higher profits were obtained during 1938-39 in the treatments in which stems were removed for fibre production. Securing an intermediate fodder crop like pea or allowing the sunn crop to seed seems to be harmful for cane and the net profit is thereby reduced considerably.

TABLE XLI

Yield of cane and other produce along with profit or loss obtained through different treatments of sunn (Shahjahanpur 1937-38)

Serial No.	Treatments	INCOME								EXPENDITURE								Profit	Deviation from control	
		Cane		Fibre		Pea-fodder		Sunn-seed		Sunn seed and sowing	Harvesting and ploughing in of sunn	Burning sunn in tanks	Rotting sunn	Seed and sowing irrigation to pea.	Harvesting pea fodder	Cost of Cultivation of cane and irrigation etc.	Total expenditure			
		Yield per acre	Price received @ as. 5 per md.	Yield per acre	Price received @ 6/8/- per md.	Yield per acre	Price received @ as. 4 per	Yield per acre	Price received @ 2/8/- per md.											Rs.
1	A=Control ..	608.50	190	..	..	..	..	..	..	190 2	..	..	..	..	..	..	135	136 0	+54 2	..
2	B=60 days whole sunn	718.54	224 8	..	..	..	..	..	..	224 8	4	2 8	..	..	..	..	135	142 8	+82 0	+27 14
3	C=60 days tops and roots,	726.69	227 1	..	..	..	..	..	..	227 1	4	6 0	..	..	..	..	136	146 0	+81 1	+26 15
4	D=75 days whole sunn	764.31	238 4	..	..	..	..	..	..	238 14	4	2 8	..	..	..	..	136	142 8	+96 6	+42 4
5	E=75 days tops and roots	775.28	242 4	2.75	17 14	..	..	..	..	260 2	4	6 0	1 14	2 8	..	..	136	150 6	109 12	+55 10
6	F=75 days tops and roots+pea	434.82	135 14	2.75	17 14	2930	73 4	..	..	227 0	4	5 0	1 14	2 8	4 5	3 2 ..	136	162 8	+64 8	+10 6
7	G=90 days tops and roots	753.96	235 10	3.38	21 1	..	..	..	..	257 9	4	6 0	1 14	2 8	..	..	136	150 6	107 3	+53 1
8	H=90 days whole sunn	783.75	244 15	..	..	..	..	..	..	244 15	4	2 8	..	..	..	..	136	+142-8	+102-7	+48-5
9	M=Sunn allowed for seed	615.06	160 15	..	..	..	..	3.65	9 2	170 1	4	2 8	..	..	..	..	136	142 0	+28-7	+25-1

\* Rs. 4 seed and sowing and Rs. 6 irrigation.

@Pea fodder taken before cane.

TABLE XLII

Yield of cane and other produce along with profit or loss obtained through different treatment of sunn (Shahajahanpur 1938-39)

Serial No.	Treatments	INCOME								EXPENDITURE								Profit	Deviation from control	
		Cane		Fibre		Pea-fodder		Sunn-seed		Gross Income.	Sunn seed and sowing	Harvesting and ploughing in of sunn	Burning sunn in tank	Rotting sunn	Seed and sowing extra irrigation to pea	Harvesting pea fodder	Cost of cultivation of cane and irrigation, etc.			Total expenditure
		Yield per acre	Price received @ as. 7-3 per md.	Yield per acre	Price received @ as 7 per md.	Yield per acre	Price received @ as 4 per md.	Yield per acre	Price received @ Rs. 3-4 md.											
		md.	Rs.	md.	Rs.	md.	Rs.	md.	Rs.											
1	A=no manure (control)	613.63	278.05	..	..	..	..	..	..	278.05	..	..	..	..	..	..	121.0	121.0	157.05	..
2	R=50 days whole-sunn	836.36	378.98	..	..	..	..	..	..	378.98	4.75	2.50	..	..	4.16	..	121.0	132.41	246.47	+80.52
3	C=50 days tops and roots	731.81	354.26	..	..	..	..	..	..	354.80	4.75	6.0	..	..	4.16	..	121.0	35.91	218.35	+61.30
4	D=60 days whole sunn	795.45	360.44	..	..	..	..	..	..	360.44	4.75	2.50	..	..	4.16	..	121.0	132.41	228.03	+70.98
5	E=60 days tops and roots.	759.09	343.06	4.81	33.67	..	..	..	..	377.63	4.75	6.0	1.87	2.50	4.15	..	121.0	140.28	237.35	+80.30
6	F=75 days whole sunn	831.81	376.91	..	..	..	..	..	..	..	4.75	2.50	..	..	0.52	..	121.0	136.67	240.34	+53.20
7	G=75 days tops and roots.	813.64	308.68	6.46	45.22	..	..	..	..	413.90	4.75	6.0	1.87	2.50	8.32	..	121.0	144.44	209.46	112.41
8	HG=75 days tops and roots-Pea	654.54	296.59	6.10	42.70	147.89	36.97	..	..	376.26	4.75	6.0	1.87	2.50	20.64	2.75	121.0	159.51	216.75	+59.70
9	I=90 days whole sunn	790.90	358.38	..	..	..	..	..	..	358.38	4.75	2.50	..	..	8.32	..	121.0	136.67	221.81	+64.76
10	K=90 days tops and roots	768.18	348.06	6.81	47.67	..	..	..	..	395.75	4.75	6.0	1.87	2.50	6.32	..	121.0	144.44	251.31	+94.26
11	M=sunn allowed for seed	663.63	300.71	..	..	..	..	9.38	30.22	331.23	4.75	2.0	..	..	4.16	..	121.0	131.91	199.32	+42.27

\*Pea fodder taken before sugarcane.

## VIII. SOILS AND GREEN MANURES

*SOIL texture*

It is generally accepted that green manuring gives the highest value on the lighter types of soils and least so on soils that are heavy or tend to crack on drying. On light soils better returns are obtained from green manuring than from equal quantities of nitrogen applied as fertilisers. Thus the increase in the yield of paddy on heavy black soils of the Godavari delta in the South amounts to 8 to 10 per cent from green manuring; whereas, on lighter grades the increase may range from 20 to 25 per cent.

Dobbs [1915] was probably the first to observe that in Madras the application of green manure on the heavy delta soils at Manganallur resulted in the complete failure of paddy, but at Samalkota during 1909 the effect was only to increase the yield of straw [Viswanath, 1937]. He attributed this failure to defective drainage conditions of the soil. Similarly, Howard and Howard [1915] reporting on the improvement of indigo in Bihar, expressed the view that green manuring should only be attempted on light, high-lying lands which were well-drained. If the soil was summer-ploughed, the land became loose which proved detrimental to the subsequent crop [Viswanath, 1937].

