

Report on  **ment of the**
Cattle and Dairy Industries of India

GIPE-PUNE-011254

BY

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CONTENTS

	PAGES.
INTRODUCTORY NOTE	v—vi
PART I.—THE PRODUCTION, COLLECTION, PROCESSING AND DISTRIBUTION OF LIQUID MILK AND THE MANUFACTURE OF MILK PRODUCTS.	
CHAPTER I.—<i>The need for an increased consumption of Milk.</i>	
India's milk production. Present <i>per capita</i> consumption. Dietary requirements. Results of milk feeding experiments. Relation to income level. Need for increasing and cheapening milk production	1—7
CHAPTER II.—<i>General discussion on the trend of development of the Dairy Industry.</i>	
Origin of organised dairying. Market requirements. Special difficulties involved in dairying under Indian conditions. India's population predominantly rural. Need for a new outlook. Requirements of the rural population. Necessity of improving methods of handling milk and milk products. Need for better marketing facilities. Conclusions	8—16
CHAPTER III.—<i>The Production, collection, processing and distribution of milk for Liquid consumption.</i>	
Introduction. Present methods of production. Need for investigation. Suggested problems. Application under village conditions. Processing of milk. Processing by heat. Cooling and refrigeration. Distribution of milk. Hygienic aspects. Prevention of adulteration. Milk standards	17—29
CHAPTER IV.—<i>The manufacture of Butter and Ghee.</i>	
Relative importance of butter and <i>ghee</i> . Production of 'country' butter and <i>ghee</i> . Outturn and quality of <i>ghee</i> . Factors affecting quality. Adulteration of <i>ghee</i> . Detection of adulteration. Sale of <i>banaspatine</i> . Marketing of <i>ghee</i> . Export market for <i>ghee</i> . Production and marketing of creamery butter. Standards for butter	30—42
CHAPTER V.—<i>The manufacture of Khoa and Dahi and of other indigenous milk products.</i>	
Importance of indigenous milk products. Products manufactured by partial desiccation. Products resulting from the souring of milk. Improvements in production and packing. Possible uses of separated milk. Provision of standards. Nutritive value of indigenous milk products	43—48
CHAPTER VI.—<i>The utilisation of skim milk in the manufacture of casein, condensed milk and dried milk.</i>	
Present production of separated milk. Imports of milk products. Export markets. Value of separated milk. Feasibility of centralising supplies. Quality of separated milk. Technical considerations. Conclusions	49—54

PART II.—THE PRODUCTION OF MILK IN RELATION OF THE BREEDING AND NUTRITION OF MILCH CATTLE.

CHAPTER VII.—*The importance of cattle in Indian Agriculture.*

Introduction. Income from sale of cattle products. Value of cattle labour. Cattle as a factor in maintaining soil fertility. Would 'mixed-farming' cheapen milk production? Conclusions 57—61

CHAPTER VIII.—*General discussion on cattle improvement.*

Issue of pedigree bulls. Pedigree *versus* approved bulls. The problem of the scrub bull 62—64

CHAPTER IX.—*The breeding and management of milch cattle.*

Importance of increasing *per capita* milk yields. Need for considering local requirements. Long range policies. Improvement of indigenous breeds *versus* cross-breeding. Value of indigenous milking breeds. Desirability of developing higher milking strains. Need for registration of milch cattle and for milk recording. The cow *versus* the buffalo. Management of milch cattle. Physiology of reproduction 65—73

CHAPTER X.—*The nutrition of milch cattle.*

India's total fodder resources. Need for increased cultivation of fodder crops. Conservation of fodder crops. Available supplies of concentrates. Rationing of milch cattle. Nutritional deficiency diseases 74—83

PART III.—RESEARCH, EDUCATION AND ADVISORY SERVICES IN CONNECTION WITH THE CATTLE AND DAIRY INDUSTRIES.

CHAPTER XI.—*Recommendations for the future development of Dairy Research, Education and Advisory Services.*

Present position. *Research*: Need for an Imperial Dairy Research Institute. Location. Qualifications of staff. Buildings and equipment. Is an experimental creamery required? Expenditure involved. Dairy research in the provinces. *Education*: Introduction. Instruction in general dairying. Syllabus for the Indian Dairy Diploma. Centres of instruction. Post-graduate training in research. Elementary dairy training. Courses of instruction at veterinary colleges. *Advisory services*: Present position. Need for a provincial service. Methods of securing coordination. Coordination with the centre. Expenditure 87—107

CHAPTER XII.—*Recommendations for the future development of Research, Education and Advisory Services in connexion with cattle improvement.*

Research: Problems of breeding and management. Nutritional problems. Fodder production. Rationing. Deficiency diseases. *Education*: Instruction at agricultural and veterinary colleges. Post-graduate experience in cattle breeding. Post-graduate research. Elementary courses of instruction. *Advisory services*: Control of cattle improvement. Expenditure on cattle improvement. Supplementary agencies for cattle improvement. *Gowshalas* and *Pinjrapoles*. Military dairy farms. District and demonstration farms. Opening of herd books. The provision of increased supplies of fodder .. 108—122

	PAGES.
<i>Summary of Principal Conclusions and Recommendations</i> ..	.. 123—134

APPENDICES.

APPENDIX I.—Terms of Reference .. .. .	.. 137
APPENDIX II.—Special Considerations relating to City Milk Supplies ..	.. 138—141
APPENDIX III.—Special Considerations relating to Hill Dairying ..	.. 142—143
APPENDIX IV.—The Provision of milk for children of School Age ..	.. 144—145
APPENDIX V.—The Importance of Goats as Milch Animals .. ..	.. 146
APPENDIX VI.—A Note on the Need for Coordination of Rural Services	147—148
APPENDIX VII.—Conversion Tables .. .. .	.. 149
APPENDIX VIII.—Itinerary .. .. .	.. 150—152
Tables 1 to 46 and Figures 1 and 2 .. .. .	.. 153—185

INTRODUCTORY NOTE.

The present Report is divided into three parts. Parts I and II consist of detailed statements of the present position and needs of the dairy and cattle industries. Although my terms of reference were largely concerned with questions relating to the future development of research and education, I found in practice that these could not be answered until the whole field of dairying and of cattle breeding and management had been surveyed. This has, however, given me an opportunity of referring to a number of special problems which require investigation, and of indicating the lines along which future developments might be planned. The more general recommendations of the Report have for convenience been grouped together in Part III. Since the dissemination of scientific and technical information falls within my terms of reference, I have made a number of recommendations in connexion with the provincial advisory services, the subjects dealt with including such questions as the control of cattle improvement and the co-ordination of the work of the central and the provincial governments.

Throughout my survey I have been given ample opportunity of investigating the various subjects which fall within my terms of reference. I desire to express my indebtedness to all those who facilitated my work by their willing co-operation and their generous hospitality during my tour. In particular I should mention the various Directors of Agriculture and Veterinary Services and the Provincial Live Stock Experts, who were responsible for local arrangements and who were at all times most willing to give me the benefit of their knowledge and experience. The general arrangements for my visit were made by the Imperial Council of Agricultural Research. I gratefully acknowledge the assistance given to me by Sir Bryce Burt, the Vice-Chairman, by Sir Arthur Oliver, the Animal Husbandry Expert, and by other officials of the Council. I am also indebted to Mr. Z. R. Kothavalla, Imperial Dairy Expert, who accompanied me on a part of my tour and who was able to give me much useful information regarding the present state of the Indian dairy industry. My thanks are also due to Mr. A. M. Livingstone,

Agricultural Marketing Adviser to the Government of India, who very kindly placed the records of his Department at my disposal. In this connexion I should refer particularly to the services rendered by Mr. D. N. Khurody, who has been in charge of the recent milk marketing surveys and who was able to provide me with most valuable information on this subject. Finally I desire to place on record my great indebtedness to Mr. A. C. Aggarwala, who acted as my Secretary-Adviser. Mr. Aggarwala was personally responsible for the arrangements connected with my tour and it is largely due to his help and guidance throughout my visit that I have been able to obtain such a close insight into the problems of the cattle and dairy industries.

NORMAN C. WRIGHT.

28th July, 1937.

PART I.

**THE PRODUCTION, COLLECTION, PROCESSING AND
DISTRIBUTION OF LIQUID MILK AND THE
MANUFACTURE OF MILK PRODUCTS.**

CHAPTER I.—The need for an increased consumption of milk.

The total output of milk in India is exceptionally large. One authority has placed the annual production at over 1,000 million maunds⁽¹⁾. A more recent survey⁽²⁾ indicates that this is likely to be an over-estimate, and that the figure lies nearer 700 million

India's milk production.

maunds. The latter figure would, however, represent the hand-milked yield, and would need to be increased by at least 15 per cent. (say, to 800 million maunds), to give the gross output of milk. The monetary value of this output is shown later to approximate 300 crores of rupees. Compared with other countries, India stands second in volume of milk production, her output being exceeded only by the United States of America. She produces over four times the output of Great Britain, over five times that of Denmark, over six times that of Australia, and over seven times that of New Zealand.

The production of milk cannot, however, be considered without reference to the needs of the population who have to subsist on it. It is here that India falls to the lowest place among those countries for which statistics are available.* This point is shown clearly in Table 1. The total production of milk is given in the first column, the human population in the second column, and the calculated production per head of population in the third column. This column provides, therefore, a measure of the adequacy of milk production in terms of the requirements of the population.

It will be seen that the countries may be classed into three groups. Six countries show productions of between 30 and 40 oz per head per day. In these countries the production per head agrees closely with the estimated consumption which is shown in the fourth column and which may probably be taken as adequate for the nutritional needs of the population. Such countries are self-supporting in so far as their milk requirements are concerned. Nine countries show productions in excess of 40 oz. per head per day. These are countries such as Australia, Canada, New Zealand and the Scandinavian nations, which have an exportable surplus of milk. The remaining five countries show productions below 30 oz. per head per day. These countries do not produce enough milk to supply their own requirements, and must either import milk products or subsist on a diet deficient in milk. A highly industrialised nation like Great Britain is able to import sufficient milk products to raise the consumption to an adequate level⁽³⁾. On the other hand countries which are predominantly rural, such as Poland, Italy,

(1) A. Oliver and M. Vaidyanathan, "Assessment of the Annual Contribution of Live Stock to Indian Economy".

(2) Results of Provincial Marketing Surveys.

*Unfortunately no similar information is available for tropical or far-eastern countries.

(3) It may be noted, however, that 60 per cent. of Great Britain's consumption is in the form of butter, a very incomplete food. The milk equivalent of the whole milk products consumed would only be about 16 oz. per head per day.

Roumania and India, cannot afford to import milk products, and their populations are therefore unable to obtain an adequate supply of milk to meet their nutritional needs. Thus it will be seen that India's consumption of 7 to 8 oz. per head per day is less than a quarter of that of the self-supporting countries.

It may be asked whether the estimate of 7 to 8 oz. is a true indication of the daily *per capita* consumption, since it is based on very rough estimates of the average milk yields and lactation periods of Indian cattle.

Present per capita consumption.

An alternative method of determining the level of milk consumption is by dietary surveys, though these are also subject to considerable error—partly because information collected from consumers is frequently unreliable (especially in dealing with a relatively uneducated population) and partly because dietary surveys necessarily apply to a very restricted section of the population. Unfortunately few such surveys have been carried out in India, but it will be well to see how far the available figures agree with the estimate already mentioned. In a survey of the food consumption of tenant cultivators in Western Punjab⁽⁴⁾ details of milk consumption are available for 39 families. The average daily *per capita* consumption was found to be 5 oz., but in addition 0.6 oz. of *ghee* was taken. As the survey related to the families of cultivators it may be assumed that the *lassi* (butter-milk), which is left as a by-product of the manufacture of *ghee* and is a most popular beverage, was also included in the diet. The total milk equivalent would thus be raised to just over 14 oz. per head per day. The Report mentions, however, that milk consumption depended on wealth as well as age, and that "the menials use little milk other than *lassi*..... The poorer non-agriculturists cannot afford to take *ghee* or milk even occasionally, except on festive days". Similar figures have been obtained in a recent investigation in the Sialkot District of the Punjab⁽⁵⁾, where the milk consumption of 60 families averaged between 5 and 5½ oz., and the total milk equivalent consumed (*i.e.*, including curds and *ghee*) was between 16 and 18 oz. per head per day. On the other hand very different results have been recorded in a dietary survey carried out in South Indian villages⁽⁶⁾. In this survey milk and milk products were found to be entirely absent from the diets of 31 out of the 44 families investigated, while the average milk consumption of the remaining 13 families was less than 3 oz. per day. This was supplemented by curds and *ghee* equivalent to a little over 4 oz. of milk, giving a milk equivalent consumption of barely 7 oz. per head daily. Spread over the 41 families, this average figure would be reduced to only 2 oz. per head per day. It has long been recognised that differences in the consumption of milk and milk products are probably associated with the marked

(4) S. Lal and W. Roberts. "Rates of Food Consumption by 71 families of Tenant Cultivators in the Khanewal Tahsil, Multan District". Punjab Board of Economic Inquiry Publication No. 29, 1935.

(5) N. C. Wilson. Unpublished data.

(6) W. R. Aykroyd and B. G. Krishnan. "Diet Surveys in South Indian Villages". *Indian Journ. Med. Res.* 24, 667 (1937).

differences in physical development of the northern and southern races of India. Such differences in milk consumption have been noted by Sir John Megaw⁽⁷⁾ and are also apparent in the estimates of milk production made in the recent provincial marketing surveys (see Table 2).

It is also found that the consumption of milk and milk products is markedly lower in urban than in rural areas. An inquiry conducted in nearly 2,500 working class households in Bombay⁽⁸⁾ showed that the average quantity of milk consumed per head per day was less than half an ounce. This was supplemented by 0.05 oz. of *ghee*. A similar inquiry among 97 families of jute mill workers in Bengal⁽⁹⁾ gave a *per capita* daily consumption of just under one ounce of milk and of 0.10 oz. of *ghee*. These figures refer, however, to selected groups of the population. Table 3 shows the collected figures for a number of typical municipalities⁽¹⁰⁾. It will be seen that the consumption in these municipalities is generally lower than the corresponding provincial estimate as given in Table 2. It is, moreover, probably true that little or no *lassi* (butter-milk) is consumed in towns unless this is specially made from curds : butter-milk itself is essentially a rural product.

In view of the wide variations in milk consumption which are found between rural and urban populations and between the populations of Northern and Southern India, it is obviously impossible to arrive at an average consumption figure from dietary surveys. The figures quoted are, however, sufficient to indicate that a *per capita* daily consumption of 7 to 8 oz. of milk (either in liquid form or as milk products) is not an unreasonable estimate for India as a whole.

The next step is to determine to what extent this daily *per capita* consumption ought to be increased in order to meet the minimum requirements of the population. European standards are only of limited value in this connection, for they are based on the assumption that the population lives on a mixed diet which includes meat and other sources of animal protein. Moreover such standards are based on the needs of the body in temperate zones. In India the climate is sub-tropical or tropical, and most of the population subsists on a vegetarian diet derived from a very limited variety of foodstuffs. Milk is, in fact, frequently the only available source of 'first-class' protein, while it also has to supply a considerable proportion of the mineral constituents and vitamins of the diet.

In view of the special importance of milk as the sole source of 'first-class' protein, the quantity needed in the average Indian

(7) Figures quoted from brief.

(8) G. Findlay Shirras. "Report on an Enquiry into Working Class Budgets in Bombay." Government Central Press, 1923.

(9) A. C. Roy Choudhury. "Report on an Enquiry into the Standard of Living of Jute Mill Workers in Bengal." Bengal Secretariat Book Depot, 1930.

(10) Figures obtained directly from municipalities.

dietary can best be calculated on a basis of protein requirement. According to European standards, about 10 to 15 per cent. of the daily intake of energy should be derived from protein. For an average man this would entail an intake of about 100 grams of protein per day. Of this, roughly one-third (say, 37 grams) should be 'first-class' protein⁽¹¹⁾. A recent Indian publication⁽¹²⁾ puts the requirement somewhat lower, namely, 65 grams of total protein, of which about one-quarter should be of animal origin. Using these two standards as a basis for calculation of the milk requirement, the following figures are obtained :—

	European Standard.	Indian Standard.
Daily requirement of 'first-class' protein per head.	37 grams.	16 grams.
Amount of milk needed to supply this quantity of protein, say.	1,000 grams.	430 grams.
or a daily intake of	35 oz.	15 oz.

It will be seen that the standard European requirement coincides closely with the actual consumption in the self-supporting countries shown in Table 1. Although the standard Indian requirement is very much smaller, *it is still double the quantity of milk at present available in the country*, namely 7 to 8 oz. per head. Moreover, the Indian requirement is based on an admittedly low standard. "This scale" it is stated "falls short of the ideal as defined by modern physiologists and may often with advantage be exceeded. It is nevertheless excessive, as far as India is concerned, *in the sense that economic circumstances and dietary habits often prevent its attainment.*" It would appear from this statement that the scale has, indeed, been somewhat arbitrarily fixed at a low figure in order to make it a feasible standard under Indian conditions. If the standard were to be set at a level more nearly akin to that aimed at in progressive European countries, the present output of milk in India would not merely need to be doubled, but would have to be increased three-fold or even four-fold.

It is significant that this general conclusion has been arrived at independently by another method of computation. In the article referred to⁽¹³⁾ an attempt was made to estimate the adequacy of India's net food supply for the nutrition of her population. It was found that whereas the total energy available was adequate and the amount of carbohydrate was actually in excess, the quantities of fat and of 'first-class' protein were markedly deficient. "Clearly" the author writes "the most important task confronting the social reformer who seeks to make India's food supply satisfy decent standards of nutrition is to increase milk production in India....."

(11) "The Criticism and Improvement of Diets." Memorandum by the Advisory Committee of the Ministry of Health, 1934.

(12) W. R. Aykroyd. "The Nutritive Value of Indian Foods and the Planning of Satisfactory Diets." Health Bulletin No. 23. Govt. of India Press, 1937.

(13) "India's Food Problem." The Economist, 26th December 1936.

A doubling of India's milk supply will not only increase the quantity of first-class protein available per head, but will also increase the element of animal fat in the Indian diet, which at present is largely supplied by vegetable oil."

While the argument for increasing milk consumption has so far been based on the requirement of 'first-class' protein, the value of milk as a 'protective' food must not be lost sight of. With a vegetarian diet derived from a very limited variety of foodstuffs, there is a serious risk of a deficiency of both minerals and vitamins. An increase in the consumption of milk would go far towards correcting the present deficiency of protective elements in Indian dietaries, particularly in so far as growing children are concerned.

The value of increasing the consumption of milk is well illustrated in the results obtained in two series of experiments in which the diet of children of school age was supplemented with a ration of milk. Two reports have been issued in connection with a scheme sponsored by the municipality of Simla⁽¹⁴⁾. This scheme was designed to ascertain the effect of adding a supplement of 1 lb. of whole milk per day to the ordinary diet of children for a period of three months. The total number of children covered in the first report was 44 and in the second report 112. The weights and heights of the children, as well as of similar (control) groups who received no milk supplement, were taken at the beginning and at the end of the feeding period. The results are shown in Table 4. It will be seen that the children receiving milk showed markedly greater increases in both weight and height over those who received no milk supplement.

A somewhat similar investigation has been carried out among residential institutions for children in South India⁽¹⁵⁾. In this investigation, however, it was not possible on account of expense to give the children whole milk and they were therefore given a supplement of skim milk reconstituted from milk powder. Moreover, the quantity fed was limited to 1 to 1½ oz. of skim milk powder, equivalent to roughly 8 oz. of liquid skim milk. The results are shown in Table 5. At the end of three months feeding children receiving the milk supplement showed a marked increase in weight and height over those receiving no milk supplement. Moreover, the same children were later used in an identical experiment, but in this case the groups were reversed, those who had previously acted as controls receiving the milk supplement. The results again showed the value of the supplement of skim milk to those children who received it. It is, moreover, significant that in this experiment the addition of the supplement of milk was found to reduce the incidence of two pathological conditions, *i.e.*, stomatitis and phrynoderma,

(14) W. H. Crichton. "First and Second Reports of the Milk Scheme sanctioned by the Simla Municipality."

(15) W. R. Aykroyd and B. G. Krishnan. "The Effect of Skimmed milk, Soya Bean and other Foods in Supplementing Typical Indian Diets." *Ind. Journ. Med. Res.* 24, 4 (1937)

both of which are now recognised to be nutritional deficiency diseases which can be prevented by the presence of 'protective' foods in the diet:

These results, together with the known deficiency of milk in the average Indian diet, are sufficient to indicate the very great need for increasing the milk consumption of the country. The question arises, however, as to whether, if the necessary increase in production is effected, the population could afford to purchase the additional milk. There is no doubt that the Indian appreciates the value of milk, and that if he has sufficient means he will increase his consumption of this food. The *per capita* consumption depends, however, very largely on income level. Table 6 shows the average family expenditure of milk and *ghee* in comparison with the total food expenditure in three urban centres⁽¹⁶⁾. The proportion spent on these two milk products (5 to 15 per cent.) is very low in comparison with that suggested in other countries⁽¹⁷⁾, but it is significant to find that this proportion rises markedly with increasing income. Table 7 shows, for example, the quantities of milk and *ghee* consumed by Bombay families at various income levels, and the relation of expenditure on these products to total food expenditure. The consumption of milk shows a ten to fifteen-fold increase, and the consumption of *ghee* a seven-fold increase, between the lowest and the highest income groups. At the same time the proportion of the total food expenditure used for the purchase of milk products rises from 3 per cent. to 11 per cent. Similar results have been obtained in a survey undertaken at Lahore⁽¹⁸⁾. The differences in income level were, however, very much greater in this survey. Table 8 shows that milk consumed increased with income level until, with incomes of Rs. 1,000 per month and over, a maximum figure of 30 oz. per head per day was reached⁽¹⁹⁾. On the other hand at income levels below Rs. 100 per month the consumption of milk was comparatively low, while in the lowest income group it was less than 3 oz. daily. The average *per capita* income in India is about Rs. 100 per year⁽²⁰⁾. It is therefore difficult to see how milk consumption can be increased among the poorer classes unless the price of milk is lowered or the income level is raised. This point is specially referred to in a recent publication which deals with the

(16) See Reports on Enquiries into Working Class Family Budgets in Bombay (1922), Ahmedabad (1924) and Bombay City (1932), and into Family Budgets of Cotton Mill Workers in Sholapur City (1925). (Govt. Central Press, Bombay).

(17) See, for example, the Report of the Committee on Nutrition of the British Medical Association (1933) where the proportion of food expenditure allocated to milk and milk products lies between 20 and 35 per cent.

(18) R. Lal Anand and A. C. Aggarwala. "The Milk Supply of Lahore in 1930." Punjab Board of Economic Inquiry, Publication No. 28, 1935.

(19) It is significant that this corresponds closely with the average milk consumption of the self-supporting dairying countries shown in Table 1. It would seem that 30 oz. milk per head constitutes the optimum daily requirement.

(20) D. G. Karve. "Poverty and Population in India." Oxford University Press, 1936.

state of nutrition of school children in South India⁽²¹⁾. The authors point out that children frequently have to subsist on diets costing only Rs. 3-8-0 per month. At present prices it is manifestly impossible for an adequate quantity of whole milk to be included in the diets of such children. In a recent investigation in Calcutta⁽²²⁾ it was, in fact, found that in three out of four hostels (two being children's orphanages) no milk or milk products could be included in the diet on account of its relatively high price.

The conclusions of this discussion are two-fold. In the first place, it is essential that the production of milk in India should be vastly increased if the population is to have sufficient quantity of this product in the diet. It is estimated that the output of milk would need to be at least doubled in order to provide even a minimum requirement. In the second place, such an increase in production would fail to achieve its object unless the price of milk could be reduced or the income level of the population could be raised. The possibility of achieving an increased production of milk will be dealt with in the second part of this report. In the present part, which deals with the utilisation of milk for liquid consumption and for manufacture, the second objective, namely, to ensure that the price of milk is within the purchasing power of the majority of the population, must be constantly kept in mind.

⁽²¹⁾ W. R. Aykroyd and B. G. Krishnan. "The State of Nutrition of School Children in South India; Part II". *Ind. Journ. Med. Res.* 24, 707, (1937).

⁽²²⁾ H. E. C. Wilson, B. Ahmad and D. N. Mullick. "A Diet Survey of Some Families and Institutions in Calcutta." *Ind. Journ. Med. Res.* 24, 161 (1936).

CHAPTER II.—General discussion on the trend of development of the dairy industry.

Organised dairying in India may be said to have a two-fold origin ; first the introduction of cream separators in 1889⁽¹⁾, and

Origin of organised dairying.

second, the establishment of large scale dairy farms by the military authorities, the first of which was started at Allahabad in 1891. Of

these two developments the latter was to prove the most important, since it led indirectly to the creation in 1920 of the post of Imperial Dairy Expert. This in turn provided a focussing point for the development of the industry and an impetus to the introduction of modern methods of handling milk. It may indeed be said that the main objective has been the introduction of Western methods into Indian dairying practice with the object of placing on the market a better quality product. Thus the policy of pasteurising and bottling milk has been encouraged and stress has been laid on the introduction of factory methods of manufacture, particularly for the production of butter.

The indirect influence of the Military Dairy Farms has therefore played a large part in initiating organised dairying in India. There is, however, one disadvantage in basing the dairying development of a country on the requirements of one particular section of the population, since such a development may fail to meet the needs of the majority of consumers. This danger is the more serious when those catered for, namely, Europeans, do not have the same dietary habits nor the same standard of living as the great mass of the Indian population. The unsuitability of European products for Indian consumption is clearly shown in the following figures relating to the utilisation of milk produced on the Military Dairy Farms.

		Milk (lb.).	Butter (lb.).	Cream (lb.).
British Troops	.. ..	13,095,577	1,041,599	194,157
Indian Troops	.. ..	3,965,817	688	36

It will be seen that only one-quarter of the milk used for liquid consumption was consumed by Indian Troops, and that their consumption of butter and cream was negligible. This is in no way quoted as a criticism of the policy of the Military Dairy Farms, which were established specifically to supply milk and milk products to British Troops and Military Hospitals : the needs of Indian Troops are catered for in other ways,—for example, by the Military Ghee Heating Depot at Agra. The difficulty only appears when the policy adopted at the Military Dairy Farms is used as a model for the development of the dairy industry in the country as a whole.

When the post of Imperial Dairy Expert was created and the problem of developing the dairy industry had to be faced no accurate

(1) It is, however, significant to note the very limited growth of the use of cream separators in India. At present there are probably less than 4,000 in the country. In comparison there are, for instance, over 50,000 in New Zealand alone although this country handles only a fraction of the quantity of milk produced in India.

Information was available regarding the relative importance of various milk products in the Indian dietary. Moreover, no experiments had been carried out to determine, for example, the feasibility of organising village milk supplies on a co-operative basis or of adapting Western manufacturing methods to Indian conditions. It was therefore inevitable that development should tend to be planned on lines which had proved successful in the more limited sphere of army requirements. It was known too from import returns that there was a market for such products as butter, and further, that this market would probably provide a more lucrative return to the milk producer than he could secure from the sale of indigenous milk products such as *ghee* and *khoa*. Such facts account for the prominence which has hitherto been given to the provision of high grade milk and of butter in official dairying circles.

At the date of my inquiry, however, a number of factors had combined to clarify the whole subject. In the first place an extensive marketing survey had just been undertaken⁽²⁾ and information was therefore available as to the relative importance of the various milk products produced in India. In the second place much new and valuable information had been collected as a result of the appointment of the Animal Husbandry Expert to the Imperial Council of Agricultural Research. In the third place a number of projects had been initiated in such directions as co-operative dairying, the establishment of village separating stations and the running of modern processing plants, the results of which I was able to inspect personally. These three factors have provided a solid foundation of knowledge and experience on which, in my opinion, the future development of the dairy industry must be based. I propose at this point to discuss in some detail the main considerations which I feel to be of outstanding importance in planning any future policy for the industry.

The first requirement of any national industry is that it should meet the needs of the great mass of the population. Thus it is essential, in considering the development of the dairy industry, to ensure that it caters for the existing taste and dietary habits of the Indian people. The only available means of determining this is to ascertain the present demand for the various products available. A rough indication of the demand is provided in the provisional estimates of milk production obtained in recent provincial marketing surveys. The results of these surveys have for convenience been combined in a single table (Table 9). It will be seen that roughly one-third of the milk produced is sold as liquid milk. Of the manufactured products the output of *ghee* is far in excess of that of all the remaining products, accounting for 75 per cent. of the milk utilised for manufacture. It is significant that the quantity of milk used for *ghee* production is substantially greater than that sold for liquid consumption. There is indeed no doubt that the production of *ghee*

(2) Provincial Marketing Surveys conducted under the general direction of the Agricultural Marketing Adviser to the Government of India.

must be considered as the most important single factor in any scheme of development of the dairy industry. Of the remaining products, *khoa* and other indigenous milk products account for nearly 15 per cent. of the milk used for manufacture, while the inclusion of *dahi* (curds)—another indigenous dish—would bring this figure to 20 per cent. Butter accounts for only 2 per cent. of the manufactured products. Moreover it will be shown later that nine-tenths of this is so-called 'country' butter, which is used almost entirely as a basis for the production of *ghee* in the household. Only one-tenth is 'creamery' butter, which therefore occupies a position of almost negligible importance in Indian dairying. Cream and ice-cream also account for very small quantities of milk, while cheese production is practically non-existent.

The same general conclusions may be drawn from figures showing the calculated values of the total output of liquid milk and milk products. These are given in Table 10. Liquid milk and *ghee* head the list with values exceeding 100 crores of rupees, though it may be noted that no allowance has been made for the value of *lassi* (butter-milk) formed as a by-product of *ghee* and invariably consumed by the cultivator and his family. The value of indigenous milk products (including *khoa* and *dahi*) is estimated at roughly 80 crores of rupees, while butter (both 'country' and 'creamery' make) total only 3 crores. Cream and ice-cream are valued at a little under 2 crores of rupees.

These figures show clearly that the items of major importance in Indian dairying are liquid milk, *ghee*, and other indigenous milk products. Western products such as butter and cheese are scarcely used except by Europeans and a small number of educated Indians who have acquired a taste for them.

It may, however, be argued that the figures so far discussed do not include imported milk products, and that these constitute a substantial item which must be taken into account. Reference to import statistics indicates that this view is untenable. A rough calculation shows that the quantities of butter, cheese and condensed and dried milk imported annually into India are equivalent to about one million maunds of milk. India's milk production is estimated at about 700 million maunds. Imports represent therefore less than 0.15 per cent. of the country's total output of milk. Again, the value of these imports is given as about Rs. 78 lakhs⁽³⁾. It has already been shown that milk and milk products produced in India are valued at some 300 crores of rupees. The milk products imported are therefore valued at less than half of 1 per cent. of the total value of products produced in India. To put the matter more strikingly, an increase in the value of *ghee* by only 1 per cent. would add more to the wealth of the dairy industry than the replacement of the whole of the imported milk products by home-produced articles.

(3) Figure obtained from the Annual Statements of Sea-borne Trade of British India.

This is a point of fundamental importance. Proposals have for example been made to spend a very considerable sum in setting up a Government Experimental Creamery which could be used for investigating the production of condensed and dried milk and of butter on a factory scale under Indian conditions. The object of the scheme is largely to demonstrate that imports of these products could be replaced by products manufactured in India. Without considering the feasibility of such a scheme (which is dealt with in a later chapter) it may, I think, be argued on grounds of principle alone that available funds should be chiefly devoted to the encouragement of the major products of the dairy industry, rather than to branches of manufacture which are of such minor importance to India as a whole. Again, persistent efforts have been made to formulate standards of quality for creamery butter produced in India, in the expectation that this will lead to improved methods of production and marketing. The provision of such standards for butter is undoubtedly desirable, but the formulation of quality standards for *ghee* (and even for *khoa*) is an infinitely more urgent subject for consideration by Government. These examples are taken to illustrate in a concrete form the contention which I have already urged, namely, that the first requirement in developing the dairy industry is to ensure that it will cater for the taste and dietary habits of the Indian population.

The second requirement of an industry is that it should be designed to suit local conditions of production, collection and transport of raw materials. In this connexion it

Special difficulties involved in dairying under Indian conditions.

might be well to make a few brief comparisons between rural conditions in India and those in certain typical dairying countries. India is essentially a country of small holdings. In

the Punjab, for instance, over 40 per cent. of holdings are of less than 5 acres, while only 12 per cent. are over 20 acres. For Bombay the equivalent figures are 48 per cent. and 12 per cent. and for the United Provinces 52 per cent. and 7 per cent. In the latter Province the average area of land per worker is 2.5 acres, while for Assam, Bengal, Bihar and Orissa, it is 3 acres⁽⁴⁾. These figures may be compared with those of Denmark, where only 10 per cent. of holdings are below 5 acres and where the average holding is just under 40 acres. In Great Britain the size of the average dairy farm exceeds 100 acres, and in New Zealand and the United States dairy farms average about 150 acres⁽⁵⁾.

The marked difference between the average size of holdings in India and in these typical dairy countries is paralleled in the number of cattle per holding. Denmark has an average of about nine cows per holding and the United States about twelve. In Great Britain dairy herds average about 25 head, a figure also shown by New Zealand. India presents an entirely different picture. The typical cultivator possesses a pair of bullocks with one or at the most two

(4) Figures obtained from Census of India, 1931, and from other sources.

(5) Figures obtained from Denmark Agriculture, New Zealand Official Yearbook, U. S. Agricultural Statistics, and other sources.

cows (usually of a draught or nondescript breed) and perhaps one or two buffaloes for milk production⁽⁶⁾. There are practically no specialised dairy farms, the production of milk or *ghee* being subsidiary to small scale crop farming. In consequence of this, as well as of the poverty and lack of education of the cultivator, methods of milk production are crude and facilities for collection are primitive. This difficulty is intensified by lack of communications between villages and main roads, and by absence of suitable forms of transport. Moreover, there are also special difficulties connected with the climatic conditions in India. The average temperature is high, reaching figures well over 100°F. during the hot weather. Yet there is often a complete lack of water suitable for cooling, while flies and dust are abundant sources of contamination of the milk. In the monsoon period the village roads are frequently so badly flooded as to be impassable. It may be mentioned, too, that the total output of milk per village is usually low, an average figure being 1,500 lb. per day.

Under these circumstances the collection and handling of milk at central depots under factory conditions would be fraught with difficulty. Personal inquiries among those responsible for running butter-making creameries revealed the fact that on arrival at depots the milk is frequently sour and unfit for the production of a high quality product. The separated milk from such a poor supply is only fit to be converted into crude casein, and is wasted as a source of human food. In a country like India where there is such an urgent need for 'first-class' protein in the diet, such a wastage of valuable food is to be deplored.

An impartial survey of the present position leads one to the conclusion, in fact, that the evolution of the indigenous milk products which are peculiar to India (*ghee*, *khoa* and *dahi*) has largely been due to the fundamental difficulties involved in handling milk under the conditions described. *Ghee* and *dahi* are made directly by the producer from naturally soured milk, so that high atmospheric temperatures and casual contamination do little damage to these products. *Khoa* on the other hand is a form of milk rendered transportable by partial desiccation—a process which also partially sterilises it and thus improves its keeping quality. It is very doubtful whether one could apply to the manufacture of these products⁽⁷⁾ the type of factory system of dairying which has been evolved to suit the products and the climatic conditions of countries situated in temperate zones.

This raises a further point. The third requirement of any industry is that it should fit into the general economy of the country.

India's population is predominantly rural.

In this connexion it is significant to note that the development of a factory system of dairying has only been successfully achieved in

(6) In a recent village inquiry carried out in important breeding tracts in Northern India the following figures were obtained:—Number of holdings surveyed 7,627; numbers of cows—dairy breed 1,363; draught breed 6,327; nondescript 4,126; number of buffaloes 10,377.

(7) With, perhaps, the exception of *khoa*.

countries which either have a large urban population or a large export market. In Great Britain, for example, where 80 per cent. of the population is urban and only 20 per cent. rural, nearly 90 per cent. of home-produced milk and milk products are consumed by the former. In the United States, where the urban population is roughly 60 per cent. of the total, 75 per cent. of home-produced milk and milk products are sold for urban consumption. Denmark and New Zealand do not possess sufficient urban populations to absorb their available supplies of milk, but these countries are able to export large quantities—the ratio of milk products exported to milk products retained being about 4 : 1 or 5 : 1. India is in a very different position. While the ratio of rural to urban population in Great Britain is, for example, 1 : 4, the ratio in India is 9 : 1⁽⁸⁾. The urban population provides therefore only a very limited market for milk, and it may be said that the industry has in large measure to find its market in the producing areas themselves. To put the situation somewhat crudely, for every seer of milk sold to towns, nine seers must be retained for consumption in rural areas, either by the cultivator himself or by his village associates. Moreover there is little chance of building up a large export trade of milk products from India, partly because of fierce competition from countries which have a more favourable climate for the manufacture of milk products consumed by Western nations, and partly because India is not yet producing sufficient milk to meet even her own needs.

The fact that the rural community constitutes the largest potential market for milk and milk products affects the whole possibility of introducing a factory system of dairying into India. Such a system entails difficulties even in highly industrial countries chiefly on account of the by-products of manufacture. In a recent report⁽⁹⁾ on the British dairy industry it is, for example, stated that “where manufacture is undertaken on the farm the by-products are available for immediate use. The extension of factory manufacture has however given new importance to the problem of the disposal of by-products”. If the manufacture of *ghce* was to be undertaken on a factory scale in India there would inevitably be large accumulations of separated milk at the manufacturing depots. Such accumulations of separated milk have, in fact, already proved a source of embarrassment to butter-making creameries. It has been pointed out that the conversion of such milk into casein is undesirable on nutritional grounds. The only alternatives would be either to return it to the cultivator or to convert it into condensed or dried milk. The former procedure does not appear feasible. There would be difficulties in returning the large volumes of separated milk to the villages, including the risk of souring during transportation, particularly at the high temperatures experienced in India. There would also be the risk of spreading disease through milk which had been indiscriminately bulked ; there would be the difficulty of ensur-

(8) See Table 11.

(9) Report of the Milk Reorganisation Commission for Great Britain, p. 107. H. M. Stationery Office, 1936.

ing the sterilisation of the containers after return to the cultivator ; and finally, it is more than likely that the cultivator and his family—always conservative in matters relating to diet—would refuse to drink the returned milk. The second alternative, namely, to condense or dry the separated milk, is equally open to objection. Apart from the technical difficulties involved through the poor keeping quality of the milk, the market for condensed and dried milks in India is strictly limited and is largely confined to proprietary brands. In any event once this very limited market was saturated the only alternative would be to return the dried product to the cultivator—obviously an uneconomic procedure even if he could be persuaded to use it in his diet. It will be seen therefore that any attempt to adopt a factory system of dairying in India would involve fundamental difficulties which it would be extremely difficult to overcome.

It is apparent from this discussion that any attempt to develop the Indian dairying industry by the piece-meal introduction of Western methods is to be deprecated. What is needed in Indian dairying is a new outlook and a new technique ; an outlook which recognises the special nature of India's problems and a technique which is designed to solve these problems. The lines along which such a technique might be developed are dealt with in subsequent chapters. It will be well, however, to indicate at this stage the main directions in which I feel that progress should be looked for.

The first essential is, to my mind, to ensure that an adequate supply of milk and/or milk products are available for consumption by the rural population. The tendency of the Indian cultivator (as indeed of most agricultural producers) is to sell as much of his products as possible for cash, even if this entails a shortage of essential nutrients in his own diet and that of his family. This fact was repeatedly brought to my notice during visits to villages and by those working in close touch with village communities. Little can be done to check this tendency in regard to the sale of milk for liquid consumption in towns. The market is relatively lucrative and sales of milk provide a valuable addition to the cultivator's income. Moreover it is arguable that such sales do not necessarily result in any decreased milk consumption in the cultivator's own household, since with increasing prosperity he will tend to expand his production, leaving a margin for home consumption at least as large as formerly. With the cultivator whose holding is remote from the market the same argument does not hold. At present such a cultivator will probably utilise most of his milk for the production of *ghee*. This is most advantageous since, in addition to selling the *ghee* for cash, he retains the *lassi* (butter-milk) for the use of himself and his family. It is essential that any alternative system of manufacture which might replace present dairying practice should still leave such valuable milk by-products with the cultivator. It has already been noted that large-scale factory dairying fails to meet this criticism.

Nevertheless, there is no doubt that the present methods of handling milk and of producing indigenous milk products are crude and primitive. Such methods only survive because the cost of labour is not taken into account and the class of purchaser is too poor or too

Need for improved methods. uneducated to be able to discriminate between a good and a bad quality product. The second essential is, therefore, to introduce improved methods of production. This should be effected by evolutionary rather than revolutionary changes of technique. One essential step in any attempt to improve methods of production is, I believe, the combination of producers on a village industry basis⁽¹⁰⁾, where the handling of larger quantities permits of the employment of more specialised labour and where the output is sufficiently large to justify the use of improved types of equipment. At the same time a village industry system avoids (so far as the manufacture of milk products is concerned) the inherent difficulties involved in the transport of milk which would be entailed in a large-scale factory system. One of the great advantages of retaining industries within the village is that the by-products of manufacture are still available for the use of the cultivator. At the same time this degree of centralisation of production is sufficient to call for some form of co-operative marketing, from which the cultivator should benefit materially.

This brings me to the third essential, namely, the need for improved methods of marketing. At present the marketing of milk and milk products is chaotic, a situation which is inevitable when small producing units market their own supplies. Improvement could be effected in various directions. Facilities could be provided for the grading and sale of more uniform products and of products of higher quality. A larger number of accessible markets could be established in producing areas where the present arrangements for the marketing of milk products are inadequate. And, by these and other similar means, the producer could be furnished with a more powerful bargaining weapon in disposing of his produce, and could avoid the heavy toll on his income which is associated with the existence of numerous intermediaries between producer and consumer.

The general conclusions of this chapter may be summarised as follows:—First, attention should be concentrated on the production of indigenous milk products such as *ghee*, *khoo* and *dahi*, and not on products of Western origin such as butter and cheese. Second, the large-scale factory system of dairying, which has been developed in temperate zones, is of very limited application in a country having a tropical climate, primitive methods of production and inadequate communications and transport facilities. Third, developments in the dairy industry must

(10) It is, I believe, most important to differentiate between the factory system, where milk is collected to a central depot from a number of villages, and the village industry system, where the milk is retained within the village

be primarily designed to meet the needs of the vast population of small cultivators rather than those of the very limited urban population. Fourth, for this purpose (as well as to ensure better methods of production of indigenous milk products) a village industry system (as distinct from a factory system) of dairying should prove the most effective form of dairy organisation. Fifth, as a general means of improving conditions in the dairy industry it is essential that more adequate facilities should be provided for the proper grading and marketing of milk and milk products.