Lander, Wilsdon and Lal [1923] and Lander [1935] confirm the above findings and state that the response to green manuring is much greater in sandy soils than in stiff soils. In sandy soils they obtained greater yield in the green manured plots than in plots receiving equivalent quantities of artificial fertilisers.

It has also been noted in Sind that in the growing of a green manure crop between the rows of another main crop like cotton, the most marked results were obtained on sandy and loamy soils [Desai, 1935].

Green manure considerably improves the texture of the soil. It makes a heavy soil porous by incorporating a considerable amount of organic matter and a light soil more compact by binding the loose particles together. Sethi [1938] records that the loose sandy particles of the soil of Kapurthala State could be bound together very satisfactorily as a result of sown green manuring.

Lander [1935] reports the results of an experiment at Brucepur (Lyalpur) during 1929 where the soil being very sandy no crop could be grown. *Guar* brought from outside and incorporated into the soil improved the texture to such an extent as to enable the plots afterwards to give excellent crop yields. Similar results have been obtained in other countries regarding the improvement in the tilth of soil as a result of green manuring. Hardly any notable quantitative data, however, exist on this subject.

In plantation crops and in orchards a large part of the beneficial effect of green manuring is generally attributed to the improvement in the texture of the soil. When deep-rooted legumes are used, as is common under estate practices, the roots tend to make the soil more porous, breaking the hard pan and opening up the sub-soil. Thus in Assam it is found that the growing of deep-rooted trees like *Albizias* opens up the subsoil and the plantation crop benefits considerably by this treatment [Mann, 1907].

The purely mechanical effect of cover crops in checking soil erosion both through wind and rain has been well recognised in tropical countries, especially in Malaya and Ceylon [Joachim *et al.*, 1930].

*Soil reaction*

According to Ramiah [1935] the increased yield of cotton following green manure crops becomes hardly noticeable when the green manure is applied to saline areas. He, therefore, lays stress on the soil reaction necessary to secure the optimum beneficial effect of green manuring.

In an experiment conducted at Mian Channu (District Multan) by Lander [1935] *senji* was used as a green manure in an alkaline plot during the successive years, 1928-39. This treatment rendered the land capable of bearing an average wheat crop, and the analytical data showed that the exchangeable calcium content of the soil was increased considerably [Singh, 1937].

In Travancore different kinds of sour leaves and stems are used to reclaim alkaline lands and increase the humus content of the soil [Narayan Iyer.

1937]. The material used are : *Phyllanthus* leaves, tamarind leaves, *palmyra* leaves, *vrali* leaves, *peranda* stems and plantain stems. The leaves of *Phyllanthus* (*Embelica officinalis*) rank first for this purpose. According to Basu [1937] *dhaincha* tends to improve alkaline soils by effecting a reduction in exchangeable sodium.

### Soil nitrogen

Mukerji [1937] summarising the experiments conducted in the past at Shahjahanpur points out that in the green manured plots the nitrogen content just after the monsoons was higher in the first foot of the soil than in the second foot ; whereas, in a neighbouring plot which was not green-manured, the top soil contained less nitrogen than the sub soil. The results of field experiments in Bihar, as cited by Rege [1941] do not, however, seem to support this conclusion. Considering the data for maturity of canes in Bihar it appears that in the green manured plots during the monsoon there is always a depletion of nitrate-nitrogen in the surface soils due to leaching. These differences may be attributed to Bihar having a higher rainfall than is usual under Shahjahanpur conditions.

### Soil moisture

The improvement in the water-holding capacity of soils as a result of green manuring is widely accepted. Lander, Wilsdon and Lal [1923], who studied the effect of green manuring with a legume and a non-legume on sandy and stiff soils, found that the addition of green manures to sandy soils increased the water-holding capacity by about 3 per cent over the control. The difference in the

case of stiff soils was, however, not significant. The figures obtained were as follows :

TABLE XLIII

*Effect on water-holding capacity of sandy and stiff soils as a result of green manuring* (Lander and associate, 1923)

Particulars	Water-holding (per cent)	
	Sandy soil	Stiff soil
Control . . . . .	6.5	19.3
Green manured . . . . .	10.3	20.2

Green manuring wheat crop on black cotton soils in the Madhya Pradesh has always proved injurious unless the annual rainfall exceeds 40 in. and few showers are received about the end of July or early in August.

After inversion of the green manure it appears imperative that the soil should receive moisture equivalent to at least 10 to 12 in. of rain to enable the organic matter to decompose, or else injury is likely to be caused to the succeeding crop. There are some experiments on record showing that under arid conditions the addition of green manures does not bring about any improvement in the soil. At the University of Pretoria, Theron and Van Wyk [1933] found that under semi-arid and sub-humid conditions green manuring every third year with cowpea failed to effect any significant increase in the crop yield. Definite injury as a result of ploughing in green manures, under dry conditions, has been reported by Thorne [1929] in his book '*Maintenance of soil fertility.*' It has been suggested that as a consequence to growing a green manure crop the soil moisture is depleted, and the moisture left in the soil may be totally inadequate for the subsequent crop. Moreover, the layer of fibrous material remaining undecomposed in the soil may further interfere with the free circulation of the subsoil water.

## IX. DECOMPOSITION OF GREEN MANURES IN THE SOIL

**W**HEN green manures are turned into the soil the plant material starts decomposition—the decay being mainly brought about by stages through the agency of micro-organisms consisting mostly of soil fungi and bacteria. Accordingly, various factors such as the reaction, texture, structure and chemical composition of soil, the nature of the plant material added, the movement of water in

the soil, soil temperature and the prevailing meteorological conditions of the locality, which provide the most favourable environmental conditions for the growth and activity of these soil micro-organisms, are essentially responsible for the rapid and complete decomposition of the green manures. The humification and subsequent mineralisation of the vegetative matter involve diverse processes

of complex character, arising out of the fact that the green manures generally applied to the soil consist largely of celluloses, hemi-celluloses and pentosans ; simple carbohydrates ; starches and other complex carbohydrates ; lignins ; complex proteins and protein degradation products ; fats and waxes ; glucosides ; tannins ; pigments and mineral matter. An extensive literature already exists on the work carried out abroad by different workers elucidating the nature of the biochemical changes associated with the disintegration of some of these ingredients. But the work actually done in India on these important aspects is extremely meagre. It is proposed here to deal mainly with the results emerging out of the investigations so far undertaken in India and make a reference, wherever necessary, to the more important results obtained by foreign authors.