I have attempted in this chapter to give a brief outline of the general lines along which I consider Indian dairying should advance. In the next four chapters I shall deal in detail with the specific problems involved in handling liquid milk and in manufacturing milk products. I hope, however, that in considering these detailed suggestions, the five main contentions mentioned above will always be kept clearly in mind.

CHAPTER III.—The Production, Collection, Processing and Distribution of Milk for Liquid Consumption.

The problems involved in the production and distribution of milk for liquid consumption have frequently been stated as if they were limited to the supply of milk to large centres of population. It is true that the consumption of milk in cities is low in comparison with that in rural areas, particularly as no supply of *lassi* (butter-milk) is normally available under urban conditions. At the outset I should, however, again emphasise the fact that the urban population constitutes a very small proportion of the total population of India. This fact is clearly shown in Table 11⁽¹⁾. Eleven per cent. of the population are classed as urban, and 89 as rural. It may probably be assumed that the special difficulties associated with city milk supplies only arise in urban centres with populations exceeding 100,000. Less than 3 per cent. of India's population reside in cities of this size. It is true that the urban population is increasing at the expense of the rural. In 1911 9.4 per cent. of the population were classed as urban, in 1921 10.3 per cent. and in 1931 11.0 per cent. This increase is, however, extremely slow and does not show any sign of acceleration. The greatest increase has, moreover, taken place in towns having populations of 20,000 to 50,000 and not in the cities of 100,000 and over. In view of these facts it would, I believe, be a grave mistake to limit consideration of the problems of milk production and distribution to a section of the community which represents such a small fraction of the total population. In this connexion it might also be timely to point out the rough distribution of the rural population. Over 40 per cent. of the rural population live in villages of under 500 inhabitants, while about 45 per cent. live in villages with populations between 500 and 2,000. For India as a whole the average village population is roughly 450. These figures re-emphasise the fact that in facing the problems of milk production and distribution in India one is dealing with an essentially rural population.

Many of these problems are more or less common to all areas, irrespective of population densities. I propose to deal with such problems in this chapter. Special considerations which apply only to city milk supplies will, for convenience, be dealt with separately in Appendix II.

Before turning to a detailed consideration of technical problems I should, however, once again stress the fact that the essential point to be borne in mind throughout this discussion is the need for providing a supply of pure milk *within the purchasing power of all classes of the population*. In an earlier chapter I have drawn attention to the urgency of increasing milk consumption in India, and I have indicated that the present low consumption of milk is largely attributable to the low income level of the population. It is essential therefore that any improvement in the methods of production and distribution of milk should be effected without adding materially to its cost.

(1) Census of India, 1931.

Owing to the very varied conditions existing throughout India it would be useless to attempt a detailed description of the methods employed in the production and distribution of milk destined for liquid consumption. In towns much of the milk is produced and sold by local *gowalas* (professional milk producers) who keep four or more cows or buffaloes. Such animals are stall-fed and get little or no grazing. In large cities very much larger herds are kept in stables by large milk dealers who purchase cows and buffaloes and dispose of them when the milk yield becomes uneconomic. In villages, on the other hand, milk production may be more or less a side-line, and the cattle are seldom sufficiently well-fed to give satisfactory milk yields. Wherever cattle are kept, however, the technique of milk production is very similar. The udders of the cows may or may not be washed or wiped with a cloth. Immediately before milking the calf is allowed to suckle (an almost universal custom) and the cow is then hand-milked, wet milking being usually employed. The milking vessel is generally a circular pot with a wide mouth, which is held between the knees of the milker. The milk is subsequently transported to the nearest market by head load, bicycle or cart. The vessels used frequently have no lids, and the mouth of the vessel is therefore generally stuffed with grass or straw. After use the vessels are scoured with mud and ashes, rinsed with water, and occasionally 'smoked' over a fire.

It is obvious that much improvement in methods will be necessary if the hygienic quality of the milk supply is to be improved. In a country like India, with a tropical climate and inadequate communications, it is specially important that milk should be produced with as little contamination as possible if it is to have a reasonably good keeping quality. Otherwise there is a serious risk of souring and consequent spoilage. It is therefore disappointing to find that the cultivators and *gowalas* show such a complete lack of knowledge of the most elementary practices associated with clean methods of milk production. Their poverty and their consequent lack of equipment will of course tend to discourage the adoption of progressive methods.

While this lack of knowledge on the part of cultivators and *gowalas* is perhaps inevitable, it was still more disappointing to find the complete absence of interest displayed in this matter by officials associated with the agricultural and veterinary services and with the Imperial Dairy Expert's section. I found, for example, that it was almost impossible to obtain reliable figures in regard to such an elementary question as the keeping quality of milk, how it differed at different seasons and with different methods of handling, and how it could be improved under village conditions of production. The Gerber 'dirt' test appeared to be unknown, or if known, not employed. In only one or two centres was I able to see the results of more accurate tests, such as the methylene blue reduction test and the plate count, which form essential weapons in the investigation and control of production methods. It may be argued that there

would be serious difficulties in applying accurate tests under village conditions, even for purposes of investigation. This argument, even if tenable, would not apply to conditions at agricultural colleges and other similar centres where facilities for laboratory investigation are available.

Matters such as these may appear elementary and of little practical importance. It is significant, however, that in every dairying country investigations along such seemingly elementary lines have formed the foundation of dairying technique. Thus the first problems investigated at the National Institute for Research in Dairying at Reading (England) were concerned with the study of the various factors concerned in the production of clean milk, including such apparently simple questions as the shape of the milk pail and the cleanliness of the milking stool⁽²⁾. Similar investigations have been carried out by workers in the United States Department of Agriculture⁽³⁾. Moreover it cannot be maintained that, since the subject has been so carefully investigated by Western workers, there is no need to duplicate the work in India. Conditions in India differ fundamentally from those in temperate climates. The cultivator is poorer and is therefore usually unable to purchase special dairying equipment. The average temperature is very much higher, though the intense sunlight is credited with a strong sterilising power. Fuel is scarce and water for cooling is seldom available or, if available, effective. It is, indeed, obvious that under such circumstances methods of producing and handling milk may have to be greatly modified from those employed in countries situated in temperate zones⁽⁴⁾. *A technique suitable for tropical and sub-tropical conditions must be devised to meet these special difficulties.*

(2) E. G. Knight, K. Freear and R. S. Williams. "A Study of Factors concerned in the Production of Clean Milk." King and Son, Ltd., London (1920). See also "Studies concerning the Handling of Milk," Ministry of Agriculture Bulletin No. 31. H. M. Stationery Office, London (1931).

(3) S. H. Ayers, L. B. Cook and P. W. Clemmer. "The Four Essential Factors in the Production of Milk a Low Bacterial Content." U. S. Department of Agriculture, Bull. 642 (1918).

(4) It would, perhaps, be desirable to give a concrete example of the point which I desire to emphasise. At several villages during my tour I had opportunities of seeing the methods adopted in cleaning vessels used for milk. This usually consisted of scouring the vessel with a mixture of earth and wood ashes, which was subsequently rinsed out with well water and then stood in the sun. This method was usually pointed out to me as an example of the dirty methods employed by the cultivator. It is however quite likely that the results are, in practice, far more satisfactory than one might suppose. In the absence of soda and refined abrasives (which form the basis of ordinary scouring powders) a mixture of earth and potash (ashes) would form a cheap but efficient cleaning mixture, while the lethal action of the sunlight might possibly be found to destroy any contaminating organisms left in the vessel after rinsing. But the point is that even a simple matter such as this has not been investigated, so that no reliable guidance can be given to the cultivator as to the directions in which his methods are sound and the lines along which they might be further improved.

In working out such a technique, two general problems are involved. In the first place it will be necessary to investigate the

Suggested problems. utility of various tests under Indian conditions. A number of tests are already available ; for example, the Gerber ' dirt ' test, the acidity and alizarol tests, the ordinary test for keeping quality, the methylene blue reduction test and the plate count and coliform test. Each of these has been found to have its special uses in Western dairying countries, but the utility of each test would need to be investigated afresh under Indian conditions. For example, the keeping quality test is carried out in Great Britain at 60°F., a temperature obviously too low for use in India. Again, it would be necessary to determine what relationship existed between keeping quality and tests such as the plate count and methylene blue reduction test, since the normal bacterial flora of milk in India may differ markedly from that of more temperate countries. It would also be desirable to pay special attention to the feasibility of devising special tests of quality for use under village conditions, the essential criteria of such tests being simplicity, rapidity and cheapness.

In the second place these tests would need to be applied to the solution of the practical problems of clean milk production. Fundamental subjects for investigation would be the effect of different methods of cleaning and milking the cow and of cleaning and sterilising milk utensils on the quality of the milk produced. In this connexion the difficulties involved in the use of steam under village conditions would need to be investigated, and alternative methods such as scalding and heating over a glowing fire (perhaps the origin of the present ineffective method of smoking utensils) would have to be studied. In all such work local habits and requirements would require to be taken into account. For example, the various types of milk container have obviously been evolved to suit the special circumstances of collection and transport. Thus for head loads a relatively light circular vessel is preferred, for bicycle transport square cans (such as kerosene tins) are employed, while for hilly districts long narrow containers suitable for carrying on the back (and often constructed of bamboo) are used. The materials of construction include earthenware, brass, copper, aluminium and tinned iron. Some of these vessels are clearly of an unsuitable design for use as milk containers, but in re-designing them or in suggesting alternative it is essential to ensure that the new vessels meet local habits of transport. Apart from these special points, the influence of more general factors would need careful study. For example, investigations would have to be made into the extent of contamination of milk by dust and by flies, the influence of these contaminants on the keeping quality of the milk, and the means by which such contamination can be avoided. Again, the possible influence of the quality of the water supply on the contamination of milk would need to be studied. Such investigations would have to cover all seasons of the year, since the technique might have to be modified to suit the monsoon, hot weather and cold weather periods.

These suggestions are not exhaustive, but they serve to show the very wide field of study which is urgently needing attention. Until these various questions have been properly investigated it is, in my opinion, useless to attempt to give expert advice to the cultivator or *gowala* on methods of improving the quality of his milk.

Moreover it will be equally necessary to show that the improved methods are capable of application under village conditions, and

Application under village conditions. that they result in the creation of a better market for the liquid milk. Attempts to foster improved methods of producing and handling milk have been made at a number of centres, among which I might perhaps make special mention of the Telankheri Co-operative Dairy at Nagpur, the Co-operative Societies at Parbatpur, U. P. and other neighbouring villages, and Singhal's Dairy at Itaura, U. P.—all of which I was able to visit personally. While these and similar projects are doing useful work, I feel that their value would be greatly enhanced if the production, transport and quality of the milk could be more carefully and systematically studied in relation to the methods of production employed. At present there is, for instance, no reliable information regarding the quality of the milk as it reaches the consumer, except in so far as this can be measured by the number of complaints received and the trend of sales. With a little organisation it should be possible to check the quality by more accurate tests and so have an objective standard by which the success of any fresh enterprise or new technique could be judged.

Even if methods of production can be improved the question still arises as to whether milk for liquid consumption requires any treatment between production and delivery to the consumer. In this connexion it should be clearly understood that in India the problems associated with milk-borne disease do not normally arise. This is due to the almost universal custom of boiling milk before it is consumed, a practice common to both the Indian and European populations. Consequently any processing which is carried out between the production of the milk and its delivery to the consumer need have only one object, namely, the improvement of the keeping quality of the milk.

This fact is of considerable significance in deciding at what stage processing should take place. If, as in Western countries, processing is largely employed as a safeguard against milk-borne disease, the ideal method is to treat the milk (usually by the process of pasteurisation) immediately before it is bottled. This limits the opportunity of subsequent re-infection during handling. Such a method is, moreover, eminently suitable for Western countries, where the relatively low temperatures allow the milk to be kept in a raw state for comparatively long periods. In a tropical climate, however, the temperature seriously affects the keeping quality. It has, for instance, been found that milk stored at 100°F. will only keep 'sweet' for about a quarter of the time of milk kept at 60°F.⁽⁵⁾

(5) Unpublished data.

That is to say, milk which would sour within 24 hours at 60°F. will sour within 6 hours if kept at 100°F. It follows that under Indian conditions any processing of the milk which may be necessary should take place as soon as possible after production. This does not appear to be the present practice. Pasteurising plants are usually located in the cities, the milk being transported in a raw state. It is very questionable whether such pasteurisation has anything but a 'sales' value, especially as I observed that the process was usually associated with the sale of milk in bottles—a form of milk distribution which is far too costly for the bulk of the milk consumed by the population.

Apart from deciding at what stage processing should be carried out, the question arises as to whether such processing should be based on heat treatment or on refrigeration or on both. A combination of the two is, of course, ideal, since the number of viable organisms is not only reduced to a minimum by heat treatment but is retained at a very low figure by effective chilling. On the other hand this inevitably adds very materially to the cost. The following brief notes may be made regarding the two processes.

It has already been mentioned that the boiling of milk is an almost universal practice among all sections of the population in India. This does not mean that all milk is sold as boiled milk: the custom is to boil milk in the household. At the same time much of the milk which is sold in the bazaars is boiled: such milk is, in fact, frequently kept simmering for long periods. In one survey 250 out of 340 seers of milk which was sold daily through *halwais* was heated milk⁽⁶⁾.

Processing by heat has, of course, one great advantage in a sub-tropical climate, since it is easier to keep milk hot than cold. It was interesting to find that at certain Military Dairy Farms the pasteurised milk is not cooled during the hot weather, but is sent out hot in bottles. This practice, however, involves two difficulties. In the first place it is now known that certain bacteria are not only able to survive pasteurisation, but that they can multiply at pasteurising temperatures. If milk is kept at such temperatures for long periods there is a risk of souring or spoilage as a result of the activities of these bacteria. In the second place it is not yet known to what extent continued heating affects the nutritive value of milk. This question is of particular importance in regard to the bazaar practice of simmering milk for long periods. In view of the widespread nature of this practice, it is very desirable that investigations should be undertaken to determine whether such continued heating does reduce the nutritive value of milk.

Turning to the general question of improving the keeping quality of milk by heating it will be realised that, if such processing is to be carried out soon after production (as has been recommended in an earlier paragraph) it will necessitate the installation of suitable processing plant either in the villages or at central collecting depots

(6) R. L. Anand and A. C. Aggarwala. "The Milk Supply of Lahore." Punjab Board of Economic Inquiry, Publication No. 28 (1933).

situated in producing areas. The requirements of the market will decide which of these two alternatives is feasible : for a milk supply to a local town (say, 5 to 15 miles distant) the former is probably the ideal ; on the other hand for city milk supplies drawn from distances of 50 to 200 miles, central collecting depots would be necessary, particularly if the milk has to withstand a long period of transport. In such circumstances it would almost certainly be essential to combine heat treatment with refrigeration.

✓If heat treatment is to be carried out in villages, it is essential to devise a suitable small-scale plant for the purpose. Existing types of equipment are too expensive and are not designed to meet the special needs of a primitive village supply. It is, for example, desirable on hygienic grounds that the container in which the milk is heated should also be capable of being used for the transport of the processed milk. Otherwise with the relatively poor facilities which usually exist in villages for sterilising utensils, there is a serious risk of contaminating the milk when transferring it from one container to another. Again, such a plant must be of simple design, easy to operate and with as few mechanical parts as possible, since it will have to be handled and repaired by relatively unskilled labour. The nearest analogy in Western dairying is the scalding of milk in a jacketed container, a procedure which is perhaps crude but is certainly effective. The requisite temperature and time of heating of the milk would, of course, have to be determined by experiment to ensure that it suited Indian conditions. A cheap and simple plant of this character has in my opinion far greater potentialities for Indian dairying than any of the more elaborate types of equipment which are found on the market.

As regards heat treatment at collecting centres, equipment of greater capacity and more efficient design could be installed, since the through-put of milk would be sufficient to meet the larger overhead charges. But here again it should not necessarily be assumed that the most effective combination of temperature and time of heating is that usually employed in Western countries, *i.e.*, holding at 145°—150°F. for 30 minutes. Extensive experiment would be necessary, using plants run on different principles (for example, holding pasteurisation, 'flash' pasteurisation, and high-temperature-short-time pasteurisation) and assessing the results by means of carefully conducted laboratory tests. It would, in addition, be essential to investigate the cost of processing. In one co-operative venture which I inspected the installation of expensive pasteurising machinery resulted in an annual deficit of roughly Rs. 6,000 on an average turnover of only 300 lb. of milk per day. In this instance neither the turnover of milk nor the location of the plant(?) justified the installation of pasteurising equipment. Failures of this kind have an unfortunate effect in discrediting other and more legitimate attempts to improve methods of handling milk. This points to the urgent need

(?) This plant was situated at a large hill station where the temperature conditions for the greater part of the year made pasteurisation quite unnecessary.

for including in all such investigations a careful study of the costs of processing.

Milk can be cooled by means of water or by artificial refrigeration. So far as village milk supplies are concerned it is doubtful how far artificial refrigeration could be successfully applied.

Cooling and refrigeration. Small-scale refrigerating coolers are on the market⁽⁸⁾, but for Indian village conditions they would probably involve too high a capital cost and too great a cost of maintenance to be economically feasible. An alternative method of refrigeration is the use of dry ice (solid carbon dioxide) which is now being manufactured in increasing quantities in India. It is likely that the cost of this would also prove prohibitive for village use. The cost of 'dry ice' is still considerable⁽⁹⁾. Moreover the difficulties of transporting this product to villages and of storing it there without wastage appear to be almost insuperable. It seems therefore that water cooling is likely to be the only practicable method available for village milk supplies. It is, however, questionable whether such cooling would in any event be of practical value unless the milk could subsequently be transported in insulated containers, since the very warm atmospheric conditions will quickly raise the temperature of the milk to a level at which contaminating bacteria rapidly multiply. Although the subject is worth attention, it seems likely that under village conditions the heating of milk will prove to be a more effective means of ensuring a satisfactory keeping quality than any attempt to cool milk.

On the other hand artificial refrigeration should be of great value in the transport of milk over long distances, as, for example, in the despatch of milk from distant producing areas to large cities. The technique of refrigeration under creamery conditions has been extensively studied, and many suitable types of plant are already on the market. So far as Indian conditions are concerned the problems of the large scale refrigeration of milk are likely to be concerned with refrigerated transport rather than with refrigeration at the creamery, which presents few difficulties. The problems involved in transport are due to the fact that during the hot weather the internal temperatures of unrefrigerated railway trucks reach extraordinarily high levels. A series of tests carried out in runs between Bombay and Jhansi in mid-May showed, for example, that the internal temperatures of railway trucks reached 120° to 130° F., and seldom fell below 90° F.⁽¹⁰⁾.

Several types of refrigerated transport might be investigated. The use of refrigerated vans would probably be ideal, but costly. An alternative would be the use of dry ice in specially constructed and insulated churns, a subject on which certain preliminary experiments

(8) See, for instance, the Reports of the Agricultural Machinery Testing Committee of the Ministry of Agriculture. H. M. Stationery Office.

(9) Figures obtained from Indian manufacturers showed that 'dry ice' could be purchased at 2 to 2½ annas per lb. A crudely made insulated container designed to store 220 lb. of 'dry ice' showed a 10 per cent. loss per day.

(10) Information obtained through the courtesy of the Railway Board.

have already been carried out⁽¹¹⁾. A further alternative would be the use of large insulated tanks, though it is very doubtful whether these would prove sufficiently effective under the severe temperature conditions of India.

The whole question of refrigeration is one which merits extensive investigation. Great progress has been made in this direction in the United States and other countries, and an effective method of refrigeration might well revolutionise the methods of handling milk in a tropical climate. In this connexion I suggest that an attempt should be made to combine the study of the refrigerated transport of milk with the recent developments in refrigerated transport sponsored by the army authorities. It is, however, again necessary to stress the fact that in a country like India the prime consideration is cost, and that no method could hope for extensive employment unless it involved an absolute minimum of expenditure.

While the problems involved in the production and processing of milk are considerable, their solution will be valueless unless a

The distribution of milk. satisfactory means of distribution is also evolved, for the handling of milk during distribution provides unlimited opportunities for

its re-contamination and adulteration. So far as specific methods of distribution are concerned, the great variety of conditions in urban and rural centres of population makes detailed recommendations impossible. Thus in some areas it is usual for all milk to be sold in bazaar shops; in others some of the milk is delivered to the purchaser's house and some is bought at retail shops; in others, again, the cow is driven from door to door and milked in the presence of the customer. All that I can do here is to indicate possible methods of ensuring that the cleanliness (*i.e.*, lack of dirt) and purity (*i.e.*, absence of adulteration) of the milk is retained throughout distribution, keeping in mind the paramount necessity of low cost. The application of such methods in practice must be worked out to suit local conditions and practices.

The need for scrupulous cleanliness in handling milk has already been stressed. In the distribution of milk, however, gross carelessness and ignorance is frequently observed.

Hygienic aspects. Milk containers are left open to flies and dust.

The measuring vessels are without handles, and after use are allowed to stand in a pool of milk drippings until again required. The quality of the milk is judged by dipping the fingers into the vessel and allowing the milk to run back into the bulk. These and other similar practices are common, and undoubtedly lead to serious contamination, with a resultant decrease in keeping quality. This probably accounts for the prevalent habit of allowing milk to simmer until sold.

The present tendency is to advocate the introduction of modern Western methods, such as pasteurisation and bottling, as the ideal method of milk distribution. I do not consider that such methods

(11) It was stated by one manufacturer that 2 lb. of 'dry ice' was sufficient to keep one maund (80 lb.) of milk cold for 24 hours.

are capable of attainment in India for very many years. I am indeed doubtful whether, in view of the dietary habits of the Indian population, they are called for at all. But in any event it is, I believe, fundamentally unsound to endeavour to replace the present crude and primitive methods of distribution by the most modern processes which have only been introduced into wealthy countries like Great Britain and the United States within the last thirty years. It is no use trying to teach the Indian dairy industry to run before it can walk.

For the mass of the population some form of 'loose' milk distribution appears to be inevitable. The 'loose' delivery of milk has been condemned in Western countries on account of the risks of spreading milk-borne disease⁽¹²⁾. It has already been pointed out that this argument does not hold for India. The problem in India is, therefore, to devise a cheap method of 'loose' milk delivery which, while not perhaps attaining an ideal standard of hygiene, will eliminate gross forms of contamination. For this purpose one might, I think, take as a model the methods and utensils almost universally employed in Great Britain about thirty years ago and still found in common use in the smaller country towns and villages⁽¹³⁾.

The possibility of applying such methods of milk distribution under Indian conditions would need to be investigated under carefully controlled conditions, and modifications would probably require to be introduced to meet local circumstances. Here, as in the problems of milk production, much work of an apparently elementary nature needs to be done. But until cheap and satisfactory methods have been worked out and tested under practical conditions I do not think that any improvement in existing methods of distribution can be looked for.

A short reference should, perhaps, be made to the 'itinerant' cow, *i.e.*, the animal which is taken from door to door and milked in the customer's presence. In theory this method has two great advantages. The milk is always delivered fresh, and the milking of the animal in the presence of the customer checks adulteration. In practice the method is, however, open to serious objection. It entails the housing of cattle in urban areas, which is undesirable on public

(12) E. F. Brown and Leland Spencer. "Is Loose Milk a Health Hazard?" New York City Milk Commission, 1931.

(13) This consists essentially of using a milk can with a wide mouth, for ease of cleaning; a hinged lid which protects the milk during transit and which cannot be removed and placed on a dirty and contaminated surface while milk is withdrawn from the can; and internal metal bands on which the handles of the measuring vessels may be hung, again preventing external contamination from spilled milk or flies. Such a milk can may be purchased comparatively cheaply, *i.e.*, from Rs. 5 to Rs. 10. I do not favour the use of taps under Indian conditions. They are difficult to clean and sterilise, and do not overcome the difficulties involved in the contamination of measuring vessels. Moreover the fat of Indian cows' and buffaloes' milk tends to rise to the surface very quickly, so that milk drawn off from a tap is liable to have a low fat content. In the simpler type of can the measuring vessel (which is invariably provided with a handle) may be used to stir the milk and this ensures a uniform distribution of fat throughout the bulk. The can and measuring vessel can be readily sterilised in scalding water.

health grounds. It is questionable whether milk production and distribution under such conditions is economic. The practice has all the disadvantages of the 'city stable' system without the advantage of centralisation—i.e., reduced labour costs, the purchase of foodstuffs in bulk, etc. And finally, since the greater part of the milk-fat is contained in the 'strippings' the customer is apt to be defrauded of a valuable part of the milk⁽¹⁴⁾.

The second essential in milk distribution is to ensure the purity of the milk, by which I mean the absence of adulteration. It is, I think, universally recognised that the prevalence of adulteration constitutes one of the most urgent and difficult problems of milk distribution.

The prevention of adulteration. Table 12 shows the collected figures relating to the adulteration of milk samples examined by provincial authorities⁽¹⁵⁾. It will be seen that from 19 to 66 per cent. of samples are adulterated. There is, moreover, no indication that the number of adulterated samples is decreasing. The mean amount of water added is difficult to assess, but Table 13 probably provides a fairly representative example of the figures generally obtained in analytical laboratories⁽¹⁶⁾. Apart from the detrimental reaction of adulteration on the sale of milk through distrust on the part of the consumer, this practice has the virtual effect of reducing the market for milk, since for every unit of water added an equivalent quantity of milk fails to be sold. Assuming that milk is, on the average, adulterated to the extent of 10 per cent. of added water, the financial loss to the dairy industry amounts to over 10 crores of rupees⁽¹⁷⁾. This is, perhaps, an over-estimate, since adulteration is partly practised in order to enable the seller to reduce the price of milk and thus increase his sales. It is, however, sufficient to indicate the magnitude of the issues involved. What can be done to remedy the position ?

One of the predisposing causes of adulteration has already been mentioned, namely, the necessity of keeping the price of milk within the purchasing power of the consumer. It is obvious that unless milk distribution can be put on to a paying basis adulteration is inevitable. This subject will be dealt with in a later chapter and in Appendix II. But apart from adulteration due to such economic difficulties, there is no doubt that wilful dishonesty plays a considerable part in the matter : and so long as the dishonest vendor can increase his profit without any serious risk of prosecution or punishment, the practice of adulteration will increase. In this connexion I should point out that appropriate legislation exists in practically all municipalities by which convicted persons can be punished. The difficulty is that this legislation is not applied effectively. Offenders are frequently not prosecuted, and if prosecuted the fine imposed is quite insufficient to act as a deterrent. Such a position cannot be

(14) Z. R. Kothavalla and co-workers. "An Investigation into the Variation of Fat and Solids-not-fat in cows' milk drawn at different times during the Process of Milking." *Journ. Cent. Bur. Animal Husb. and Dairying*, 2, 122 (1930).

(15) Figures obtained from the Public Health Commissioner, New Delhi.

(16) Figures obtained from the Provincial Marketing Officer, Bengal.

(17) Namely 10 per cent. of 107 crores of rupees (see Table 10).

dealt with by recommendations of a technical character and lies outside the scope of my report.

It is, however, legitimate for me to indicate the lines along which improvements might be effected in certain technical aspects of adulteration. In the first place it is necessary to have reliable methods for the detection of adulteration. For this purpose it is essential that standardised apparatus and tests should be employed. At no centre did I find standardised apparatus in use. Yet considerable errors may be made through the employment of, for example, unstandardised butyrometers and lactometers. Specifications are now available for standardising these instruments⁽¹⁹⁾, and it should be made obligatory to use apparatus of approved design in carrying out all official tests. Further, existing conversion tables for the determination of total solids in milk are based on the milk of European breeds. It is essential that similar tables should be worked out for milk derived from Indian breeds of cattle and from buffaloes.

In the second place, attention should be given to the actual standards laid down in milk legislation. These have been formulated

Milk standards. without a sufficient basis of fact, and, moreover, show a serious lack of uniformity throughout India. The Imperial Council of Agricultural Research are endeavouring to remedy this position by formulating a set of standard regulations which might be adopted by provincial governments and municipalities. I consider that this is a most useful contribution to the problem. I feel, however, that further information is required on certain aspects of the subject before any final recommendations should be drafted.

Standards for milk may be based on one of two methods. An arbitrary standard may be laid down to which all milk must conform. Alternatively milk may be legally defined as the unaltered lacteal secretion of the cow. In practice these two standards may be combined, as, for example, in Great Britain where there are 'presumptive' standards below which milk is presumed to have been adulterated.

The difficulty of accepting an arbitrary standard is that it takes no account of the normal day-to-day variations in the composition of milk nor of the fact that the quality of milk secreted by different animals of the same breed may vary. It has, for example, been shown in Great Britain that the frequency with which a bulk sample of milk falls below the presumptive standards of 3 per cent. fat and 8.5 per cent. solids-not-fat depends on the number of cows in the

(19) "British Standard Apparatus and Methods for Determining the Percentage of Fat in Milk and Milk Products by the Gerber Method. Part I, Apparatus; Part II, Methods"; "British Standard Specification for Density Hydrometers for use in Milk"; and "British Standard Specification for Floating Dairy Thermometers." Published by the British Standards Institution, London, as Bulletins 695, 696 (Parts I and II) and 734.

herd⁽²⁰⁾. With a large herd the mixing of milk from a number of cows tends to even out any abnormally high or low values, so that the average values for the mixed milk tend to fall slightly above the presumptive standards. With a small herd, on the other hand, one or two animals which give abnormally high or abnormally low values will seriously affect the average values for the milk. In spite of the fact that such milk is genuine, it may frequently fall below the presumptive standards. This point is of particular significance under Indian conditions, where milk is frequently derived from a very small group of animals. The only known method of overcoming this difficulty is to use the so-called "freezing-point" method of testing the milk. This test is almost infallible as an index of the genuineness of milk. The present "freezing-point" values have, however, only been worked out for European breeds, and the method would therefore have to be tried out extensively on the milk of Indian cattle and buffaloes before it could be applied to Indian conditions⁽²¹⁾.

One further point might be mentioned. At present there are dual or even triple standards for milk, corresponding to the average composition of cows' milk, buffaloes' milk, and mixed milk. This, I am informed, leads to considerable difficulties in the detection and prevention of adulteration. An alternative would be to fix a single standard for all types of milk. This would of course need to be a relatively low standard, and would enable milk of high fat content to be 'toned' with separated milk. Separated milk is of great value as a supplement to the Indian dietary on account of its high content of 'first-class' protein and mineral constituents. It may too be noted that in their recommendations, the Technical Nutrition Committee of the League of Nations⁽²²⁾ suggest that 3.0 to 3.5 per cent. is the optimum fat content of milk so far as nutritional requirements are concerned. Moreover the 'toning' of milk with separated milk has none of the disadvantages of adulteration with water, since the nutritional value is not reduced, while the cost of milk would be cheapened. It has been objected that the Indian population favour a high fat content in milk, but I understand that this is largely due to the fact that many families make *ghee* in the home because they cannot purchase unadulterated *ghee* in the market. If *ghee* adulteration could be prevented, and a product of guaranteed purity could be placed on the market, the need for liquid milk of high fat content would disappear. The provision of a single standard for milk might be open to abuse, but, in view of the high nutritional value and the cheapness of 'standardised' or 'toned' milk, the suggestion does, I believe, warrant careful consideration.

(20) J. F. Tocher. "Variations in the Composition of Milk." H. M. Stationery Office, Edinburgh (1925).

(21) It has been objected that determinations of the "freezing-point" present special difficulties owing to high atmospheric temperatures and the consequent difficulty of using ether. Such difficulties should not be insuperable, especially in view of the increasing availability of 'dry ice'.

(22) "The Problem of Nutrition. Volume II. Report on the Physiological Bases of Nutrition." (League of Nations Publication, 1926.)

CHAPTER IV.—The Manufacture of Butter and Ghee.

It has been pointed out that the manufacture of *ghee* is of special importance in Indian dairying economy, since this product leaves the greater and most valuable part of the milk—the non-fatty solids contained in the *lassi* (or butter-milk)—for the use of the cultivator and his family. This also applies to the production of ‘country’ butter. ‘Creamery’ butter leaves separated milk as a by-product, but under present conditions most of this is utilised in the manufacture of casein, and is thus lost as a nutrient.

Since *ghee* making leaves the greater part of the milk with the cultivator it cannot be expected to yield an economic return. Valued at, say, 9 annas per lb.⁽¹⁾, *ghee* gives a cash return of Rs. 3-6-0 per 100 lb. of milk, while the same quantity of milk sold liquid at 1 anna per lb.⁽¹⁾ would give Rs. 6-4-0, or roughly twice the sum realised for *ghee*. Yet far more milk is utilised for *ghee* manufacture than is sold for liquid consumption (Table 2). This is, of course, partly due to the fact that cultivators situated in areas remote from towns cannot market their milk in a raw state, though this market is in any event very limited. It is also partly due to the fact that *ghee* production meets the special needs of the cultivator, since it provides him with a cash sale, in addition to leaving him the *lassi*.

Compared with *ghee*, the output of both ‘country’ and ‘creamery’ butter is very small, as shown by the following figures.

Product.	Quantity of milk used in production (maunds).	Percentage of total production.
<i>Ghee</i>	363,700,000	97·2%
‘Country’ butter	9,036,000	2·5%
‘Creamery’ butter	1,304,000	0·3%

Moreover ‘country’ butter is chiefly used for the home production of *ghee* (in order to avoid purchasing an adulterated product), so that the use of butter *per se* is almost negligible.

In the present chapter I shall deal mainly with the production and marketing of ‘country’ butter and *ghee*. A short account of the production and marketing of ‘creamery’ butter will, however, also be included.

As ‘country’ butter is invariably an intermediate product in the manufacture of *ghee* it will be best to deal first with its production and properties. ‘Country’ butter is most commonly obtained by churning whole milk which has been allowed to sour, usually after addition of ‘starter’ from the previous day’s batch. The

(1) Retail prices.

soured milk or *dahi* is broken up and poured into the vessel in which it is to be churned, additional water being added if necessary to reduce the consistency of the mass. The milk is churned with a rotating wooden pole to which beaters are attached, this pole being rotated by a small piece of rope which is twisted round it and pulled alternatively backwards and forwards. After 15 to 20 minutes the *dahi* starts 'breaking', and water is added to assist the separation of fat, which rises to the top of the mass in the form of grains. This is usually over-churned to collect it into lumps. Excess butter-milk is pressed out by hand. The daily outputs of butter are allowed to accumulate over several days before sale or conversion into *ghee*.

'Country' butter is invariably colourless. Owing to the fact that it cannot be collected into grains it is never washed during manufacture, and it consequently contains a relatively large proportion of casein, and is greasy in appearance. It has an acid taste and a roma, the acidity increasing with the period of storage.

Since 'country' butter is an intermediate product in the manufacture of *ghee*, the question whether it is worth while to try to improve its production must depend on whether such improvement will favourably affect the quality of the *ghee*.

Ghee itself is essentially clarified butter-fat. It may be produced from 'country' or from 'creamery' butter. The latter is a relatively common procedure in certain districts of North Bihar, where mechanical cream separators have been extensively installed. The butter is boiled over a medium but steady fire, being stirred until the mass is melted. After boiling for some time a muddy coloured scum gathers on the surface and is removed with a perforated ladle. The effervescence gradually diminishes as the moisture content is reduced, while particles of curd (casein) are seen to rise and circulate from the bottom of the pan. At this stage a characteristic aroma is noticeable, and this is an indication that the *ghee* has been sufficiently heated. After settling and cooling for some hours, the *ghee* is removed to separate containers (either to small earthen pots or kerosene tins) for sale. The casein residue is found as a semi-solid mass at the bottom of the pan, and represents about 0.5 per cent. of the *ghee*.

For large supplies of *ghee* (for example, to meet army requirements) the product may need to be refined and blended. This is carried out by testing individual consignments of *ghee*, deciding the proportions of each necessary for the required blend, and then mixing the bulk in heating tanks. The reheating not only enables blending to be effected, but assists in the refining process, the mixed product being re-filtered before packing for storage or distribution.

Ghee is judged partly by its appearance and texture and partly by its taste and aroma. It should have a slight yellowish colour. It should have a fine granular texture and should be neither greasy

nor waxy. The aroma of well made *ghee* is typical and its taste slightly acid. There should be no taints or abnormal flavours.

I have felt that it was desirable to include this short account of the production and properties of *ghee* before dealing in detail with possible methods for improving its manufacture and quality.

In the country method of production up to 10 or 15 per cent. of fat may be lost although such fat is, of course, actually retained

The out-turn and quality of ghee. although in the *lassi* and consumed by the cultivator's family. But this involves an equivalent loss of cash returns from the *ghee*, an important item for the cultivator. The first direction in which improvement might be effected is, therefore, in the total out-turn. It has been suggested that the use of the cream separator will result in a greater out-turn per unit of milk. Two sets of workers claim to have obtained increased yields by the use of separators and of modern methods of churning⁽²⁾. In neither instance, however, are the results based on a sufficient number of tests to justify the authors' conclusions. A method based on an entirely new principle, that of separating the milk, re-separating the diluted cream, and making the *ghee* direct from the re-separated product (*i.e.*, omitting the intermediate step of butter-making) has been published recently⁽³⁾ and is under test at the Imperial Dairy Institute. Both these methods have, however, the disadvantage that the by-product from manufacture is separated milk and not *lassi*. I am informed that the Indian villager prefers the latter as a beverage, although this may only be the result of a very conservative taste. The difficulty might be overcome by making a skim-milk *dahi* from the separated milk.

A more fundamental difficulty is involved in the relation between total out-turn and quality. It is essential that quality should not be sacrificed in efforts to obtain higher yields of *ghee*, for this would merely result in a lowered market value for the product. Experienced merchants state that *ghee* made by the 'separator' method is inferior in quality to *ghee* made by the 'country' process, and that the souring of milk in the latter process imparts a particularly acceptable flavour. Only one series of well-controlled experiments can be found in the literature on the subject⁽⁴⁾, and the report of this series bears out the above contention, the authors stating that "the distinctive aroma was present only in the *ghee* prepared from *dahi* (soured milk)". The same authors obtained a larger out-turn of *ghee* from sour than from fresh milk. It might also be

(2) A. K. Y. Narayan Aiyer. "Methods of Butter-making Local and Improved." Dept. of Agriculture, Mysore State, Bull. 9 (1916); Z. R. Kothavalla and S. Cox. "Results of the Experiment in *Ghee* making by the Country and Separator Methods." *Journ. Cent. Bur. Animal Husbandry and Dairying*, 1, 95 (1927).

(3) M. F. French. "Some observations on the Methods of making Clarified Butter (*Ghee*) with some Notes on a new Method." *Bull. Imp. Inst.* 34, 33 (1936).

(4) A. D. Steward and N. L. Banerjee. "Some observations on the progress of making *Ghee*, and its effect on the Legal Standards." (1929).

mentioned that the use of the 'country' method has one other advantage, in that the *dahi* does not deteriorate if churning has to be unduly delayed. Elasticity in point of time is a valuable factor in fitting the method into the programme of agricultural operations, which sometimes occupies the entire time of the cultivator and his family.

It is apparent that the whole subject of the relation of the out-turn and quality of *ghee* to the method of manufacture requires thorough re-investigation. Such investigation should be carried out on an adequate scale and, as far as possible, with methods of control of quality based on objective tests.

This raises a further point of great importance in relation to *ghee* making. At present no information is available regarding the

Factors affecting quality. factors concerned in the quality of *ghee*: whether, for example, the flavour is dependent on the free acid content, on an incipient breakdown of fat constituents through bacterial action or heating, or on other factors not directly concerned with the fat constituents. It is interesting to find that the army requirements (so far as quality is concerned) are based on the acidity of *ghee*, the standard value being under 9 points⁽⁵⁾, *ghee* with an acidity between 9 and 11 points being accepted for blending, and *ghee* having an acidity in excess of the latter value being rejected. Table 14 shows the results obtained with a series of samples tested during 1935-36. It will be seen that the greatest number of samples had acidities of between 7 and 9 points, and it may be taken that this represents typical results for a *ghee* of a very good quality. It is instructive to note that the acidity of 'creamery' butter should not exceed 3 to 4 points, a value given by only 3 per cent. of the samples of *ghee*. This may perhaps account for the disfavour in which *ghee* produced from creamery butter is held by experts.

It is almost certain that the greater part of the acidity of *ghee* is developed during the initial souring of the milk and the storage of 'country' butter prior to *ghee* making. It is, however, interesting to find that the acidity of *ghee* itself increases during storage in spite of the low moisture content of the product. Figures obtained from the Military Food Laboratory, Kasauli, show that *ghee* may increase in acidity by as much as 7 points over a period of two years' storage, the increase being more rapid in the hot weather than at other periods of the year.

Another point of importance in relation to the production of *ghee* is the seasonal variation in the quality of the product. It is stated that the best *ghee* is produced between November and March, and that *ghee* produced during the monsoon period is of definitely inferior quality. Again, most *ghee* is of mixed origin in that it is derived from the butter-fat of both cows and buffaloes, but distinct local preferences exist for *ghee* in which the fat of one or the other

(5) A 'point' of acidity means the amount of acid, reckoned as oleic acid, contained in 10 grams of a sample of *ghee* which is exactly neutralised by tenth normal sodium hydroxide. This is 0.292 per cent.

predominates. Neither of these points has, so far as I can ascertain, been investigated in any detail, although the implications are of considerable economic importance.

This general discussion serves to illustrate the very large field open for useful investigation. The effect of process of manufacture, of temperature, of heating, of season of the year and of conditions of storage on the out-turn and quality of *ghee*, and the chemical and physical factors affecting flavour, palatability, and texture (a question which I have not dealt with) are all practically unexplored subjects. Moreover it is on such investigations that any future improvements in technique and methods must ultimately be based. I consider that the importance of *ghee* in the dairy economy of the country justifies extensive study of the many problems connected with its production and properties. I suggest that in any such study, the co-operation of the Military Food Laboratory, Kasauli, should be sought, since this institution has had a unique opportunity of investigating methods of control of *ghee* quality.