Hutchinson and Milligan [1914] who worked on the Pusa soils report that nitrification of green manures is governed by the moisture and pore-space of the soil. Their results on nitrification in relation to soil moisture are given in Table XLIV.

TABLE XLIV

*Nitrification of sunn with different saturations of soil moisture after incubation for a period of eight weeks (Hutchinson and Milligan)*

Particulars	Per cent soil moisture	Per cent nitrification of the total nitrogen added as G.M.
1. Air-dry . . . . .	0.0	10.8
2. $\frac{1}{4}$ th saturation . . . . .	12.0	59.4
3. $\frac{2}{3}$ th saturation . . . . .	18.0	67.8
4. $\frac{1}{2}$ saturation . . . . .	24.0	52.2
5. Full saturation . . . . .	48.0	0.0

According to the above authors three-eighths saturation should be the optimum moisture content for nitrification of green manures. As already mentioned, a large number of workers in America and elsewhere have similarly shown that environmental conditions such as aeration and moisture supply influence to a marked extent the rate of decomposition of plant material in the soil [Starkey, 1924 ; Sievers and Holtz, 1926 ; Neller 1920 ; Potter and Snyder 1917 ; Waksman 1924 ; Lyon and Wilson 1928 ; Gainey 1929 ; etc.]. In general, it has been shown that increasing the temperature, aeration and moisture supply (up to a certain limit) stimulates the process of humification of the organic matter.

Briscoe and Harned [1918] in their experiments at Missouri Experimental Station, America found that a direct relationship existed between the bacterial count and the amount of organic matter added. Löhnis [1926] is of the view that addition of green manures to a soil already rich in humus is accompanied by a marked increase in the activity of the micro-organisms, as reflected by an acceleration in the rate of decomposition.

#### Carbon

According to expectation green manuring should increase the organic matter content of the soil. But in actual practice this beneficial effect of green manuring is hardly secured to the fullest extent in India, due specially to the fact that among the factors which govern the mineralisation of humus in the soil, temperature plays a very important part. The higher the temperature the quicker is the loss of organic complexes from the soil through the formation of gaseous decomposition products. Thus, it may be possible to build up soil organic matter in temperate climates ; but in tropical regions where high temperatures are prevalent the increase in the total organic matter is rather very poor.

The only work on record done in a tropical country is from Ceylon where Joachim [1931] has shown a gain in the organic matter of the soil as a result of growing a cover crop. The increase was from 3.7 to 4.6 per cent in two years and 5.3 per cent in four years. Joachim and Pandittesekere [1928] have also observed a reduction in the organic carbon and nitrogen of the soil as a result of cropping—the reduction of organic carbon in the case of green manured plots being, however, less than that from the unmanured ones. The loss of total nitrogen recorded by these workers in the plots receiving green manure was, on the other hand, more than in those left unmanured. The results are shown in Table XLV.

TABLE XLV

*Reduction of organic carbon and nitrogen in green-manured and un-manured plots in Ceylon (Joachim and Pandittesekere)*

Particulars	Green manured (per cent)	Unmanured (per cent)
Organic carbon . . . . .	0.02	0.07
Total nitrogen . . . . .	0.05	0.01

*N. B.*—The carbon-nitrogen ratio remained practically the same, i.e. 9.6 at the start and 9.8 at the end of the season.



There seems to be lack of data to establish conclusively whether the soil organic matter is increased permanently as a result of green manuring under tropical conditions.

### Nitrogen

Much confusion exists regarding soil nitrogen. Some workers [Hartweel and Pember, 1924 ; Christensen, 1919 ; Fulmar, 1917, etc.] in other countries have observed an increase ; whereas others [Lyon and Wilson, 1928] have recorded a decrease as a result of systematic green manuring. The general consensus of opinion in India however is, as stated by Desai [1933], that almost all forms of organic matter stimulate the nitrogen-fixing bacteria of the soil and thus bring about an increase in its nitrogen content. Further, according to Desai [loc. cit.] non-leguminous plant materials on decaying in the soil fix much more atmospheric nitrogen than the leguminous ones.

The application of plant material generally results in an increase in the soil nitrates ; but if these are lost in drainage or denitrified there might be an ultimate reduction in the total nitrogen content of the soil. If, however, organic matter specially rich in carbohydrates are applied there may be an actual decrease in soil nitrates. This fact was first brought to light by Hutchinson [1919] and Lyon and Wilson [1928] and has since been accepted by other workers. This is, however, not borne out by the observations made by Dhar and his co-workers [1936 ; 1937] who have shown that the application of an energy rich carbohydrate material like molasses to the soil is followed by an increase in the available nitrogen content of the soil.

### Carbon-nitrogen ratio

It is more or less universally believed that the carbon to nitrogen ratio is one of the most important limiting factors governing the nature and course of the decomposition of plant materials in the soil. [Jensen, 1929 ; Whiting, 1926 ; Heck, 1929, etc.]. The soil micro organisms require food for energy and for body building purposes. Food for energy is supplied mainly through carbohydrates ; whereas, proteins supply material for growth. Under favourable conditions a pure culture of *Spirochaeta cytophage* requires one part of nitrogen for every thirty parts of cellulose decomposed [Hutchinson and Clayton, 1918-19]. A proper balance of carbon and nitrogen in the plant material, therefore, seems to be essential to secure optimum results.

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If carbon is in large excess the organisms will grow till the available supply of nitrogen is exhausted ; and with a surplus of nitrogen the bacterial activity will generally stop when the whole of carbon is utilised. The decomposition proceeds most satisfactorily only when the values for the carbon and nitrogen contents of the decomposing material are optimum under specific conditions of temperature and soil reaction. Waksman and Tenny [1927] have, for instance, shown that for neutral and alkaline soils in temperate regions, a carbon to nitrogen ratio of less than about 22 to 1 is required to produce nitrification, and in acid soils the ratio is approximately 15 to 1. If the nitrogen figure in acid or neutral or alkaline soils is in excess of the corresponding optimum value, benefit to the soil is likely to follow from the surplus balance of nitrate which becomes available as plant food. It is also assumed that incorporation of carbonaceous materials having a wide carbon to nitrogen ratio will generally deplete the soil of its existing available nitrogen. This is attributed to the micro-organisms utilising for their own metabolism whatever nitrogen is available in the plant material and further consuming the soil nitrogen in the form of nitrates. If no soil nitrate is available the microbial activity will ultimately stop. The injurious effect of the root portions left as residue in the soil from carbonaceous plants having wide carbon-nitrogen ratios, like *Sorghum*, soybeans, cowpeas, etc. on succeeding crops has been explained on this assumption by a large number of workers in America and elsewhere [Akhurst, 1932, Turk, 1932, etc.].