Any attempts to improve the quality of *ghee* will be largely abortive unless adulteration with cheaper and inferior fats can be checked. Constant statements were made to

The adulteration of *ghee*. me that it is practically impossible to purchase unadulterated *ghee* on the open market. Official figures lend support to this view. It will be seen from Table 15 that from 7 to 65 per cent. of officially examined samples are classed as adulterated. This table shows, moreover, that adulteration is not being checked ; in several instances it appears in fact to be on the increase.

There are no figures available which provide any estimate of the average amounts of adulterant added to *ghee*. The chief fats used are *banaspatine*⁽⁶⁾, *charbini*⁽⁷⁾ and certain pure vegetable oils such as groundnut oil, coconut oil, and cottonseed oil. A very rough estimate of the quantities of adulterants used may be obtained from figures relating to the quantities of these products available in India. *Banaspatine* is produced at five factories. The potential capacity of these factories is stated to be 33,000 tons per year but the present output probably does not exceed 25,000 tons. In addition to this about 1,000 tons are imported from foreign sources. It is the opinion of some of the manufacturers that about 90 per cent. of the total supplies (or 23,500 tons) are used for the adulteration of *ghee*. As regards *charbini*, no direct estimates are available, but an indirect calculation from the figures for the annual productions of hides in India⁽⁸⁾ indicates that there would be available at least 11,000 tons

(6) Under the Punjab Pure Food Act, 1929, *banaspatine* means any article of food, whether mixed with *ghee* or not, which resembles *ghee*, but is derived from vegetable fat and contains no animal fat other than milk fat. It is usually referred to as *vegetable ghee*, and consists largely of hydrogenated vegetable oils.

(7) Under the Punjab Food Act, 1929, *charbini* means any article of food, whether mixed with *ghee* or not, which resembles *ghee* or *banaspatine*, but contains animal fat other than milk fat.

(8) Figures taken from the Hide Cess Enquiry Committee's Report, 1930.

of *charbini* per year. Figures for the production of other Indian vegetable oils available for the adulteration of *ghee* cannot be gauged with any accuracy. At a very rough estimate one might perhaps place this quantity at 15,000 tons. This would bring the total amount of available adulterants to just under 50,000 tons, or 1,400,000 maunds. The annual production of *ghee* is estimated at 23,000,000 maunds. The amount of adulterant available would thus work out at just over 6 per cent. of the total out-put of *ghee*. At a retail price of Rs. 32 per maund, the amount of genuine *ghee* replaced by adulterant would represent over 3 crores of rupees. It is probable, in view of the results of analyses already referred to, that this greatly underestimates the loss to the dairy industry as a result of the adulteration of *ghee*. If adulteration could be checked this additional income could be added to the wealth of the countryside, with consequent advantage to the rural population. It may be mentioned that *banaspatine* can be purchased at from Rs. 10 to Rs. 12 per maund and *charbini* at from Rs. 6 to Rs. 12 per maund, as compared with Rs. 25 to Rs. 40 per maund for *ghee*. Adulteration is therefore a very paying proposition for the dishonest merchant.

As with the adulteration of liquid milk, part of the difficulty in checking adulteration is due to lax administration of the law, a subject which I have dealt with in the previous chapter. But the absence of quick and reliable methods of detecting adulteration is also partly responsible for this widespread practice. A brief discussion of this latter aspect of the problem is therefore desirable.

The present official standards for *ghee* are based on the refractive index and the Reichert-Meißl value, the latter giving a measure of the volatile fatty acids present in the fat. The actual standards vary somewhat from province to province. In the Punjab and in Bengal the refractive index⁽⁹⁾ is fixed at 40 to 42.5, in Bihar and Orissa at 40 to 42, and in the Central Provinces at 40 to 46.

The standard Reichert-Meißl values are between 24 to 32 for the Punjab and between 19 to 36 for the Central Provinces. In Madras Presidency the value may not fall below 20, and in Bengal below 24, while in Bihar and Orissa there are separated minimum values for *ghee* produced from cows' milk (*i.e.*, 24), buffaloes' milk (*i.e.*, 30) and mixed milk (*i.e.*, 28). The latter value corresponds with the army specification. It may be mentioned that the common adulterants have low Reichert-Meißl values, but variable refractive indices, animal fats having higher and coconut oil lower values than those of genuine *ghee*. It will be instructive to examine typical figures for *ghee* given by different authorities. As regards refractive index, workers at the Imperial Dairy Institute⁽¹⁰⁾ have given values for 11 samples of village-produced *ghee* from 42.8 to 43.4. The extreme values recorded for *ghee* produced from the milk of individual breeds

(9) Expressed throughout as butyro-refractometer readings at 40°C.

(10) S. D. Sunawala and Z. R. Kothavala. "Study of the Various Standards adopted for the Examination of Indian Butter and *Ghee*." *Agric. and Live-stock in India*, 5, 480 (1935).

were 43.0 and 45.1. No consistent differences were observed between *ghee* obtained from cows' and from buffaloes' milk. These workers suggest that the standard should be fixed at 42.0 to 45.5. The army authorities specify extreme values for genuine *ghee* as being 40.0 to 42.5⁽¹¹⁾. A third group of workers⁽¹²⁾ find values varying between 40.0 and 44, the majority of samples falling between 42 and 43. The frequency distribution of these various values are shown in Table 16. Similar differences are found in the Reichert-Meissl values recorded by these three authorities. Such differences are, perhaps, attributable to the fact that the Reichert-Meissl value of the fat of cows' milk differs from that of buffaloes' milk, the former having a value of around 26 to 28 and the latter of well over 30. This difference is shown clearly in Table 16. The first group of workers were dealing with specially prepared samples of cows' and buffaloes' *ghee*, with the consequence that the results show two maxima. The second group were handling *ghee* which was chiefly obtained from Indian States on the western borders of the United Provinces, where buffaloes predominate. The third group probably obtained their samples from the eastern section of the United Provinces, and from Bihar, where cows tend to predominate. This explanation does not, however, account for the marked differences in the ranges of refractive indices observed by the three sets of workers.

This discussion is sufficient to show that even in the two tests normally used as standards there are considerable differences of opinion regarding the range of values of genuine samples of *ghee*. Variations due to local differences of climate and fodder, to season of the year, and to method of manufacture and storage have not been studied in any detail. Nor have other supplementary tests been fully investigated. In this connexion it may be mentioned that the need for a quick and simple method of determining adulteration will become urgent if proposals for the grading and improved marketing of *ghee* materialise at an early date. At present I understand that private merchants are charged exorbitant fees if they obtain the assistance of official analysts in the examination of their *ghee*, while the length of time taken for such examination makes purchase on a quality basis almost impossible⁽¹³⁾. I consider, therefore, that, in view of the important issues involved, special attention should be given to the re-investigation of methods of analysis of *ghee* and to the formulation of standards suitable for use in various parts of India.

Any discussion of the adulteration of *ghee* would be incomplete without reference to the conditions of sale of *banaspatine*. Al-

Sale of banaspatine. though this product is largely used as an adulterant of pure *ghee*, it is also on sale under the name of 'vegetable *ghee*' or even as '*ghee*'. As a cheap source

(11) Figures obtained from the Military Food Laboratory, Kasauli.

(12) N. N. Godbole and Sadgopal. "Butter-fat Composition, Nutritive Value, etc." Benares Hindu University, 1930.

(13) It is stated to be not uncommon to have to pay a fee of Rs. 16 per sample, while analysis may involve a delay of 7 to 14 days.

of fat this product cannot be objected to ; the case is equivalent to that found in Western countries, where butter and margarine are both marketed. The objection arises when the vegetable product is used to adulterate the genuine one, or when it is sold under a name (such as vegetable butter or vegetable *ghee*) which is apt to deceive the customer as to its real origin and composition. In Western countries the latter difficulty has been met by providing legislation which prevents misrepresentation. Thus under the Food and Drugs (Adulteration) Act, 1928, it is specifically laid down in regard to margarine that "the Minister shall not approve any name if it refers to or is anything connected with the dairy interest", while every package containing margarine must be distinctively labelled⁽¹⁴⁾. This enactment has been most effective in preventing vendors from selling vegetable fat substitutes or butter mixtures as dairy products. I suggest that similar legislation regarding *ghee* and its vegetable substitutes would prove of great value in meeting the present difficulties of vendors of genuine *ghee*. Such legislation might also include regulations for the registration of *banaspatine* factories and of all consignments of this product⁽¹⁵⁾.

Even if *ghee* of better quality and of guaranteed purity can be produced it will still be necessary to develop improved marketing

The marketing of *ghee*.

At present the *ghee* producer is handicapped in two directions. Firstly, he is frequently out of reach of a convenient market at which he could dispose of his produce⁽¹⁶⁾. The consequence is that he either has to store his output for prolonged periods, with consequent lowering of quality, or he has to deal through middlemen, who fail to give him a fair price and who frequently adulterate the *ghee* in order to increase their profits or reduce their prices. Moreover any such reduction in prices hits the producer who is able to sell the genuine article, since he is forced to sell his pure produce at the lower rates. It is clearly desirable that additional markets should be established so that every *ghee*-producing area is adequately provided for.

Secondly, the producer has no means of getting his *ghee* graded and tested for purity, so that whether the quality is good or bad, whether it is adulterated or pure, he still receives the same price. Under such circumstances there is no encouragement to produce a better article.

It appears therefore that the establishment of *ghee* grading centres is urgently called for. Legislation is now available⁽¹⁷⁾ under which Government can prescribe official standards for the grading of certain classes of produce, among which are included milk products. I do not consider, however, that grading alone would

(14) 18 and 19 Geo. 5. Ch. 31, Sections 6 and 23.

(15) *Ibid.*, Sections 8 and 9.

(16) Instances were quoted to me of producers who were more than 100 miles from the nearest market.

(17) Agricultural Produce (Grading and Marking) Act, 1937.

prove effective ; it would probably be necessary to encourage the establishment of blending and packing stations, perhaps on the lines of the Military Ghee Heating Centre at Agra. Such stations might be organised on a co-operative basis, by private individuals or by Government itself. Co-operative efforts have already been made in this direction, notably in the United Provinces where several *Ghee Merchants' Associations* have been formed. But the present organisations hardly go far enough in the direction of grading and of blending, nor are the results of the laboratory tests always trustworthy. In such developments it is essential that Government should take the lead and should itself provide facilities for the testing and grading of the *ghee*.

It has already been stated that the establishment of grading stations will necessitate the development of quicker and cheaper tests for adulteration and quality. Another direction in which investigation is desirable is in the methods of packing *ghee*. For relatively large quantities the existing tin containers are quite suitable, though methods would need to be devised for closing these containers in such a way that they could not be tampered with after being graded⁽¹⁸⁾. But for smaller quantities it would be advantageous to have small non-metal containers which would prevent contamination during handling and would effectively check adulteration by the shop-keeper.

One further point. It was remarkable to find that *ghee* is seldom if ever advertised in India. This is probably due to the poor and variable quality of the produce and to the absence of any proprietary brands. If grading and marketing are to be successfully established it is, I believe, essential that they should be supplemented by adequate advertisement. It was significant to find that a single firm of importers of condensed and dried milk products spent Rs. 2 lakhs a year on advertisement, although the sale of their products would represent only a minute fraction of the value of the *ghee* at present produced in India. A relatively uneducated population is particularly susceptible to propaganda. The value of advertisement as a means of popularising the improved grades of *ghee* should not therefore be neglected in any future marketing developments.

During the years 1924 to 1929 *ghee* amounting to roughly 38,000 cwt. (53,000 maunds) was sold for export from India⁽¹⁹⁾. Between 1929 and 1935 there was, however, a fall of over 33 per cent. in the quantity exported.

At the same time the value per maund of *ghee* fell from Rs. 70 to Rs. 41. The total value of the exported *ghee* showed therefore an even greater fall, from Rs. 38 lakhs to Rs. 14 lakhs, or 63 per cent. (Table 17). The quantities exported are, of course, very small in comparison with India's total output of *ghee*, which amounts to about 23 million maunds. It has been suggested, however, that this fall in exports is due to a deterioration in

(18) Several methods have been tried out in the United Provinces in connexion with the sale of *ghee* under private trade marks.

(19) Annual Statements of Sea-borne Trade of British India.

the quality of the *ghee* produced in India. As this is a point of considerable importance in relation to the foregoing discussion, it seemed desirable to obtain further evidence on the point. Figures were therefore obtained regarding the imports of *ghee* into Malaya, which is India's chief customer⁽²⁰⁾. These figures are also shown in Table 17. It will be seen that, while India's total exports decreased by roughly 33 per cent. between 1928 and 1935, Malaya's total imports fell by over 50 per cent. during the same period. The percentage of Malaya's *ghee* imported from India remained substantially constant at about 95 per cent. It is apparent, therefore, that India not only held her own in the Malaya market, but was able to find additional markets in other countries during this difficult period. These facts do not bear out the suggestion that deterioration in the quality of Indian *ghee* is affecting the export trade: the decrease in the latter is a result of general world depression in trade. In this connexion the following official comment regarding Malaya's reduced imports of *ghee* are significant⁽²¹⁾:—"Probably this is partly due to the extensive repatriation of Indian immigrant labourers which occurred as a result of the slump, and to decreased purchasing power of those who were left. I should imagine that the 1936 figures would show a rise with the partial return of prosperity and the resumption of immigration. The position may, however, also be affected to some extent by the drive which has been in progress to popularise locally produced fats, notably coconut oil, in place of imported fats." This comment affords both encouragement and warning: encouragement, in that it implies a possible re-opening of India's export trade in *ghee*; and warning, in that it indicates the increasingly serious competition of vegetable oil substitutes. It re-emphasises the need not only for maintaining but for improving the quality of Indian *ghee*.

It has already been stated that 'creamery' butter represents only a minute fraction of the output of Indian dairy produce, being equivalent to about 0.3 per cent. of the output of *ghee* or to roughly 0.1 per cent. of the output of total milk products. Its consumption is limited to the European population and to a small number of Indians who have acquired European tastes.

There are, however, indications that the demand for 'creamery' butter is improving. Imports of this product show progressive increases, as is seen from Table 18⁽¹⁹⁾. It might be supposed that these increases represent displacements of Indian produced butter. Returns from three prominent Indian producers show, however, that while imports of butter increased by 23 per cent. between 1933 and 1934, their own combined output increased during the same period by over 30 per cent. Imported butter constitutes, in fact, a relative-

(20) Figures obtained through the courtesy of the Colonial Office.

(21) Communication from the late Director of Agriculture in Malaya, forwarded through the courtesy of the Colonial Office.

ly small proportion of India's total consumption, as shown in the following table :—

Type of butter.	Quantity of milk used in production. (Maunds).	Percentage of total butter production.	Percentage 'creamery' butter consumption.
Indian 'country' butter	9,036,000	86·0%	..
Indian 'creamery' butter	1,304,000	12·5%	89·5%
Imported 'creamery' butter	154,000	1·5%	10·5%

The development of refrigeration will probably tend to popularise still further the consumption of 'creamery' butter. While, therefore, such butter is still a dairy product of minor importance in India, the needs of this branch of the industry should not be neglected in any future scheme of development.

Indian creameries have special difficulties to contend with in producing a butter of high standard and satisfactory keeping quality. The first is to secure an adequate supply of good quality milk. The second is that manufacture has to be carried out under exceptionally warm atmospheric conditions. The third is the fact that the fat from buffaloes' milk is stated to be unsuitable for high class butter production. It is even held that Indian cows' milk is unsuitable for this purpose. In consequence of these difficulties Indian 'creamery' butter is frequently subject to a number of defects which seriously affect its sale in competition with imported butter. It is significant in this connexion that much of the Indian 'creamery' butter fails to command as high a price as the imported product.

So far as texture is concerned, Indian butter has a tendency to greasiness and frequently lacks grain. This defect is generally recognised to be due to excessive working of the butter while in a soft condition, and is consequently largely attributable to lack of proper facilities for chilling. As regards palatability, Indian butter frequently lacks the flavour and aroma typical of the Western product. This may be due to a variety of causes, but it is significant that I found the use of properly cultured 'starters' to be exceptional. A third and not unusual defect is the early development of rancidity, a fault associated with bacterial and mould growth. The occurrence of this defect is not surprising in view of the very poor quality of the incoming milk and cream. It was, for example, reported from one creamery that as regards the methylene blue reduction test (a measure of the bacterial contamination of the incoming milk) "half-an-hour was the limit for the *best* milk, while some samples decolourised the solution within a few minutes". At another creamery it was stated that the incoming milk was of such poor quality that after separation the separated milk was so acid as to be only fit for casein making. Although my tour was undertaken in

the cold weather I personally saw many churns of sour milk arriving at one creamery, and of 'gassy' cream at another.

None of these defects should be incapable of remedy if the subject were to be systematically studied. I found, however, an entire lack of published information on the points mentioned above. There are no published records regarding the comparative values of buffaloes' and cows' milk for butter-making; no controlled experiments have apparently been made to determine the influence of the quality of the incoming milk on the keeping quality of the butter, nor has the effect of high atmospheric temperature and other adverse factors been investigated. I was informed that experiments had been made on the use of properly cultured 'starters', but no published records of such experiments were available to guide creamery managers.

It was suggested to me that the investigation of these problems required large scale factory equipment, and a proposal for acquiring such equipment is included in the Anand Experimental Creamery scheme. The problems mentioned above can, however, be more satisfactorily studied on a small (hand churn) scale. The careful control necessary in experimental work makes small scale investigation preferable to large scale processing, both on the score of expense and accuracy; the application of the findings to factory conditions is a matter involving modifications of detail and not fundamental principles. In any such work it is essential to have adequate chemical and bacteriological control throughout the production and storage of experimental batches of butter.

In the meantime efforts to improve the quality of the incoming milk supply by advisory work and propaganda will certainly reduce the difficulties of the butter trade. Such efforts should, if possible, be accompanied by the establishment of a system of payment for milk on a quality (*i.e.*, cleanliness) basis. If better milk could be obtained it might enable the separated milk which is formed as a by-product to be converted into a more valuable product than casein, so that the additional cost of payments for quality would be recovered. This subject is dealt with in detail in the next chapter.

One further point should be mentioned. It has been suggested that the time is ripe for establishing legal standards for 'creamery' butter similar to those enforced in Western countries. Such standards would include a maximum moisture content and absence of adulterants. The latter subject has been dealt with in connexion with *ghee*, and need not be further discussed. As regards moisture content, it is difficult to decide a suitable standard until a more thorough investigation has been made into the technique of production and the keeping quality of butter under Indian conditions. At present it is suggested that the Western standard of 16 per cent. moisture content should be adopted, a figure which is already included in the food legislation of various provinces. It is impossible to say without extensive investigation whether this standard is a reasonable one.

In this connexion it appears to me that improvement in the quality (*i.e.*, texture and palatability) of the product is of more immediate importance than the setting up of any legal and arbitrary standard of moisture content. If a customer can purchase butter of good flavour and texture, I believe that he will be indifferent as to whether the legal standard is, for example, 16 or 18 per cent. moisture. This is particularly true of a product such as 'creamery' butter, which may be looked upon as a luxury trade. From this point of view I consider that the whole question of butter standards might better be dealt with through the institution of a grading scheme than by general legislation.

CHAPTER V.—The manufacture of khoa and dahi and of other indigenous milk products.

Apart from liquid milk and *ghee* the most important dairy products produced in India are *khoa*, *dahi* and certain other indigenous milk products. The importance of these products is partly due to the extent of their production. The quantity of milk utilised for their manufacture approximates 95 million maunds⁽¹⁾, which is more than twice that utilised for the whole of the production of manufactured milk products in Great Britain. The monetary value of this output is estimated at over 80 crores of rupees (Table 3). These figures emphasise in a striking way the magnitude of the output of indigenous milk products in India. The importance of these products is, however, also partly due to the high return which they give per unit of milk. This fact is shown in Table 19. It illustrates a point of unique interest, since it will be seen that the manufactured products (with the exception of *ghee* and 'country' butter) realise more per maund of milk than liquid milk itself. This is contrary to the experience of practically all Western countries⁽²⁾.

In describing the methods of preparation of these products, it will be convenient to divide them into two groups, namely, products manufactured by the partial desiccation of milk (*khoa*, *rabree* and *mallai*), and products resulting from the souring of milk (*dahi*, *channa*, and *cheese*). General problems which are more or less common to all the products will then be dealt with.

In the production of *khoa* and related products the keeping quality of the milk is preserved by its conversion into semi-solid form, the heat and the concentration of milk constituents both tending to eliminate bacterial growth. In *khoa* making the milk (usually in quantities of about 5 lb.) is evaporated in a round-bottomed shallow iron pan over a fairly hot and steady fire. The milk is stirred continuously to prevent scorching, a special scraper being used for this purpose. As the volume becomes less the stirring is increased, and the operator has to exercise skill in maintaining a uniform consistency to the mass. After 15 to 20 minutes heating the mass takes on a pasty consistency. At this stage the pan is removed from the fire, and the pasty mass is well worked with the flattened end of the scraper, being spread several times in a thin layer across the bottom of the pan. This gives the product a good grain. When the mass can retain its own form it is considered to be ready. *Khoa* is mainly used for making sweetmeats. It should be white in appearance, and should have a smooth

(1) This is equivalent to 760 million gallons. According to the Report of the Milk Reorganisation Commission (1936) the amount of milk utilised for the manufacture of butter, cheese, cream and condensed and dried milks in Great Britain during 1934-35 amounted to 338 million gallons.

(2) For example, milk is sold wholesale for liquid consumption in Great Britain at 14d. to 15d. per gallon, but when used for the manufacture of milk products its average realisation value is only about 5½ d.

texture. The taste should be sweet and wholesome, with a slight but pleasantly cooked flavour. On keeping the surface becomes yellowish and dull in appearance, while deterioration is judged by the presence of cobweb-like threads on breaking. *Khoa* itself keeps sweet for 4 to 5 days in the cold weather and 2 to 3 days in the hot weather, but the addition of sugar in the making of sweetmeats prolongs the keeping quality to 3 to 4 months.

Rabree might be described as a sweetened form of *khoa*, but its manufacture requires greater skill and it is looked upon as a great delicacy. Stirring is avoided during making, and the solids are separated from the milk by removing successive thin films of coagulated material from the surface by means of bamboo splints. These films are placed on the sides of the heated pan. When the milk has been reduced to about one-fifth of its initial volume the pan is removed from the fire and the whole mass is gently mixed, care being taken not to injure the flakes. Sugar is then added and after cooling and settling, the *rabree* is ready for sale. *Rabree*, on account of its lower temperature of manufacture and its higher moisture content, is more perishable than *khoa*. Uniform formation of flakes, uniformity of colour and freshness of taste are the main points looked for by discerning purchasers. *Khurchan* is a similar product to which arrowroot has been added during manufacture.

The third product in this group is known as *mallai*. This is a form of clotted cream which is sold and consumed unsweetened. It is usually made by simmering large quantities of milk (say, 20 lb.) until a thick layer of milk-fat and coagulated albumin forms on the surface. This is skimmed off with a flat ladle and laid aside to cool. The process is repeated twice, when most of the fat has been removed. The residue is caramelised and is not saleable as milk. *Mallai* should be smooth and white in appearance, and has a taste typical of clotted cream. It has a very limited keeping quality.

The products in this group are only produced on a large scale in Northern India, and are particularly popular in the United Provinces, the Punjab and Bombay Presidency. It has been estimated that out of every 100 maunds produced, *khoa* accounts for 85 maunds, *rabree* and *khurchan* for 10 maunds, and *malai* for 5 maunds.

Probably the simplest way of preserving milk for human consumption in a tropical country is to allow it to sour, since this checks putrefactive changes while giving an acid taste to the milk which is particularly refreshing in hot climates⁽³⁾. *Dahi* is milk which has been soured by inoculation with a lactic acid 'starter'. The milk is usually boiled for a short while and then allowed to cool. While still luke warm a small quantity of the previous day's supply is put in, care being taken not to disturb the surface layer of fat, which gives the product a rich appearance and is used as an index of the quality of milk used. After leaving for

(3) C. V. Wiser. "The Foods of a Hindu Village of North India." Bureau of Statistics and Economic Research, U. P. Bull. 2, p. 62, Allahabad, 1926.

6 to 8 hours, the *dahi* is ready for sale. It has already been noted that *ghee* is prepared from soured milk, so that it may be said that the production of a form of *dahi* lies at the foundation of India's *ghee* industry. The residue from churning *ghee* (*lassi*) is, indeed, the most common form in which milk is consumed in India. *Dahi* itself is also a popular food, which is taken with rice or wheat *choppatties* either salted or with sugar. It also forms the basis of a special type of *lassi* which is commonly sold in cities and is prepared by beating up the *dahi* with water and ice and adding salt or sugar to taste. Good *dahi* should have a creamy and smooth surface free from bubbles, while the cut surface should be trim and free from holes—an interesting instance of a natural objection to the presence of gas-producing bacteria. The taste should be mild rather than sharp.

Channa is a product of a very different type. It is produced from boiling milk which is clotted either by the addition of sour whey or by reagents such as alum. After settling the *channa* is strained off into a coarse muslin cloth, in which it is allowed to hang for draining. This product is, in fact, a crude form of moist casein. It is used as a basis for sweetmeats, and is capable of being transported for distances up to 300 miles without deterioration. It is therefore particularly suited for the poor transport conditions of Bengal, where it is chiefly produced. The properties looked for are whiteness, firmness of body and a small grain, and a non-acid flavour.

The production of cheese in India, either of Indian or European varieties, is extremely small. The chief Indian cheeses are *Dacca* cheese, *Surti* cheese, and *Bandal* cheese. *Dacca* cheese may be taken as typical of the small type of medium pressed cheese. It is made from buffaloes' milk with the use of rennet. The curd is pressed in small cane baskets with a board and stones. Pressure continues for from 7 to 10 days, when the cheese is smoked with wood and cow-dung smoke. The cheese keeps well after smoking. *Bandal* cheese is typical of the soft type of cream cheese. It also is smoked, a treatment which renders it offensive to many palates. *Surti* and other local types of cheese also have distinctive methods of production.

Of the products in this group, *dahi* is of outstanding importance for the reasons already noted. It is moreover produced and used universally throughout India. The production of *channa* is largely limited to Bengal and to parts of Bihar and of the United Provinces. Cheese is only found as a local product and its production is noted in all Provinces as "negligible" (4). It is probable that the main requirements of cheese in India, the consumption of which is limited to Europeans, is met by imports from abroad. These imports, which

(4) Reports of provincial marketing surveys. It has been suggested that the low consumption of cheese is due to the fact that an animal product (rennet) is used in its production, and that the use of a vegetable substitute for rennet would stimulate the demand. It should however be pointed out that the eating of cheese does not fit in with the normal dietary customs of the country.

are shown in Table 20⁽⁵⁾, give no indication of expansion, although they show a rapid recovery from the effects of the crisis,—a finding which might be expected in regard to a product which is consumed solely by the wealthier section of the population. The present annual value of imported cheese is Rs. 8 lakhs, and the amount of milk utilised in its manufacture would be about 150,000 maunds, which is equivalent to only 0.002 per cent. of India's total milk production.

The above details regarding the methods of manufacture have been given because I feel that they are essential for a proper understanding of the problems involved in the production and marketing of *khoa*, *dahi* and related products. No published information is available on the subject, and present methods are based on the cumulative experience of past generations.

It will be realised from the foregoing description that the manufacture of indigenous milk products in India is carried out on most primitive lines. Moreover, the quantities of milk employed in the manufacture of the desiccated products (about 5 lb.) are clearly uneconomic from the point of view of both labour and fuel. There is obvious need for a careful investigation of the methods of manufacture of these products. *Khoa* offers a particularly hopeful field for study, not only because of its wide sale but because its manufacture does not involve the production of by-products. It appears possible that its manufacture could be placed on a village industry basis or even on a factory basis. The problems involved are largely engineering problems; the provision of a plant capable of handling the larger outputs while retaining those essential heating processes which give the product its characteristic flavour. It is possible that some type of hand-drier might be employed, though existing types of such plant would need very considerable modification if they were to meet the special requirements of *khoa* production. The output of the product is, however, sufficient to justify considerable outlay in determining the feasibility of such a development.

Side by side with improvements in the production of *khoa*, improved methods of packing would be needed. At present *khoa* is packed in baskets and leaves. This is unhygienic, and undoubtedly reduces the keeping quality of the product. In view of the fact that the slightly cooked flavour of *khoa* is one of its desirable characteristics it would seem that this product is one which might be packed in air-tight containers and sterilised by heat, thus giving it an indefinite keeping quality and rendering its transport simpler and cheaper. The additional cost involved would probably be offset by the decreased losses due to deterioration.

It is questionable how far *rabree* and *mallai* could be dealt with on these lines, since their manufacture is more largely dependent on the personal skill of the maker. Any development would have to depend on the success achieved with *khoa*. But the manufacture of

(5) Annual Statements of Sea-borne Trade of British India.

dahi might certainly be improved. At present no information is available regarding the types of lactic acid bacteria used in the production of *dahi* in different districts, nor is anything known of the relation of the types of organism to the flavour and texture of the product. A survey would quickly show how far the bacterial flora varies under present conditions of production, and to what extent such variations can be correlated with palatability and market demand. By subsequent distribution of the most satisfactory 'starters' the quality and uniformity of *dahi* might be substantially improved, with benefit to both producer and consumer. The importance of such work in connexion with *ghee* production should not be overlooked.

It will be shown in the next chapter that limited quantities of separated milk⁽⁶⁾ are available in certain districts. Such separated

Possible uses for separated milk.

milk is not actually wasted, as it is largely used for the manufacture of casein. It is however lost as a source of nutriment. It has been suggested that efforts should be made to establish condensing and drying factories to absorb this milk, but in most localities such a development is impracticable. I consider that the possibility of utilising separated milk in the manufacture of indigenous milk products would repay further investigation. Such milk is already used for this purpose in some areas, but the complaint is made that the quality of the product is so inferior as to make it of little value. *Khoa* made from separated milk has, for example, a tougher and less acceptable texture, and is apt to crumble, a criticism which also applies to *channa*. On the other hand *dahi* made from separated milk lacks body. It is obviously undesirable that such products should have an equal value in the market to whole milk products, but there is undoubtedly room for attempting to improve the methods of production in such a way as to make the separated milk products more readily saleable.

The establishment of recognised standards of quality for *khoa* and related products would do much to encourage the introduction

The provision of standards.

of improved methods of production and packing. At present the standards (where they exist) are of doubtful utility. For instance, under the Punjab Pure Food Act (1929) *khoa* must have not more than 10 per cent. moisture and not less than 20 per cent. fat. Yet according to manufacturing practice the *khoa* out-turn from milk should be 25 per cent.⁽⁷⁾ This would give *khoa* a moisture content of nearly 40 per cent. The minimum fat content of such *khoa* would be 14 per cent., but the minimum fat content of a sample containing 10 per cent. moisture, if made from whole milk, would be 27 per cent.⁽⁸⁾ That is to say, with a moisture content of 10 per

(6) I refer here to machine separated milk, not to *lassi*.

(7) i.e., 4 seers of milk yield 1 seer of *khoa*. This ratio is so widely recognised that it is commonly used as a method of determining the quality of milk at wholesale milk markets.

(8) Assuming the original milk to contain 3.5 per cent. fat and 8 per cent. solids-not-fat, which are the minimum legal standards under the Punjab Pure Food Act (1929).

cent., the fat content of *khoa* could only fall below 20 per cent. if the milk were to be 'toned' with separated milk. Clearly the existing standards need re-examination.

This introduces a further point. No provision is made in the food legislation of most provinces for standards of quality of milk products made partly or wholly from separated milk. If the proposals put forward earlier in this chapter are adopted, it will be necessary to formulate standards not only for whole milk products but for products manufactured from separated and from half-cream milk.

The final, and perhaps the most important, consideration in connection with *khoa*, *dahi*, and similar indigenous products is their nutritive value. There is at present a complete lack of information on this point. It is widely held that sour milk—either in the form of *dahi* or *lassi*—is more highly digestible and nutritious than fresh milk, and that it is particularly wholesome as a food in hot climates⁽⁹⁾. On the other hand I have been told that the excessive heating to which milk is subjected during the manufacture of *khoa* will seriously affect its nutritive value. Neither of these views has so far been substantiated by direct experiment. The question is one of obvious importance in view of the extent to which such products constitute the staple forms in which milk is consumed by a large section of the Indian population. I am strongly of opinion that experiments should be undertaken at an early date to determine accurately the nutritive value of these various indigenous milk products in comparison with milk and separated milk. The experiments should not, I believe, be confined to laboratory animals. Comparative tests should be made into the value of the products as supplements to typical Indian diets on the lines of those already carried out with skim milk powder⁽⁹⁾. Only by such tests will it be possible to determine the real value of the various products in the human dietary.

(9) W. R. Aykroyd and B. G. Krishnan. 'The Effect of Skimmed Milk, Soya Bean and other Foods in Supplementing Typical Indian Diets. *Indian Journ. Med. Res.* 24, 4 (1937).

CHAPTER VI.—The utilisation of skim milk in the manufacture of casein, condensed milk and dried milk.

It is sometimes stated that there is a serious wastage of separated milk in India. Another view held is that a considerable output of separated milk, while not actually wasted, is utilised in a manner which does not yield a profitable return. In the present chapter I intend to discuss in detail these views and to indicate the extent to which separated milk might be more profitably handled.

By separated milk I mean the by-product of the mechanical separation of cream. It has already been stated (Chapter IV) that over 99 per cent. of the *ghee* produced in India is manufactured by the indigenous method in which the by-product is *lassi*, and that this is invariably consumed by the cultivator and his family. In view of the overwhelmingly rural nature of the population this practice cannot be objected to, for it ensures that the peasant class retain for their home consumption the most valuable part of the milk. This means, however, that the supplies of separated milk available for manufacture are very limited. On the assumption that the daily output of creamery butter in India is 20,000 lb., the quantity of separated milk produced annually will be roughly 90 million pounds, or a little over one million maunds.

At present a considerable proportion of this is used for the manufacture of casein for export. This export trade has remained fairly constant for the past few years at about 8,000 cwt. per year. The amount of separated milk required to produce this quantity of casein would be roughly 40 million pounds, or nearly half of India's total output of separated milk⁽¹⁾. The remaining half is stated to be used in the production of indigenous milk products such as *dahi* and in the 'toning' of whole milk sold for liquid consumption. It may, I think, be definitely asserted that the quantity of separated milk actually wasted (*i.e.*, thrown away) is negligible. Exhaustive inquiries in the more important producing areas show that separated milk can be economically converted into casein so long as the price of the latter exceeds Rs. 70 per ton. During the past three years the price has averaged about Rs. 260 per ton and has not fallen below Rs. 117 per ton.

The suggestion has, however, been put forward that since there is a valuable import trade in condensed and dried milks, an effort should be made to utilise the present output of separated milk for the manufacture of these products. It is therefore desirable to examine in some detail the extent of the import trade in condensed milk and milk powder. These products are classed into two categories; first, milk foods for infants or invalids wholly or mainly milk, and second, condensed and preserved milks. The first category consists almost exclusively of proprietary brands of milk foods which it would be extremely difficult to displace with home-produced products. The average quantity imported during 1932-35 was 10,000

Imports of milk products.

gories ; first, milk foods for infants or invalids wholly or mainly milk, and second, condensed and preserved milks. The first category

(1) It is not known how much casein is sold for use in India.

cwt. per year, which is equivalent to about 80,000 maunds of fresh milk. In view of the special nature of this class of imports and of its small volume it does not appear either feasible or necessary to attempt to replace it with products produced in India.

The second category includes unsweetened and sweetened condensed milks, milk powder and certain other miscellaneous milk products. On the basis of replies received to a special questionnaire, the annual imports may be roughly classified under seven heads, as shown in Table 21. The total imports amount to roughly 200,000 cwt. and are valued at about Rs. 50 lakhs. They represent an output of just under 700,000 maunds of fresh milk. These quantities are very small in comparison with India's total output of milk products. Moreover, it will be seen from Table 22 that the imports (and therefore the consumption) show no tendency to expand⁽²⁾. The question arises therefore whether, if condensed milk and milk powder were to be produced in India, an additional market could be found for these products in the export market. The present imports of condensed and dried milks into Ceylon amount to 36,000 cwt., and

Export markets. the market is rapidly expanding⁽³⁾. Malaya imports 600,000 cwt. of condensed milk, while other Far Eastern countries absorb about an equal amount. South Africa and East Africa import some 300,000 cwt.⁽⁴⁾. These combined quantities (including India's own imports) represent the equivalent of roughly five million maunds of fresh milk. If Table 21 may be taken as typical of the imports of all these countries (no separate figures being available other than those for India), the amounts of whole milk and of separated milk used in the production of the milk imports would be one million and four million maunds respectively. There is therefore a fairly large potential market for condensed and dried milk, although this still represents a very small fraction of India's total output of milk. It is, of course, questionable whether, even if India was able to produce these products, she could capture the market against the keen competition of countries which already have an established export trade. The figures are, however, impressive enough to justify serious consideration of the possibility of establishing condensing and drying plants in India.

In deciding whether such a development is feasible, three questions must be answered. First, is the milk cheap enough; second, can it be supplied at convenient centres in sufficiently large quantities; and third, is the milk of a sufficiently high quality to enable manufacturers to produce a good product?

There is considerable doubt whether even the first question can be answered in the affirmative. Separated milk is valued in India at about Re. 1 per maund⁽⁵⁾. Assuming that the working costs of production of sweetened condensed skimmed milk are £20 per ton (a

Value of separated milk.

(2) Annual Statements of Sea-borne Trade of British India.

(3) Imports into Ceylon have increased from 17,525 cwt. in 1932 to 35,848 cwt. in 1936.

(4) *International Review of Agriculture*, June 1936.

(5) Figures obtained from Provincial Marketing Officer, Bihar.

typical British figure), a cwt. of this product could be produced in India for about Rs. 18. The value of the imported product is roughly Rs. 28⁽⁶⁾ per cwt., but this includes an import duty of between 20 and 30 per cent. (according to country of origin) as well as heavy costs of advertising and distribution. The market value of the imported product in competition with Indian export trade would be unlikely to exceed Rs. 20. Again, skim milk powder can be purchased in India at Rs. 36 per cwt.⁽⁷⁾ With similar working costs per ton and valuing the separated milk at Re. 1 per maund, skim milk powder could be produced in India at Rs. 30 per cwt. If the import duty is deducted from the value of the imported product, however, the two prices exactly tally. The above figures are admittedly approximate, but they are, I think, sufficient to show that the possibility of building up an export market for condensed milk and milk powder produced in India is open to considerable doubt. On the other hand the duty of 20 to 30 per cent. on products imported into India would give an Indian manufacturer a great advantage in his home market.

I will now turn to the second question. Can adequate quantities of separated milk be supplied at convenient centres? The quantities

required by manufacturing firms are exceptionally large. Inquiries among firms already importing condensed milk and milk powder into India indicate that such quantities should not be less than 30,000 lb. per day. Assuming an average yield of 6 lb. of milk per day per milking animal, it would require 5,000 animals to produce this amount. It is estimated that the average Indian village possesses some 200 to 300 milking animals. A daily output of 30,000 lb. would therefore require the complete milk production of some 20 villages, which might be located within a 6 to 7 mile radius of a central factory. This area would in practice probably need to be larger, since part of the output of milk would presumably be retained in the villages for home consumption. No information is available as to the possibility of finding areas of this character which might form suitable centres for condensing or drying factories. In one or two localities, where large butter-making creameries are already established, the requisite supplies of separated milk might be available. But if more than one or two centres were required, a detailed survey of the main milk-producing areas would have to precede any question of developing production on a large scale.

This brings me to the third question. Can separated milk be supplied which is of sufficiently good quality for manufacture? At present the answer is a categorical negative.

Quality of separated milk. Personal inquiries in likely areas and conversations with men who have been responsible for managing large butter-making creameries both show that the present supply of separated milk would be entirely useless for either condensing or drying. In the words of one experienced manager,

(6) *i.e.*, 4 annas per 1 lb. tin.

(7) Information obtained from Dr. W. R. Aykroyd.

“ the whole difficulty is that the milk is produced on too small a scale by a very large number of producers : such small quantities could not be handled profitably if delivered direct by the producer to the creamery, while the collection of milk by middlemen results in its deterioration before arrival at the creamery..... I am firmly convinced that if any concern requires large quantities of first-class milk, it will only be possible to obtain it by organising milk production on large farms under hygienic conditions ”. Another equally experienced manager stated that the milk supplied to his creamery was always very acid on arrival, and that the resulting separated milk was only suitable for casein making. In his view the condensing and drying of milk would only be possible if a really good supply of milk were to be available, but that under these circumstances the cost of the milk would be prohibitive. Such authoritative opinions must carry great weight. They agree, indeed, with the experience of all those who have had to produce condensed milk and high-grade milk powder, namely, that the quality of the original milk is one of the main factors which affect the quality of the manufactured product.

Briefly then, it may be said that the manufacture of condensed milk and milk powder for export does not offer a hopeful field for development ; that such products might, however, be able to displace those at present imported into India ; but that this would depend largely on whether the requisite amounts of good quality separated milk could be collected at suitable manufacturing centres.

There are, however, a number of purely technical considerations which must be taken into account in connection with the production

Technical considerations.

of condensed milk and milk powder. As regards condensed milk, the chief demand in India is for sweetened condensed skimmed milk. The production of this type of condensed milk is particularly affected by the hygienic quality of the incoming milk, since the product is not completely sterilised during manufacture. Moreover, both sweetened and unsweetened condensed milks are particularly susceptible to defects associated with the protein content and the mineral balance of the milk. The methods of processing in Western countries have not only to be modified according to the locality of the factory, but also according to the season of the year. No information is available to show whether milk from Indian cows or buffaloes can be successfully condensed, or what alterations in technique might be necessary to ensure the production of a good product. In this connexion it would obviously be a serious mistake to establish a condensery at a high cost until the feasibility of condensing and its major difficulties under Indian conditions have been ascertained on a small scale. It may perhaps also be mentioned at this point that the total output of condensed milk necessary to displace the imported products would not occupy more than two or three large plants of, say, 30,000 lb. capacity.