The maximum nitrogen content of plant material for optimum microbiological activity in temperate climates has been found to be 2 per cent and in Malaya and other tropical countries 1.7 per cent [Waksman and Tenny, 1927]. Plant materials containing less nitrogen than 1.7 per cent are, therefore, believed to deplete the soil of its existing nitrates and might thus be detrimental to succeeding crops. Any nitrogen over this limit becomes available to plants, and the crop will accordingly benefit considerably. The distinction between legumes and non-legumes as green manures, therefore, becomes quite arbitrary, and any plant material which is capable of supplying nitrogen above the limit required for micro-biological activity will prove in general beneficial to plant growth.

On the basis of the above hypothesis the choice of plants as green manure should be mostly on

their carbon and nitrogen contents. The carbon content may be considered to be fairly constant, near about 40 per cent in plant materials and, hence, an approximate idea of the carbon to nitrogen ratio can be obtained merely by considering the percentage of nitrogen in the plant. Leaves, being generally richer in nitrogen than stems, are, as a rule, more efficient as soil fertilisers than the latter. With age the percentage of nitrogen in the plant decreases, and thus tender plants may be assumed to act better than the more mature ones on being ploughed in the soil.

No systematic chemical analysis for the carbon and nitrogen contents at different ages of some of the most important and commonly used Indian green manuring plants has been undertaken. Hence, it is not at present possible to furnish data indicating on the above considerations the relative decomposability of the common Indian green manuring materials. This aspect of green manuring requires immediate attention in India.

Even if different plant materials have the same carbon-nitrogen ratio, it has at times been found that their rates of decomposition in the soils are not precisely the same. In order to be able to judge accurately their relative course of decomposition in the soil, besides the carbon-nitrogen ratio it will also be necessary to take into consideration their lignin, cellulose and hemi-cellulose contents. According to Waksman *et al* [loc. cit.] the water soluble portion of a plant is also an important factor in determining the ease with which it may be acted upon by soil micro-organisms. Soluble substances, specially the hydrolysable constituents like soluble carbohydrates and proteins, are the first to be attacked by the micro-organisms. A more tender plant is usually richer in water-soluble constituents, and hence, in the green condition humification takes place much more quickly and efficiently than when either the plant is more matured or incorporated in a dried state [Ba<sup>1</sup>, 1922 and others].

#### *Decomposition of cellulose and lignin fractions*

As has been shown above, the changes which occur in the composition of green manures on being incorporated into the soil are chiefly the result of micro-biological activity. It is possible that some chemical action may also be responsible; but the actual extent and course of such actions have not yet been clearly understood. When plant residues are turned into the soil there is a considerable increase in the number of soil micro-organisms. Allen, Abel and Magistad [1934], for

instance, found that ploughing in pine-apple stumps resulted in an increase in the number of soil micro-organisms. The summary of their results, showing the count in the number of bacteria, fungi and actinomycetes before and after a period of three weeks, is given in Table XLVI.

TABLE XLVI

*Increase in the soil micro-organisms in millions per gm. of soil*

Particulars	Bacteria	Fungi	Actinomycetes
1. Before ploughing in	0.2	0.4	0.1
2. After ploughing in	7.1	23.1	5.1

It will be observed that soil fungi are much more active in decomposing plant materials than either bacteria or actinomycetes. Similar conclusions were arrived at by Waksman and Skinner [1926] who also suggested that cellulose was the first to be attacked by the fungi.

Rege [1927] has laid particular emphasis on the cellulose, pentosan and lignin content of the added plant material, and found that both the cellulose and pentosans could be decomposed easily; whereas, lignin remained practically unaffected even after several months. He arranged different organic materials in the order of their pentosans and lignin contents and showed that this order was in agreement with the relative ease with which they decomposed in the soil. Waksman and Tenny [1927, 1, 2; 1928] too observed that cellulose and hemi-celluloses were the first to be decomposed and that during the first month practically no lignin was lost. Table XLVII shows the results of their observations on corn stalks.

TABLE XLVII

*Decomposition of corn stalks in the soil (Waksman and Tenny)*

Constituents	Per cent loss after			
	27 days	68 days	205 days	405 days
Cellulose	58	70	94	96
Hemi-cellulose	53	62	84	87
Lignin	7	31	44	57

It will be noted from the above that at a period when practically all the cellulose material had disappeared lignin decayed only upto about 50

per cent. Lignin may, therefore, be considered to be more resistant to the action of micro-organisms, and it may even be assumed that the lignin fraction of the organic matter would not undergo decomposition to any appreciable extent during the short period the green manures remain in the soil before the planting of the succeeding crop.

*Nitrification of green manures*

*Aerobic conditions.* Hutchinson and Milligan [1914] studied the nitrification of sunn at different stages of growth. They observed that nitrogen in plants four weeks old nitrified to an extent of 67.8 per cent; in plants six weeks old to an extent of 50 per cent and in plants ten weeks old only to 34.5 per cent. They further demonstrated that although the total nitrogen added to the soil might be greater by incorporating more mature plants than younger plants, the total amount of nitrates formed in the soil was invariably more with the latter. Thompson, Johnson and Sabr [1917] have shown that legumes contain about 45 per cent of nitrogen in the water-soluble condition which can easily be converted into an available form for the plants.

Bal [1922] and Joshi [1922] working with different green manuring plants showed that leaves get nitrified easily; whereas, roots and stems were found to be comparatively resistant. With regard to the age of the plants, Bal [loc. cit.] reports that certain plants do not show any decrease in the rate of decomposition with advancing age, and this is believed to be due to there being no change in the soluble constituents and total nitrogen content with advanced maturity. Practically the same result has been obtained by a number of workers, notably by Lohnis [1926] and Leukel *et al.* [1929]. Lyon and Wilson [1928] do not consider all legumes to be necessarily more effective than non-legumes for increasing the soil nitrates. In their opinion advantage lay with those crops which reached less advanced stage of growth before being ploughed under, even when the total quantity of green matter produced was less than that of the more matured crop.