As regards milk powder, the first point to be decided is whether, in the event of its production in India, the plant used should be of a

roller or a spray-drying type. The former involves a very much smaller capital outlay. Separated milk powder produced by the roller process is, however, very insoluble and is used in most Western countries only for the feeding of stock. If the object of manufacturing milk powder in India is to produce a product for human consumption, particularly in connexion with the provision of reconstituted separated milk for children of school age, it would need to be spray dried milk. This would involve a relatively high capital expenditure. Moreover, milk powder production would entail special difficulties in a country having a monsoon season. The combination of high atmospheric temperature and humidity during this period would necessitate an abnormally high air capacity in the drier, and might also lead to difficulties in the handling of the dried powder, which is intensely hygroscopic. So far as total output is concerned, attention would need to be given to the available market. From Table 21 it will be seen that the present consumption of milk powder (as measured by imports) is between 250 and 300 cwt. per year. A full size commercial spray-drying plant will produce at least a ton of powder per day. The present output in India would, therefore, only be sufficient to occupy one plant for, say, 12 to 15 days. Even if a strong drive were to be made to popularise the use of separated milk powder as a supplement to the diets of school children, it is doubtful whether the output of one plant would be fully occupied. An additional market might be found in the development of the ice-cream trade, especially in view of the rapid extensions at present taking place in refrigeration. Army requirements might also absorb part of the output of a spray-drying plant, since for transport purposes a milk powder which could be readily reconstituted in the field would be ideal. The difficulty of meeting army requirements is, however, that there are such large differences between peace and war requirements. Peace requirements are only one to two tons per month : in time of war, however, the requirement might rise to between 100 and 200 tons⁽⁸⁾.

The above discussion indicates some of the more obvious difficulties which would be met with in any attempt to establish

Conclusions.

condensed milk or milk powder factories in India. The idea is superficially an attractive one, but in view of the exceptional difficulties with which the Indian dairy industry is faced, I am quite certain that any considerable expenditure (such, for example, as that envisaged in the Anand Experimental Creamery scheme) is not meantime justified. If condensing and drying factories are ultimately to be built in India, they should, I believe, be erected by firms who already have a long experience of the trade and an established Indian market for their products. I consider, therefore, that any official assistance which may be given should be in the direction of surveying the available supplies of milk, examining their quality, and determining on a small scale the suitability of the milk for processing. These are the three primary requisites on which any commercial firm would need

(8) Figures quoted by the courtesy of the Quartermaster-General in India.

to have accurate information before giving serious consideration to the establishment of a condensing or drying factory in India.

Finally, I should once again reiterate the contention which I put forward in Chapter II, namely, that India has an essentially rural population, and that in any development of the dairy industry the needs of this section of the population must be paramount. If it was necessary to choose between establishing a factory system for converting separated milk into milk powder or leaving the separated milk in the villages for local consumption, I should unhesitatingly recommend the latter alternative.

PART II.

THE PRODUCTION OF MILK IN RELATION TO THE
BREEDING AND NUTRITION OF MILCH CATTLE.

CHAPTER VII.—The importance of cattle in Indian agriculture.

It will not be out of place to preface this part of the report with a brief statement of the size of the cattle industry of India and of its importance in Indian agriculture.

Introduction. Numerically India possesses the largest cattle population of any country in the world. A recent estimate⁽¹⁾ places the world's cattle population at about 690 million animals. Of these 152 million are located in British India and 36 million in Indian States. India possesses therefore nearly one-third of the world's cattle population. Next in order are the Soviet Union (with 65 million) and the United States (with 58 million), but each of these has barely one-third of India's total. Great Britain has only seven million animals, or one-thirtieth of the Indian cattle population. These figures indicate the magnitude of the Indian cattle industry.

Owing to adverse climatic and economic conditions the productive value of this industry is not commensurate with its size. It is of course difficult to assess the monetary value of live stock products in a country where the greater part of the output is consumed by producers instead of being marketed. This difficulty is intensified in India where the male cattle are chiefly valuable on account of their use for draught purposes, and where meat is not a staple article of the diet. In the present discussion I shall deal with the subject from two aspects: first, the actual value of produce derived from cattle, and second, the potential value of cattle to Indian agriculture.

The income from the sale of cattle products can be fairly closely estimated. It has already been shown (Table 3) that milk and milk products may be valued at about 300 crores of rupees. This is roughly equivalent to the value of India's total output of rice, and is three to four times the value of the output of wheat⁽²⁾. Miscellaneous products such as hides, skins and offals are also an important though relatively small source of income from cattle, especially as these are largely sold for export. India is, in fact, the largest exporter of hides and skins in the British Empire, her products representing one-third of the total Empire exports⁽³⁾. India's yearly output of this group of products is valued at roughly 40 crores of rupees. It is significant that the trade in hides and

(1) U. S. Dept. Agric. Yearbook, 1935, pp. 556-557. The figures quoted refer to the years 1926-1930. According to the Fourth Census of Live Stock held in 1935 the total cattle population of India is now estimated at 214 millions.

(2) The production of rice is estimated at 32 million tons. At Rs. 10 per ton this gives a value of 320 crores of rupees. The production of wheat is estimated at 9½ million tons. At Rs. 80 per ton this gives a value of 76 crores of rupees.

(3) A. N. Duckham. "Animal Industry in the British Empire." P. 222 Oxford University Press, 1932. In 1928 the total Empire exports of hides and skins were valued at £42,200,000, of which India's share was £14,000,000.

skins, which represents only a minor by-product of the cattle industry, has a greater monetary value than the total Indian output of sugar, which is valued at about 30 crores of rupees⁽⁴⁾. It may also be mentioned that, although live cattle do not represent a large source of income, the potentialities of Indian draught breeds have in the past been widely recognised, the annual export at one time having reached nearly 2,000 animals at an average value of Rs. 250 per head.

It is, however, in the relation of cattle to the agricultural economy of the country that their unique value becomes apparent. **Value of cattle labour.** Cattle labour represents probably the most important contribution of live stock to Indian agriculture. In the words of the Royal Commission on Agriculture in India⁽⁵⁾ "In most parts of the world cattle are valued for food and for milk; in India their primary purpose is draught for the plough or the cart..... Without the ox, no cultivation would be possible; without the ox, no produce could be transported". It is obviously difficult to place a definite monetary value on cattle labour. An inquiry into the value of cattle labour in holdings in the Punjab⁽⁶⁾ has shown that between 15 and 20 per cent. of the costs of cultivation fall under this head, a figure which has I understand been confirmed in a more recent investigation⁽⁷⁾. Assuming that the total value of India's output of agricultural produce approximates 2,000 crores of rupees⁽⁸⁾, the share of cattle labour would be between 300 and 400 crores of rupees. An alternative method of calculation may be taken from the Royal Commission's Report⁽⁹⁾ where it is estimated that the cost of feeding and depreciation of a pair of bullocks averages Rs. 175 per year. On the Commission's assumption that a pair of bullocks are needed to cultivate 10 acres of 'net sown area' (of which there are 230 million acres in British India and 70 million acres in Indian States) the cost of cattle labour works out at 525 crores of rupees for all India or 400 crores of rupees for British India. The latter value may therefore be taken as a conservative estimate for the country as a whole.

The second indirect source of income attributable to cattle which is, however, even more difficult to assess is their contribution to the fertility of the land. An attempt has been made to arrive at a rough estimate of the cash value of cattle manure, and a provi-

(4) i.e., an output of 1,200,000 tons of sugar at Rs. 150 per ton and an output of gur of 4,000,000 tons at Rs. 50 per ton.

(5) Report of the Royal Commission on Agriculture in India, p. 166. Cmd. 3182 (1928).

(6)

(7) Investigation carried out under the direction of the Imperial Council of Agricultural Research.

(8) The figure given by Findlay Shirras ("The Science of Public Finance") for 1922 was, 1,983 crores of rupees. According to M. Vaidyanathan (private communication) this had risen in 1929 to 3,400 crores, but had fallen again by 1936 to 2,000 crores.

(9) Loc. cit., p. 194.

stional figure of 270 crores of rupees has been suggested⁽¹⁰⁾. This figure is obviously open to criticism, as indeed would be any estimate based on the very meagre information available. No figures exist, for example, to show what proportion of cattle dung is used as fuel, although this is believed to be very large. Nor have controlled experiments been carried out to determine the value of farm-yard manure under the widely varying climatic and soil conditions of India. There is little doubt that the widespread extension of 'composting' would greatly enhance the value of cattle manure as a medium for increasing soil fertility.

I believe that it is necessary, however, to look at this subject from the wider aspect of the possible effect of a 'mixed farming' system on the productive capacity of the land. At present India is virtually attempting to maintain a relatively dense human population by methods only applicable to an 'extensive' system of farming, a system in which large acreages have to be relied upon to off-set low crop yields and poor grazing lands, and in which little attention is paid to the maintenance of soil fertility. Such methods may be suitable for newly developing countries, such as Australia and Canada, where the human population is small and ample land is available. In these two countries there is, for example, an average of only two to three persons per square mile. In India there are nearly 200 persons per square mile, a figure equivalent to that of Denmark or the Netherlands. With such dense populations it is essential that the output of produce per acre should be high, and for this purpose the fertility of the soil must be maintained. It has aptly been said that under these circumstances the development of Indian agriculture urgently requires "the dove-tailing of the arabic and animal husbandries into one 'mixed-farming' system". "It is evident" states the same authority⁽¹¹⁾ "that the cattle problem dominates the whole situation. . . . I think that no rapid increase (in crop yields) can come until the 'mixed-farming' system is adopted." Such a 'mixed-farming' system would involve not only the application of all available manure, but the cultivation of leguminous fodder crops which contribute so markedly to soil fertility. The fodder crops so grown would, in turn, provide an ideal source of food for cattle, and particularly for milking stock.

This is, therefore, a question of the utmost importance not only to the cattle industry but to the whole future development of dairying. At present one is faced by a somewhat perplexing problem. Milk is chiefly produced as a by-product of agriculture: the milking stock are largely fed on dry fodder which would otherwise be valueless, and the labour costs are negligible. Under such conditions the cultivator can afford to sell his milk at a remarkably low price, 6 pies per lb. being not uncommonly accepted.

(10) A. Olver and M. Vaidyanathan. "Assessment of the Annual Contribution of Live Stock in India to Indign Economy."

(11) B. A. Keen. "The Real Problem in India." Paper read before the Royal Institute of International Affairs, March 1st, 1932.

On the other hand figures obtained from a study of the costs of production of milk on Military Dairy Farms⁽¹²⁾, as well as from other large dairy concerns, give costs of production of from 6½ to 11 pies per lb., while another independent investigation showed a figure of just over 1 anna per lb.⁽¹³⁾. The specialised production of milk does not appear, therefore, to be economically feasible unless an exceptionally good market is available. It has been suggested that the way to increase milk production in India is to create a more lucrative outlet for milk and milk products. This might be true in a country with a large and relatively rich urban population : it is not, I believe, applicable to Indian conditions where 90 per cent. of the population are rural, and where a large proportion of the cultivators are compelled to live on a subsistence agriculture. Moreover, the provision of a more lucrative outlet for the milk is not consistent with the prime necessity (referred to in Chapter I) of maintaining a low price for milk in order to stimulate increased consumption.

The solution of the problem appears to me to be along the lines indicated above, namely, the development of a 'mixed-farming' system. In such a system the production of animal products such as milk is carried on side by side with a system of cropping in which leguminous fodder crops take an important place, and in which full use is made of the increased quantities of cattle manure. In this way soil fertility is maintained, and the resulting increase in crop yields indirectly off-sets any increase in the cost of production of milk. It is significant to note the success of such a 'mixed-farming' system in another backward agricultural country⁽¹⁴⁾. "Larger yields of crops are being secured and the farmers, in addition to having more ample food supplies and larger quantities of economic crops for sale, are also being provided with supplies of animal products, such as milk and butter, for their consumption and sale. There is no doubt that they have been enabled to live better than was possible under the old order, and in consequence it is expected that their own health and that of their families will benefit."

It is of course questionable how far 'mixed-farming' can be introduced under the wide variety of climatic and soil conditions of India. There is, however, little doubt that there is great scope for development along these lines in many irrigated tracts. At present there is a very general impression that the introduction of irrigation rapidly leads to the deterioration and even to the virtual extermination of good breeds of cattle. This is, for example, true of Sind and of certain tracts in the United Provinces. If full advantage is

(12) K. P. R. Kartha. "A Note on the Comparative Economic Efficiency of the Indian Cow, the Half-bred Cow, and the Buffalo as producers of Milk and Butter-fat." Animal Husbandry Wing Meeting, February 1933.

(13) W. J. Hansen and N. R. Joshi. "Cost of Milk Production in Allahabad." *Agric. and Live Stock in India*, 4, 245 (1934).

(14) E. A. Stockdale. "Report on the Agriculture of Nigeria, the Gold Coast and Sierra Leone." Colonial Advisory Council Publication, No. 270 (1936).

to be derived from irrigation, I am convinced that farming in irrigated areas will have to be modified to allow the inclusion of a 'mixed' system in which both the crop and animal husbandries play their part.

This brief discussion is, I think, sufficient to give some indication of the magnitude of the cattle industry and of its actual and potential value to Indian agriculture. In
Conclusions. actual value (including the value of dairy products) the industry contributes at a very rough estimate about 1,000 crores of rupees to the agricultural income of the country, which has been assessed at a total of 2,000 crores of rupees. The potential value of cattle as a means of raising the level of fertility of the soil and of thus increasing the output of both cash and food crops is, I believe, incalculable.

CHAPTER VIII.—General Discussion on Cattle Improvement.

Before dealing in detail with the problems involved in the breeding and feeding of dairy cows, it seems desirable to discuss briefly the steps which have so far been taken to improve the general standard of Indian cattle. I should make it clear that the measures adopted have been largely limited to draught breeds and general utility animals, and have not included milking breeds. A very full discussion of the measures necessary to improve Indian cattle is given in the Report of the Royal Commission on Agriculture. It is not necessary for me to recapitulate the conclusions of the Report. It may, however, be said that the two chief methods of improvement adopted have been the provision of pedigree and improved bulls, and the castration of inferior males. It will be instructive to see how far effect has been given to the Royal Commission's recommendations in these two matters.

As regards distribution of pedigree bulls issued from Government Farms, the Royal Commission drew attention to the very limited progress achieved up to 1926 in comparison with the needs of the cattle population of the country⁽¹⁾. The Commission calculated that an annual supply of some 200,000 bulls was needed, but showed that in the major provinces only a little over 500 per year were actually issued. Table 23 indicates the comparatively slow progress made since the date of the Commission's Report. Although the number of bulls issued annually from Government Farms has been nearly doubled, the total is still only a minute fraction of India's requirements. These figures do not, however, show the total number of bulls issued, since approved animals from sources other than Government Farms are also distributed in certain provinces. Thus 300 to 400 approved bulls are distributed annually in the United Provinces, 40 to 50 in Bombay Presidency, and 20 to 30 in Bengal. A fairer estimate of progress is therefore given by the number of pedigree and approved bulls actually at stud. These are shown in Table 24. The Royal Commission estimated that India needed roughly one million breeding bulls; the present number of pedigree and approved animals represents only one per cent. of this requirement. Moreover it is significant that the number of new bulls issued each year is only slightly greater than that needed to replace existing animals on a 10 to 15 per cent. basis of annual wastage.

It may be urged with some justification that these figures give a misleading impression of the real success achieved by the policy of bull distribution, since they give no measure of the actual improvement in local stock which has taken place as a result of the scheme. There is no doubt that such improvement has been most marked: it was indeed apparent to me during my tour that in those areas in which pedigree or approved bulls had been placed the stock were invariably of an improved physique and appeared to be better cared for. It is, however, unfortunate that some quantitative measure of

(1) Report of the Royal Commission on Agriculture in India, p. 213. Cmd. 5132 (1928).

improvement is not available. It is here, I believe, that breeding control and the registration of progeny would be of special value. Such a system of registration would not only provide a measure of the progress achieved, but would also provide a reservoir of improved stock for distribution to other districts. Probably the best example of the application of this system is to be found in the Bombay Presidency. Here, although there are only 289 bulls noted as 'at stud', there is a register of over 2,000 improved cattle. Similar systems have also been adopted in the North-West Frontier Province and in certain tracts in the Panjab.

This raises the general question as to whether in attempting to accelerate progress in live stock improvement reliance can be placed on bulls selected from improved cattle tracts as well as on bulls bred at Government Farms. On the one hand it has been urged that the breeding records of stock reared under village conditions have a high degree of unreliability, and that such animals could not adequately replace the farm-bred bulls of guaranteed pedigree. On the other hand it has already been pointed out that the number of farm-bred bulls is seriously limited and quite inadequate for the needs of the country. Farm-bred bulls are, moreover, stated to be unsettled and difficult to handle, while they do not always represent the type of animal which the cultivator requires. There is, too, the question of cost. Farm-bred bulls are relatively expensive to rear: I was, for instance, informed that bulls at two large provincial centres cost from Rs. 200 to Rs. 400 to rear, while they were sold to District Boards for distribution in villages at Rs. 100. Village-bred bulls, on the other hand, can be reared at almost negligible cost to Government. Moreover the purchase of village-bred bulls for distribution gives a most valuable stimulus to improved cattle-breeding in the selected areas: by providing a market for such improved stock, Government is giving direct encouragement to progressive breeders.

I think that this question might be summed up by saying that if any widespread effect is to be obtained by the distribution of bulls, it is essential that increasing use should be made of the improved (and registered) animals bred under village conditions in selected breeding tracts. Only by this means will it be possible to supply the vast number of breeding bulls required throughout India. On the other hand it is equally necessary that 'type' should be preserved within each breed. For this purpose it is, I believe, essential to maintain Government breeding farms where the methods of breeding can be accurately controlled and breeding records can be thoroughly relied upon.

The second general method of effecting cattle improvement on an extensive scale is by the castration of all inferior males. The number of animals castrated at veterinary hospitals and dispensaries and on tour have more than doubled during the last decade as shown in Table 25. Progress in this direction has, however, varied from province to province, and it is significant that two-thirds of the

The problem of the scrub bull.

total number of castrations have been done in three provinces, the remaining provinces showing very small returns (Table 26). It is, of course, extremely difficult to determine the extent of improvement of stock which has taken place as a result of this widespread castration policy. No records are available to show what proportion of castrations are carried out on the undesirable types of 'scrub' bull, and what proportion merely replace castrations previously carried out by the more crude village methods⁽²⁾. It is stated that there is difficulty in getting young stock castrated at a sufficiently early age, a point which formed the subject of one of the recommendations of the Royal Commission. This recommendation, which was that experiments should be carried out to determine the effect of early castration on subsequent development⁽³⁾, does not appear to have been put into effect.

While it is difficult to assess the value of the present castration policy so far as the country as a whole is concerned, there is, I feel, one direction in which future action should be concentrated, namely, the intensification of castration measures in selected breeding areas. A policy which included the distribution of pedigree bulls to selected areas and the registration of progeny in those areas, combined with the castration of all inferior male stock and if possible the inoculation of all local stock against rinderpest, would represent an ideal method of effecting live stock improvement. If, as I recommend in a later chapter, breeding, castration and disease control are placed under a single Department, it should not be difficult to ensure that a real drive is made along these lines in the direction of improving India's cattle.

(2) It is interesting in this connection to note the comment of one Director of Veterinary Services "In areas where the local zamindars are deriving benefit from cattle breeding they very definitely discriminate against the scrub bull, and we have comparatively little difficulty in castrating their inferior male stock".

(3) *Loc. cit.*, p. 238.

CHAPTER IX.—The Breeding and Management of Milch Cattle.

In the previous chapter I have dealt with certain general methods of effecting improvement in the breeding of Indian cattle under village conditions. These methods have so far been chiefly applied to cattle of draught type. In the present chapter I propose to discuss in detail the breeding and management of cattle of predominantly milking type.

I have already stressed the need for increasing and cheapening milk production in India if the population is to be able to secure adequate supplies of milk at a reasonably low price. There is probably no single measure which could do more towards achieving this aim than an improvement in the milk yields of Indian cattle. At present the milk yields of village cattle are exceptionally low. Table 33 shows, for example, typical yields estimated in recent surveys⁽¹⁾ for British India. The average is only a little over 600 lb. per year, which would represent a maximum average daily yield of, say, 4 to 6 lb. On theoretical grounds alone this yield is bound to be uneconomic, since the amount of food required for the maintenance of the cow is very high in comparison with its production requirements. Any increase in the *per capita* yield would spread this maintenance cost over a larger output of milk, with a consequent lowering of food cost⁽²⁾. The cost of labour and of depreciation of stock would also be reduced with the higher yield. Table 27 shows that this conclusion is borne out in practice⁽³⁾. The figures show clearly that the higher the yield the lower are the relative costs of labour, depreciation and food. Moreover it is significant that the reductions in the relative costs of these items are greatest at the low levels of milk production which are characteristic of Indian village cattle. Figure 1 illustrates this fact in relation to feed costs. It will be seen, for instance, that by raising the level of milk production from 7 lb. to 14 lb. per day the food requirement per lb. is reduced by nearly 50 per cent. Figure 2⁽⁴⁾ shows that this finding is identical with that arrived at independently in

(1) Results of Provincial Marketing Surveys.

(2) This statement needs amplification. It has been stated in Chapter VII that the cultivator can afford to dispose of his milk at a price below the costs of production as found on Military Dairy Farms and other specialised milking herds. The cultivator's present method of milk production is, however, only cheap in the sense that it does not involve him in any direct additional expenditure, the animals being fed on the by-products of the cultivation of food crops such as rice, wheat, maize and millet. But it is in fact an extremely uneconomic method of milk production. The low yields involve a relatively high cost of maintenance per unit of milk produced; poor feeding delays the attainment of maturity and therefore lengthens the unproductive period of life; while inadequate nutrition and poor management also tend to lengthen calving periods and therefore to reduce the total output of milk during the life span.