Joachim [1926, 1, 2; 1927] made a comprehensive study of nitrification of a few typical green-manure plants of Ceylon, and the results of his laboratory and field experiments showed that (i) maximum nitrate accumulation took place

between the sixth and the eighth week of incorporation; (ii) the maximum nitrification percentage varied from 23.3 for *Albizzia*, to 77.7 for *Crotalaria* in the laboratory and 40.2 for *Tephrosia* to 126.4 for *dadap* in the field; and (iii) the use of non-leguminous leafy material like sun-flower resulted in as great a nitrate accumulation as when leguminous crops were employed. The summary of his results is given in Table XLVIII.

TABLE XLVIII

*Nitrification of green manures—laboratory and field experiments (Joachim)*

Treatment	Laboratory experiments	Field experiments	C : N ratio of the G.M. (Edou, 1930)
	Maximum per cent notified after two months	Maximum per cent notified after two months	
<i>Gliricida</i> . . .	43.7	86.3	..
<i>Albizzia</i> . . .	23.3	66.3	..
<i>Dadap</i> . . .	68.6	126.4	11.2
Wild sun flower	67.2	105.0	..
<i>Crotalaria</i> . . .	77.7	70.5	..
<i>Tephrosia</i> . . .	60.0	40.2	11.5
Cattle manure . . .	27.5	57.9	14.4

Recently this problem has been studied by Singh and Singh [1937], and these authors have determined the relative rate of nitrification and decomposition of the whole plant, leaves, stems and roots of sunn under field conditions. They observed that the major part of the leaves was decomposed within four weeks and after a period of eight weeks 37.5 per cent of the stems and 19.6 per cent of the roots only remained un-attacked. The plant as a whole was decomposed to the extent of 70 per cent. However, the experimental technique adopted for the determination of undecomposed organic matter being somewhat faulty, these data can be accepted only as a rough approximation.

According to the same authors leaves contribute most to the soil in terms of nitrogen, both available and total—the maximum being attained in the six-inch layer of soil after four weeks of burial. The next in order of nitrification were the roots and stems. A considerable quantity of nitrogen mostly that derived from the leaves was found to have been washed down as a result of leaching. They, therefore, concluded that the beneficial

effect on the succeeding crop of the nitrate-nitrogen derived from the undecomposed leaves would mostly be washed off before the stems and roots decomposed completely. Thus it was assumed that after eight weeks of burial the top six inches of the soil would be containing only the nitrates formed from the roots and stems, without there being any enrichment from the nitrates resulting from the earlier decomposition of the leaves. Their results for the first six-inch layer are tabulated below :

TABLE XLIX

Total and available nitrogen content of the 0 in. to 6 in. depth of soil during decomposition of various parts of sunn at different periods of burial [Singh and Singh, 1937] (Nitrogen in parts per million)

Week of sampling after burial	Leaves		Roots		Stems	
	Total N	Available N	Total N	Available N	Total N	Available N
Original soil	1375	53	1360	52	1340	51
4th week	2075	168	1565	93	1495	82
6th week	1565	105	1745	107	1625	86
8th week	1490	55	2010	111	1935	105

**Anaerobic conditions.** The practice of green manuring rice fields, in which the green matter is turned in and the surface soil flooded, results in an anaerobic decomposition of the plant materials. The work of Harrison and Aiyar [1913] on the gases which are evolved from swamped soils in which paddy is

cultivated has shown that large quantities of nitrogen and methane are given off as a result of the decomposition of organic matter. Under anaerobic conditions nitrification being impossible denitrification starts and whatever nitrates could be accumulated during the hot season get denitrified. Moreover, in the normal fermentation process of the proteins of green manures through the amino-acid stage a large quantity of ammonia is produced. Thus nitrogen, methane and ammonia are the chief products of decomposition under submerged paddy field conditions.

Nitrogen comes to the surface of the water and is lost into the atmosphere ; whereas, methane is oxidised to carbon dioxide through the agency of the bacteria contained in the film of green algae developing on the submerged soils. The algae itself utilise the carbon dioxide, liberating oxygen a solution of which is carried down to the root zone. This provides a thorough and efficient aeration of the roots of paddy which derive considerable benefit thereby.

The ammonia liberated could according to some authors be utilised by the rice plant for its nitrogen nutrition [Joachim and Kandiah, 1927]. Joachim [1929] has actually shown that maximum paddy yields are obtained as a result of late green manuring, and this coincides with the period of maximum ammonification at a stage of crop growth when the rice plant needs greatest nitrogen.

It thus seems fairly established that green manuring under paddy field conditions involves the dual function of aerating the root area and production of nitrogen in the form of ammonia which could be utilised by the rice plant. There is, however, considerable loss of nitrogen which escapes in the gaseous form under such conditions.

## X. SUMMARY

**GREEN manuring crops**  
Many species of crops, both legumes and non-legumes, are used as green manure. But the crop of most universal use is sunn (*Crotalaria juncea*). Next in order of importance is probably dhaincha (*Sesbenia aculeata*) which can withstand drought and grow on badly-drained soils. Many plants belonging to the species *Phaseolus* have been reported as useful for

green manuring purposes. The extent to which these plants are actually used as green manure is not known, although *pillepesara* or *ran-mulki* (*Phaseolus trilobus*) has recently found much favour in Madras and Bombay-Deccan. Cowpea (*Vigna catjung*), guar (*Cyanopsis psoraloides*) and arhar (*Cajanus indicus*) are similarly used for green manuring. There are scattered references to the use of non-legumes as green

manures in different regions ; but hardly any non-leguminous plant has been generally adopted for green manuring purposes. No winter green manure has been reported excepting *senji* (*Melilotus parviflora*) and berseem stubbles which are used to some extent in the Punjab and Sind.

The choice of specific green manuring crops depends particularly on the locality and the nature of the main crop to be green manured.

A large number of workers in India have expressed the view that non-legumes are just as effective as legumes, although the latter may be more beneficial on soils of poor fertility. Wherever possible, leaves, tender twigs and stems of many trees and wild plants are also used as green manure for paddy.

Very little information is unfortunately available on the chemical composition of some of the most important green manuring plants of India. Some analytical data collected from the available literature have been tabulated.

*Raising or burying.* There may be practical difficulties in growing a green manuring crop, especially in those tracts where irrigation facilities do not exist and monsoon starts late.

Sunn could be sown with the early rains in May or even in the middle of March if irrigation is available. The budding stage (generally 75 days after germination) or the flowering stage is considered by some to be the best period for burying in sunn, although at Shahjahanpur the maximum amount of nitrogen is reported to have been secured from sunn after 50 days' growth followed by that of 60, 40 and 30 days. Older plants are generally regarded as harmful and even detrimental to crop yields. A period of two months has been found to be the optimum for decomposition of sunn, and this interval has, therefore, been recommended between its burial and the sowing of a succeeding crop. Berseem stubbles in Sind are, however, left only for about two weeks in the soil before sowing cotton.

It has been the general practice to bury a green-manure crop deeper in light soils than in sils tending to be clayey. Older crops should be buried as near the surface as possible.

Although there is evidence to prove that growing a green-manuring crop *in situ* is more beneficial than bringing it from outside, there are equally convincing facts on record in favour of

ploughing in green manures grown on other fields.

Composting of sunn before incorporation into the soil for areas with low rainfall has been advocated by a number of workers. In the Punjab and Sind some green manures are grown as inter-crops.

The practice of burning a green manuring crop and utilising the ash thereof as manure is not prevalent in India.

#### *Different green manuring crops*

*Quantity of green matter and nitrogen added to the soil.* In Bombay Presidency for medium soils the average yield of green matter varies from 20,000 lb. to 25,000 lb. per acre. In rich soils the yield may go upto about 70,000 lb. per acre. In Madhya Pradesh the yield of *sannai* varies from 15,000 to 22,000 lb. in the wheat or cotton tracts and 4,000 to 10,000 lb. per acre in the rice tracts. In Uttar Pradesh the yield of sunn varies from 15,000 to 25,000 lb. per acre. *Dhaincha* has been found to yield 9,000 to 13,000 lb. of green material per acre.

According to data available in Uttar Pradesh the quantities of nitrogen turned in by burying sunn 50 and 60 days old are 73.6 lb. and 70.8 lb. per acre, respectively.

*Application of different green manures to crops.* Green manuring as a practice has been adopted in India for (a) transplanted paddy ; (b) sugarcane and (c) irrigated wheat.

Increased yields of paddy as a result of green manuring have been reported from Madras, Madhya Pradesh, Bengal, Orissa and Uttar Pradesh. Sunn, cow-pea or *dhaincha* have been reported as useful for this purpose.

The increase in the yield of sugarcane as a result of green manuring has been estimated at about 50 per cent over unmanured canes. Sunn is generally used as a green manure ; although at Jorhat (Assam) cowpea and in the Deccan canal area *ranmulki* and *patada shevara* have been mentioned as suitable alternatives.

Green manuring wheat is considered feasible only in tracts where sufficient autumn rains are available or irrigation facilities exist.

There are scattered references to the beneficial effect of green manuring other field and grain crops.

*Value of different parts of green-manuring crops.* Leaves of green manures have been attributed the greatest manurial value. The roots of certain leguminous crops have been considered by some workers injurious to succeeding crops, although berseem stubbles have an established reputation as soil fertiliser in Sind. Singh and Singh [1936] found leaves of sunn the most efficient followed by roots and stems. At Shahjahanpur whole sunn plants led to best results followed by tops and roots.

*Green manuring for dual purposes.* The stalks of guar and cowpea could be fed to cattle, giving the benefit of roots and leaves to the soil.

The use of sunn stems for fibre production and ploughing in tops and roots as green manure have been tested at several stations and there are indications that extra profit might accrue from the sale of the fibre obtained thereby, if the green manure is meant for sugarcane.

*Residual effect in the soil.* In the Punjab the beneficial effect of green manure seems to last for four to five years ; but at Pusa, sunn as a main source of nitrogen, appeared insufficient in a two-year four-course rotation. In Ceylon the effect of green manuring is reported to last only for about six months so far as the soil nitrogen is concerned.

#### *Green manuring with artificials*

*Application of fertilizers to green-manuring crops.* The application of 20 lb. of N plus 50 lb. of  $P_2O_5$  resulted in an increase in the yield of sunn-hemp at Padegaon. Next in order was found to be  $P_2O_5$  alone at 50 lb. per acre. The beneficial effect of phosphates on the growth of green manures has also been noted in Assam and Ceylon. It has been assumed that the addition of phosphates at the time of raising the green manure crop will benefit even the succeeding crop.

#### *Fertilizing effect of artificials with green manuring*

(a) *Nitrogenous artificial.*—The addition of sulphate of ammonia at the time of burying in green manure has resulted in increased yields of paddy as compared with green manure alone. For sugarcane a supplement of sulphate of ammonia, castor cake or farm-yard manure gave increased yields over green manure alone at

Shahjahanpur and Kanpur. At the latter station castor cake and rape cake gave higher yields than groundnut cake or sulphate of ammonia. For wheat a supplement of groundnut cake gave the best results at Kanpur followed by castor cake and sulphate of ammonia.

(b) *Phosphatic artificials.* There is ample evidence of the beneficial effect of adding phosphates to green manures for paddy. The only places where such additions proved ineffective are Nagina in Uttar Pradesh and three stations in Madras. Green manuring with superphosphates seemed to be more effective than green manures alone for crops like maize and oats at Pusa. It has been suggested that phosphates with green manures become more available to plants and thus increase crop yields.

(c) *Lime.*—Lime used in conjunction with green manures has been reported to be beneficial for some crops.

#### *Green manuring and rotation of crops*

*Legumes in rotation.* Bajri after kulthi yields 25 per cent more than bajri after bajri in Bombay. Certain rotations followed in the Punjab where leguminous crops are interposed in order to increase the fertility of the soil are described. In Madras the rotation of rice and sugarcane or cotton and sorghum has been made more effective by growing a leguminous crop in between. Similarly, in Bombay Presidency the harmful effect of jowar on cotton could be eliminated by growing a green-manure crop in rotation, and in Sind berseem cultivation invariably results in higher yields for seed cotton. The beneficial effect of legumes grown in rotation has also been observed at Pusa.

*Rotation for sugarcane.* At Pusa it was found that the yield of cane could be considerably increased if three green pulses intervened instead of two in a four-year rotation. In Bihar the usual rotation is sugarcane—monsoon crop for fodder or seed, (rabi)—green manure—cane. Maclean [1937] has suggested changing this to green manure—wheat—follow—sugarcane. In Uttar Pradesh sunn green manuring of sugarcane is considered advantageous over having cotton in the kharif ; and at Padegaon green manuring sugarcane with sunn or patada shevra is found to be the best followed by fallow, cotton, jowar and groundnut in the kharif.

*Economics of re-manuring*

There seems to be a net saving of Rs. 50 to Rs. 70 on green manuring sugarcane with sunn in the Deccan Canal area and Rs. 80 to Rs. 90 in the Uttar Pradesh.

*Cost of green manures on unit nitrogen basis*

The cost per lb. of nitrogen from sunn as compared with other artificials and manures in the Uttar Pradesh and farm-yard manure in the Deccan Canal tract has been calculated and in all cases sunn green manuring seems to be the cheapest.

*Green manuring paddy.* In the Uttar Pradesh sunn green manuring paddy gave a net profit of Rs. 53-2 if grown *in situ* and Rs. 37 if brought from outside. The addition of superphosphates lowered the profits. In Bihar at Sabour and Gaya green manuring paddy gave a extra profit of Rs. 10 to Rs. 15 per acre. The addition of superphosphates increased the net profit from Rs. 14 to Rs. 17 per acre.

*Green manuring other crops.* Under Sakrand (Sind) conditions the gain in favour of green manuring onion and potato crops as compared with farmyard manure averaged to Rs. 9 per acre.

*Green manuring for dual purposes.* For wheat using sunn as green manure an additional profit of Rs. 3-14-11 was obtained at Pusa when fibre was extracted from the sunn stems as compared with green manuring with the whole plants. Green manuring paddy with roots and tops of

sunn and removing stems for fibre gave always a low margin of profit at Nagina. However, for sugarcane material increase in the net profit has been reported from Shahjahanpur if stems are removed from sunn and utilised for fibre production.

*Soil and green manures*

It has been suggested that response to green manuring is much greater in sandy soils than in stiff soils. Green manuring improves the texture of the soil, making a heavy soil porous and light soil more compact. Deep-rooted leguminous trees or plants open up the subsoil.

In the Punjab *senji* is used as a green manure for improving the alkaline nature of the soil and in Travancore different kinds of sour leaves and stems have similarly been employed for this purpose.

Green manuring improves the water-holding capacity of the soil. But after inversion the soil must receive moisture equivalent to at least 5-6 in. of rain; otherwise, injury might be done to the succeeding crop. Green manuring under arid or semi-arid conditions is, therefore, not considered safe.

*Decomposition*

Various theories advanced for the decay of the organic matter in the green manures and other factors affecting their disintegration in the soil have been discussed.

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## APPENDIX

## EXTRACTS FROM THE REPORT ON THE SURVEY OF GREEN MANURING PRACTICES IN INDIA BY SARDAR SURJAN SINGH SIDDHU—I.C.A.B. 1947.

DURING 1946-47 the Indian Council of Agricultural Research sanctioned a scheme on Survey of Green Manuring Practices in India. The object of the survey was to find out the present state of green manuring of crops in India, the obstacles and difficulties that are experienced in the expansion of this method of manuring and the maximum limit to which the practice can be expanded under normal circumstances. The report was submitted by Sardar Surjan Singh Siddhu, Special Officer in 1947 and brief extracts from the report are given as under.

*Difficulties in the wide spread use of green manuring*

Green manuring can raise the fertility of the soil but the application and utility of this practice depends on various factors. These factors are climate, land, labour, capital and management. If these factors are not favourable the practice could not be easily taken up by the cultivator.

The unbalanced and uncontrolled rural economy does not favour green manuring as a regular practice. The *zamindar* is unprogressive and does not function properly in our agricultural economy. He does not encourage any agricultural development by his tenants. The tenants, on the other hand, have no fixity of tenure. They pay more attention to immediate gains and cannot afford to invest any capital outlay on any long-term improvement. The low precipitation and lack of irrigation facilities are other major obstacles since green manuring gives best results only where there is plenty of moisture in the soil. Moreover, there is shortage of labour, difficulty in getting green manure seeds and canal water at the right time. There is also not proper propaganda or education with a view to develop the practice of green manuring in the different states and provinces of India.

Green manuring for *kharif* crops like paddy becomes difficult as very little time is left for the growth of the green manuring crop if early rains are not assured. Moreover, severity of hot weather preceding the *kharif* season becomes detrimental to the young green manuring crop in case there are long breaks in rains and no irrigation facilities available. Small and scattered holdings also react adversely on this practice in general.

*Ideal agricultural characteristics of green manuring plant*

The plant should be of rapid growth so that it may produce early and bulky organic matter. It should have abundant succulent and soft tops which may add to the soil easily available plant food material for the next crop. The plant should have the ability to grow on a poor and sandy soil and should not be handicapped for want of good soil. The plant should have higher percentage of moisture which would help in quicker decomposition in the soil. It should be a legume to assist nitrogen fixation from the atmosphere. It should be less woody and fibrous otherwise it may not rot easily. It should have less water requirement for its growth.

*Plants used for green manuring*

Leaves of trees near hills and forest are used extensively as green manure in Madras. *Sanai* is the chief green manuring crop which is sown in mid-May and ploughed in as six week's old crop for paddy. Green leaves are similarly puddled. Wild indigo (*Tephrosia purpurea*) is purchased by the cultivators from the people who bring it from the adjoining hills and applied to sugarcane. It is also sown broadcast before the harvest of paddy in November or if there be not enough moisture then in January when winter rains are expected,

and ploughed in next July for paddy. Portial (*Thepesia populnea* N.O. *Malvaceae*) and *Pongamia glauca* are common trees with plenty of soft broad leaves. The leaves of these trees are commonly used for green manuring and are considered very good for this purpose. Other varieties for green manuring are *Prosopis juliflora* which is grown on bunds and the leaves are lopped every now and then; *Sesbania spiciosa* a new variety of *Sesbania* obtained from South Africa which is softer than *S. aculeata* and is therefore considered better; and *Sesbania grandiflora* which is a bigger plant and gives bigger leaves.

*Pongamia glabra* known locally as *karajwa* is a tree growing extensively in dry regions of Mysore and Madras with a rainfall of 20 in. or less. It has heavy foliage with big individual leathery leaves. It supplies as much as 50 to 150 md. of green leaf from a single tree. Besides, the nut yields a kernel having high percentage of oil which could be used for burning purposes or for soap making. The oil-cake makes a valuable fertiliser.

*Different crops used for green manuring*

*Guar* (*Psymopsis psoroloides*) is a green manuring crop of Eastern Punjab and Sind and is suitable for dry climates. It can be used as green manure only under irrigated conditions. It is a good and nutritive cattle fodder. For green manuring the seed could be drilled in or broadcast in May or June. It gets a good start with rain or irrigation and can be ploughed in before the middle of September. It is used for wheat in the Punjab and to some extent in Sind.

*Crotolaria striata* is suitable for moist regions like Malabar. It is not used *in situ* but grown outside and two cuttings of green matter of about 8,000 to 15,000 lbs. are available which could be used for sugarcane, coconut, areca nut or vegetables. *Sanai* (*Crotolaria juncea*) is a crop grown in Northern India for fibre and green manuring. In Madras it is also grown for green fodder and hay. It is a very quick growing crop. It is sown broadcast with the break of the monsoon and is ready for ploughing in after 8 to 10 weeks. It makes 5 feet tall crop, with succulent and soft tops and is ideal for decomposition in the soil. Light sandy soils are eminently suitable and heavy clay soils with bad drainage are unsuitable for this crop. However, it grows in wet paddy lands of Madras.

*Dhaincha* (*Sesbania aculeata*, *S. spirulosa*, *S. gigantea*) common variety is *S. aculeata* which is a plant used for green manuring in wet regions. It can tolerate good amount of salinity in the soil. It is used extensively in Bengal from where the seeds are exported to Madras and Orissa. It is sown broadcast at the rate of ten lb. per acre. It has a quick growth second to *sanai* and is quite soft and succulent in early stages when it should be ploughed in as green manure. On being mature it becomes very woody.

*Kalonji* (Madras), *Sarphanki* (U.P.), wild indigo (*Tephrosia purpurea*) is a common weed of the uncultivated lands of Northern India. It is a legume and has plenty of nodules in the roots. In Madras it is used as a green manure crop. The plant is hardy and can grow in any type of soil. It thrives well generally in the driest part of the year, viz. January to June. It has a very low water requirement for it can grow with the scantiest moisture contents of the soil which would not support any other vegetation. It sheds its leaves during the hot weather, but with rains or irrigation it shoots forth fresh foliage. The seed is hard and slow to germinate and hence it is given some pre-treatment before sowing. Seed could be sown in September, October, November or even upto February in the standing field of paddy. It will grow and give a stand of 4 ft. high crop. In hot weather it will shed all its leaves but will throw out fresh leaves with the first break of monsoon. It could then be puddled in the field and paddy transplanted. It gives about 4000 to 5000 lb. of green matter.

Leguminous weeds which are found in U.P. and which could be adapted as green manuring crops are *Cassia obtusifolia* (panwar or chakor), *Tephrosia purpurea*, *Indigofera* sp., *Lathyrus aphaca* (matri), *Lathyrus cativus* (lesari), *Lathyrus sphaericus*, *Vicia sativa* and *Vicia hirsuta*.

*Philipesara* (*Phaseolus trilobus*) is an important leguminous fodder crop grown in the Circars of the Madras Presidency. It is a trailing herb with many branches prostrate on the ground which reach a length of even six feet. The root system is full of nodules. It is a very nutritive green fodder. It can be used as a green manure crop. Seed is sown broadcast in the standing crop of late paddy just before its harvest at the rate of about 15 lb. per acre. Irrigation is given to the crop and the crop is ready for green manure in next July. For sugarcane it is sown in September. The first few cuttings are used as fodder when in December the land is ploughed for sugarcane. The yield is about 25,000 lb. when grown from November to July.

In *rabi* few crops are used as green manures since all leguminous crops are valuable seed or fodder crops. Pea is used very rarely as green manure. The last cutting of berseem can be ploughed in as green manure for sugarcane but it is a valuable fodder crop. Same is the condition with *shaftul* (*Trifolium alexandrum*) and *metha*. *Senji* (*Melilotus parviflora*) may have some possibilities as green manure due to its bulk for sugarcane. *Kesari* (*Lathyrus sativus*) is sometimes used as green manure in Sind.

#### Technique of green manuring

Green manuring is practicable only in those areas which have well distributed rainfall over the growing and post-burial period of the green manuring crops. It could also be adapted in regions where timely irrigation facilities are available. It is, however, an unsuitable practice for unirrigated areas with 20 in. or less precipitation.

In wet lands where paddy is the usual crop green manuring has been taken up with success. The technique of green manuring in wet lands is very simple and needs no special care or attention. Not much propaganda is necessary for spreading the use of green manuring in such areas, the only help that cultivator wants is the timely supply of good seeds for green manure crops. In Madras, seed of *sana* is not easily available. In the local markets the cost of the seed was very high and cultivators had to depend on the Departmental supply. It is difficult to raise green manuring seeds in low-lying paddy lands. Seed raising should, therefore,

be done on dry high lands. Poor quality high level lands could easily be utilised for raising seeds of green manuring crops which being legumes will require little cost for production but would give a fairly good return. Seed raised on such high lands should be moved to low-lying wet areas through Departmental agencies by obtaining priority over transport.

In dry lands the factors that affect the suitability or otherwise of green manuring are :—

- (a) *Soil*—light soil is the best and heavy the worst.
- (b) *Moisture*—scarcity and excess are harmful.
- (c) *Temperature*—extremes undesirable.
- (d) *Soil aeration*—poor aeration harmful.
- (e) *Cultivation*—Time and type of cultivation a vital factor.
- (f) *Crop to be green manured*—these have to be carefully selected.

#### Research

Useful plants should be discovered which could be utilised as green manures. For example white clover which is found in Ootacamund and in Simla in hot weather at a height of 1000 ft. forming a thick mat of vegetation on the surface is a leguminous weed and could be cultivated in winter months on the plains. It may turn out to be a fine fodder and an excellent legume. A tree *Pongamia glabra* which yield a large quantity of green leafy material may turn out very valuable for green manuring purposes if planted on village-common lands, waste lands, road sides etc. The tree also yields a nut the kernel of which gives an oil for burning or soap making leaving the cake which is an excellent fertiliser. This tree is very common in East Mysore with a rainfall of about 20 in. per annum.

Further research on green manuring should proceed on selection of suitable leguminous plants which grow as local weeds and which have all the good points of a green manuring plant. Plants growing both in the *kharif* and *rabi* should be studied from this point of view. The main consideration should be that the plants selected should be quick growing, succulent, easily decomposable with low moisture requirement and low co-efficient of transpiration, able to produce maximum amount of nitrogen and organic matter in shortest possible time and to fit in the existing practices of the agriculturists. Crops suitable for dry, moist, wet, hot and cold climates should be discovered so that the crops may suit the various parts of India.