(3) K. P. R. Kartha. "A note on the comparative economic efficiency of the Indian cow, the half-bred cow and the buffalo as producers of milk and butter-fat." Animal Husbandry Wing Meeting, February 1933. The figures refer to animals of different breeds, but serve to illustrate the general principle involved.

(4) U. S. Yearbook of Agriculture (1935), p. 599.

other countries. The trading results of a well-known herd of Indian dairy cattle may be quoted as an example of the benefit derived from high milk yields⁽⁵⁾. While the average milk yield of the cows in this herd was below 4,500 lb. there was a constant trading loss averaging at about Rs. 1,500 per year. An increase in the *per capita* milk yield to between 5,500 and 6,300 converted this loss to an average profit of Rs. 1,200 per year. While other factors may to some extent have contributed to this achievement, the correlation with increased milk yield is too clear to be a mere coincidence.

These facts will serve to emphasise the importance of improving the milk yields of Indian cattle. It is, however, equally necessary to take into account the diverse needs of the different branches of the Indian dairy industry in deciding the breeding policy to be adopted. It will be understood that these needs vary according to local circumstances. For city milk supplies, for example, an animal is required which will give relatively high yields. Fodder is costly, and the rent of premises is also a heavy item of expenditure. Only a high producing cow can be maintained economically under such conditions. At the other extreme there are draught breeds in which the primary purpose of retaining the cow is to produce good working bullocks. Milk is here an entirely secondary consideration, though it is obviously desirable to obtain as much milk as possible from the cow provided that this does not result in any deterioration in the inheritance of draught quality. Between these two extremes there are so-called 'general utility' stock which give bullocks of reasonably good physique, and cows with a fair though not high milk yield. The breeding policy to be adopted will obviously depend on the nature of the local requirements as well as on the type of cattle available.

It is, however, also essential that, having decided what policy to adopt, this should be continued uninterrupted over a long period of years. There is no branch of animal husbandry in which changes of policy can do so much harm as in breeding: if the changes are frequent no constructive breeding is possible; on the other hand if a policy which has been maintained over a long period is ultimately abandoned through some adventitious factor such as financial stringency, many years of constructive work will be wasted. Unfortunately I found that the value of adopting long-range cattle breeding policies had not in the past been sufficiently appreciated in India. There was a general tendency to change the method of breeding prematurely if satisfactory results were not quickly attained. As an extreme example I may quote one College dairy herd, in which seven changes had been made in the breeding methods over a period of less than 25 years. The adverse results of this vacillating policy were quite apparent at the time of inspecting the herd. There are also instances in which the results of valuable breeding work has been destroyed by precipitate Government action. The history of the Scindi breed provides one of the worst instances of such short-sighted policy.

(5) Private communication from Lyallpur Agricultural College.

I have felt it desirable to stress these two points—the necessity of formulating breeding programmes to meet local needs and the urgency of ensuring that such programmes are not prematurely interrupted—because they form the foundations of any successful breeding policy. I will now turn to certain questions which are of special importance in deciding on breeding policies in India.

Owing to the relatively low milk yields of indigenous Indian breeds it is, perhaps, natural that breeders have tended to rely on

Indigenous versus cross-breeding. cross-breeding with sires of high-yielding European breeds to raise the productivity of local stock. This policy has been widely adopted by the Military Dairy Farms and also in a number of Agricultural College dairy herds. The immediate results are certainly striking. The first cross (half-bred) gives on an average double the yield of its indigenous dam, while it also breeds more regularly. With further crossing the results have not, however, been so successful. Mating half-bred to half-bred is of very questionable value; even if a fixed type could ultimately be obtained (which is doubtful) the amount of 'culling' of unsatisfactory animals would make the method extremely expensive. Back crossing improves the constitution but reduces the milk yield. Forward crossing, on the other hand, while maintaining milk yield is liable to result in a deterioration of physique and in high mortality, particularly among calves. This latter difficulty has to a great extent been overcome by improved technique in calf rearing. Deterioration in the constitution of adult stock appears to be due not so much to the cross-breeding as to the effect of high milk yield under the rigorous climatic conditions of India. Thus it has been shown that there are indications of increased susceptibility to disease and loss of constitution even among Indian dairy cattle when their milking performances improve⁽⁶⁾. Typical milk yields of the various crosses are shown in Table 28. The striking and immediate effect of the introduction of European blood on milk yield is clearly shown.

It must, however, be emphasised that these results have been obtained in herds in which there have been exceptional facilities for the control of breeding. At other centres where cross-breeding has been practised the results have not been so satisfactory. Even in some College herds the deleterious effect of badly controlled cross-breeding is apparent from a superficial inspection of the stock. Moreover at Military Dairy Farms and in Agricultural College herds the animals receive adequate and well-balanced rations. In this connexion I would emphasise a point which has been made in a recent publication, namely, that while European cattle have been bred to carry those characters which assist the effective use of the largest possible quantity of food, Indian cattle have been developed to make the most efficient use of the smallest quantity of food⁽⁷⁾. It is not surprising therefore that in the hands of *gowalas* and similar uneducated owners of milking stock the results of cross-breeding have

(6) K. P. R. Kartha (*loc. cit.*).

(7) J. Matson. "Cattle in relation to Agriculture in India". *Journ. Cent. Bur. Animal Husbandry and Dairying in India*, 2, 83 (1928).

been frequently disastrous. Type is entirely absent, the animals may or may not give good yields of milk, and there is a noticeable deterioration in physique. Such results are inseparable from uncontrolled methods of cross-breeding combined with indiscriminate feeding. It is for this reason that I am convinced that, however valuable cross-breeding may be in herds which are under expert control, the general adoption of a policy of cross-breeding to improve the yields of country stock would be fatal to the development of sound dairying in India.

If, however, cross-breeding is to be discouraged, what alternative remains which will provide animals of equally satisfactory milking capacity? The answer to this question may be found in the extensive breeding experiments which have been carried out at various centres and which show that by careful selection indigenous strains of Indian cattle can be built up which are capable of giving remarkably high milk yields. Table 29 shows the improvement effected in four prominent Sahiwal herds. This improvement has been extremely rapid, the average milk yield in two of the herds having been more than trebled within 20 years. Table 30 shows the distribution of milk yields of three other pure-bred Sahiwal herds. In comparison it may be noted that the average lactation yield of the Ferozepore herd over the past four years has been roughly 7,000 lb. milk in an average of 340 days. Out of 290 recorded lactations 30 exceeded 8,000 lb., 16 exceeded 9,000 lb., and 6 exceeded 10,000 lb. These figures not only show the marked and rapid improvement which can be effected through careful breeding, but indicate that the levels of milk yield finally obtained are comparable with those found for average European stock⁽⁸⁾. Other breeds have not received so much attention as the Sahiwal, but there is evidence to show that these also have great potentialities for milk. The average yields of animals in the Haryana and Tharparker herds which were established by the Imperial Dairy Expert at Karnal in 1923 have increased from under 9 lb. to between 13 and 14 lbs. The average lactation yields of animals in these herds are now over 3,500 lbs. in 300 days. Seindi cattle have not been so carefully studied, but there are indications that this breed also has high milk potentialities. At the Hosur Cattle Farm the average lactation yield of the Seindi cows is 3,250 lbs. milk in just over 300 days. At the Imperial Dairy Institute they have shown a 20 per cent. increase in yield in three years.

I do not think that it is necessary to quote further examples of the potentialities of indigenous Indian breeds to give high milk yields. The policy of encouraging the breeding of such indigenous stock in preference to cross-breeding has been strongly advocated in other tropical countries. In a Report on Cattle Breeding in Jamaica and Trinidad⁽⁹⁾, Dr. Hammond states "Apart from the time it

(8) According to Agricultural Statistics (1935) the average lactation yields of British dairy cattle were 4,820 lb. and 5,390 lb. in 1924-25 and 1930-31 respectively.

(9) John Hammond, "Report on Cattle-Breeding in Jamaica and Trinidad". Empire Marketing Board Publication No. 58 (1932).

would take, I can find no evidence that mere selection (combined with better feeding) of the local stock would not produce equally good results. There can be little doubt that European stocks, *even when bred pure*, gradually lose their type under these (tropical) conditions and require continual importations to maintain their form and constitution". Mr. F. A. Stockdale, writing of conditions in Nigeria⁽¹⁰⁾ states "The introduction of strains from outside will only add to the complications which already exist and produce an even more heterogeneous collection of animals than at present exist. In my view a policy of rigid selection from the local cattle would be more calculated to produce results of lasting value than could be achieved by the introduction of the blood of strains of cattle from outside". I consider that these views are equally applicable to Indian conditions.

In practice, however, one of the difficulties is that the building up of high milk yielding strains is relatively slow in comparison with the immediate results obtained by cross-breeding with European stock. On account of this fact it appears almost inevitable that reliance will continue to be placed on cross-breeding for high milk yield until there is a sufficient nucleus of high yielding Indian cattle to supply the necessary number of improved stock for use in localities where high milk yields are specially desired, as for example, in the production of milk in the vicinity of cities and large towns. This indicates the extreme urgency of taking immediate steps to extend the facilities for selecting and improving indigenous milking strains of Indian cattle. Definite proposals with this object in view are put forward in Chapter XII.

I should perhaps add that I do not consider that such efforts should be limited to those breeds which are recognised as predominantly milking types. Table 31 shows that improvement can be looked for in the milking capacity of most breeds other than those of purely draught type, such as the Amrit Mahal and the Hissar breeds. Even the latter breed is found to possess strains of special milking potentialities. In any such breeding for milk yield among draught cattle it is, however, essential to guard against deterioration of draught qualities. This point was stressed by the Royal Commission on Agriculture who stated that "in attempting to secure more milk from the five types of draught cattle still to be found in many parts of India, there is a real danger that the qualities which have in the past commended them to cultivators will be lost"⁽¹¹⁾.

(10) F. A. Stockdale. "Visit to Nigeria, Gold Coast and Sierra Leone." Colonial Advisory Council Publication No. 270 (1936).

(11) I have not felt it necessary to discuss the controversial questions involved in dual purpose breeding. I believe that the controversy is largely founded on a misconception of the genetic implications of such breeding, as well as of the needs of the cultivator. The subject has been adequately dealt with by Sir A. Olver in an article entitled "The Inadequacy of the Dual Purpose Animal as a Goal of Cattle-Breeding in India". *Agric. and Live Stock in India*, 6, 389 (1936). It is also referred to in an informative paper by Colonel A. Matson entitled "Cattle in relation to Agriculture in India". *Journ. Cent. Bur. Animal Husb. and Dairying in India*, 2, 185 (1928).

An essential step in developing high milking strains of Indian breeds of cattle is the establishment of herd-books and of a system of milk records. In purchasing draught animals it is possible to judge the merits of an animal by its conformation and performance. Milk animals, however, present a different problem since conformation is only one indication of milking capacity, and performance can only be judged from carefully kept records.

The need for registration of milch cattle.

Preliminary steps have already been taken in this direction. Through the initiative of the Imperial Council of Agricultural Research, information has been collected which will enable the characteristics of the seven chief milking breeds to be defined⁽¹²⁾. This is obviously the first essential step in the establishment of herd-books. Arrangements are being made to open the herd-books and to establish milk records systems at an early date. I shall refer to this proposal in more detail in Chapter XII. At this stage I should, however, point out certain incidental advantages of the scheme. In the first place it will provide a most useful index of progress in the breeding of milking types. At present there is no systematic information available on this subject. It is known that the yields of individual herds show improvement and that the number of animals of proved milking strains is increasing. There is, however, no central authority which is in a position to collect this scattered information and collate it into a form which will show the extent of progress achieved. In the second place the collection of milk records will form a most valuable source of information for future investigations into factors affecting the yield and quality of milk. This has been the experience in Great Britain, the United States and other advanced dairying countries, and it should prove of even greater value in India where conditions are so diverse and where accurate records are difficult to obtain. I should point out that investigations into such subjects as the shape of the lactation curve and the effect of age on lactation yield are of more than academic importance. The results of such investigations enable milk yields obtained under different conditions to be standardised to a single basis of comparison, a procedure which is essential for a true judgment of milking performance⁽¹³⁾. In the third place the defining of types in connexion with the establishment of herd-books will be of direct educational value to practising agriculturists as well as to students of agriculture and veterinary science. In this connexion I was somewhat surprised to find that at many educational centres the only diagrams for use in explaining the 'points' of dairy cattle were those issued in connexion with European stock-judging. It is obviously desirable that Indian students should be taught stock-judging in relation to their

(12) The breeds so far included are the Sahiwal, Scindi, Tharparker, Hariana, Gir and Ongole, and the Murrah buffalo.

(13) Work of this nature has already been carried out by L. C. Sikka. *Indian Journ. Vet. Science and Animal Husbandry* 1, 63 (1931) and 3, 240 (1933), and by K. P. R. Kartha. *Ibid.* 4, 36, 124 and 218 (1934). The establishment of a proper system of milk records will enable the results of these authors to be confirmed and extended.

own dairying types, and not to imported breeds. I might note also that a scale of points for judging buffaloes did not appear to be used at the majority of colleges. This also should be remedied when the definitions of herd-book types are once available.

These three advantages are, of course, entirely subsidiary to the main purpose for which the herd-books and milk record registers are to be established. They serve to show, however, that apart from its purely commercial aspect, the proposal is of direct value from the point of view of both education and research.

The Royal Commission rightly stressed the importance of she-buffaloes as the chief milk-producing stock in India. Thus they wrote that "it is the number of she-buffaloes, not the number of cows, that has to be taken into account when seeking an index of the milk production of a province..... Wherever an important market for *ghee* exists, it is the she-buffalo which mainly supplies it....."⁽¹⁴⁾. It is indeed not difficult to explain the popularity of the she-buffalo. Her average milk yield is markedly higher than that of the ordinary village cow, the butter-fat content of her milk is also higher than that of cows' milk, while she appears to possess a remarkable ability to convert coarse fodders into milk. Considering the poor nature of the fodder normally available under village conditions and the hard conditions under which the animals have to live, the hardiness of the she-buffalo is a most valuable asset to the cultivator.

The popularity of the buffalo is reflected in the census statistics. Table 32 shows the number of cows and she-buffaloes recorded at five-year intervals during the past twenty years⁽¹⁵⁾. It will be seen that while the number of cows has scarcely altered, the number of buffaloes has risen by 13 per cent. The importance of the buffalo is also seen in Table 33, which shows the number of cows and she-buffaloes, their relative milk yields and the extent to which they contribute to the total milk production⁽¹⁶⁾. Numerically cows exceed she-buffaloes in every province but the Punjab. The she-buffalo makes up for this deficiency, however, by her higher milk yield, with the consequence that in five out of the ten provinces she actually produces more than half the total milk production. It is significant that the main *ghee* producing areas of India are situated in these provinces. In British India she-buffaloes provide 47.5 per cent. of the total milk supply; in India as a whole (though the figures are incomplete) they provide nearly 45 per cent.⁽¹⁷⁾.

The value placed on his she-buffaloes by the cultivator is also apparent from their better nourished appearance in comparison with country cows, and from the fact that even under village conditions their milk yields are exceptionally high. It is questionable whether under present conditions of feeding and management the dairy cow

(14) *Loc. cit.*, p. 184.

(15) Agricultural Statistics of India, 1934-35.

(16) Results of Provincial Marketing Surveys.

(17) These figures exclude the output of goats' milk.

could displace the buffalo : as has been aptly stated " when prices of fodder are low the she-buffalo can compete with any breed in butter production and beat the ordinary Indian cow in the production of both milk and butter. This is the main reason why the villager prefers the buffalo to the cow notwithstanding the fact that he has to pay a higher price for the buffalo "(3). Whether the same argument would hold if the cultivation of better types of fodder crops were to be widely employed is doubtful. The Military Dairy Farms have found that under good conditions of feeding and management the ordinary Sahiwal can produce as much milk as the buffalo, while high milking strains of the breed will produce over half as much again. On the other hand it should be pointed out that no serious attempts appear to have been made to improve the milk yields of buffaloes by selection and breeding from high yielding strains—a subject which is worthy of extensive study. In the meantime it is certain that for many years the she-buffalo will more than hold her own in competition with the cow as the premier milk producing animal of India.

In a country which has an exacting climate such as that experienced in the plains conditions of India, management is an extremely important factor. This is true even under village conditions, where high milk yields are not looked for. But with intensive milk production there is bound to be a constant rivalry between constitution and economic performance. This is a subject which has received comparatively little attention in India. It is therefore extraordinarily interesting to find that where systematic investigations have been carried out (as in the Military Dairy Farms) it has been shown that the preservation of constitution is a very definite limiting factor in attempts to improve milk yields beyond a certain level. It has been found that this maximum limit of milk production is affected by numerous external factors, such as diurnal and seasonal variations in temperature, the humidity and the extent of artificial protection given to the animal against excessive heat. Cross-bred stock are more susceptible to such influences than pure-bred Indian stock, and these in turn are more susceptible than buffaloes. These conclusions have not only been reached by general observation, but by direct physiological tests such as a study of the respiration rate and body temperature.

Any breeding policy must, in fact, take very carefully into account the environmental conditions under which the animals have to live. Attempts have, for example, been made to improve the size and draught quality of dwarfed country-bred stock by supplying sires of a larger physique. Such attempts may do more harm than good unless they are accompanied by measures to improve the environment of the stock, including their feeding. It is interesting to note in this connexion that the special distribution of a thousand improved bulls which forms part of the recent cattle improvement scheme in Bengal has been accompanied by the distribution of over a million cuttings of Napier grass.

The constitution of milking stock is closely related to other factors concerned in management. Early maturity and increased frequency of calving are two such factors. In a series of interesting experiments at the Imperial Agricultural Research Institute⁽¹⁸⁾ it has been shown that heifers of Indian milking herds can be calved successfully at far earlier ages than had hitherto been deemed possible, while at this and at other centres the length of the 'dry' period has also been markedly reduced. These changes in technique are obviously valuable from an economic point of view, since they tend to shorten the periods of unproductive life. The investigations have, however, so far been carried out only under optimum conditions of feeding and management. It remains to be seen whether they could be applied under the adverse environmental conditions commonly existing in less efficiently run herds. It is indeed quite possible that the late maturity and long dry periods of country-bred stock constitute natural safeguards against overstraining the constitution of inadequately nourished stock, giving opportunity for growth and for the replacement of body tissues utilised in the production of milk.

These and other points of management are of fundamental importance for the maintenance of a sound constitution in high milking stock. In the past insufficient attention appears to have been paid to this subject. I am strongly of opinion that the matter should be looked on as one of the major subjects for investigation in connexion with the breeding of improved stock.

This discussion would not be complete without a brief reference to the potential importance for the Indian cattle industry of recent

The physiology of reproduction.

investigations into two subjects, namely, hormone therapy and the technique of artificial insemination. Hormone therapy provides a possible method of treating the various breeding irregularities which are found among Indian stock. Some success has already been achieved in this direction but the subject is one which merits much close and continuous study in conjunction with a well equipped laboratory. The technique of artificial insemination has now reached a stage when it is capable of widespread application in the breeding of live stock. It has been practised with great success in the Soviet Union, where it was necessary to build up large herds of improved stock within a relatively short period of time⁽¹⁹⁾. India is of course, faced with an exactly similar problem. It is very questionable how far the method could be applied as a direct means of improving country stock: the difficulties of transport, the lack of communication, and the ignorance and probable prejudice of the cultivator would present almost insuperable obstacles. There is, however, no doubt that the utility of the method ought to be investigated in some of the large Government cattle breeding centres, where adequate facilities are available and where breeding control is possible.

(18) Wynne Sayer. "Feeding and Handling Experiments on the Pure Pedigree Sahiwal Herd." *Archie and Live-Stock in India*, 4, 105 and 481, (1934). Also personal communications.

(19) A. Watt. "The Technique of Artificial Insemination." Imperial Bureau of Animal Genetics, Edinburgh (1933).

CHAPTER X.—The nutrition of milch cattle.

There is no doubt that the majority of Indian dairy cattle are seriously underfed. This is apparent from a superficial inspection of village stock, which lack the sleekness and bloom of well fed cattle and not unfrequently have an emaciated and malnourished appearance. It is equally apparent from the slow rate of growth and maturity and the long dry periods of Indian cattle which are kept under village conditions. Thus it is quite usual for a cow to drop her first calf at 4 to 5 years of age, and to have calving intervals of up to 600 days. That these are not hereditary failings is proved by early maturity and controlled breeding experiments in herds where the feeding and management are satisfactory. Moreover, it is significant that a careful analysis of the yields of purchased cows show that such animals give an average increase of 60 per cent. in their milk yields solely as a result of better feeding and management. It may indeed be stated that inadequate nutrition is at present the most important single factor in accounting for the low yields of 'country' cows. "We are satisfied" the Royal Commission have stated⁽¹⁾ "that no substantial improvement in the way of breeding is possible until the cattle can be better fed."

India's total fodder resources.

It is difficult to arrive at any accurate estimate of total quantities of feeding stuffs available in India. This is partly due to the inaccuracy and inadequacy of available statistical data. It is also partly due to the fact that little attention is paid to the feeding value of the different types of fodder. It is very desirable that steps should be taken to improve the sources of information at present available on these two subjects.

I have, however, attempted to arrive at a figure, admittedly approximate and open to criticism, which would give some indication of the quantities of feeding stuffs available for cattle. This information is summarised in Table 34. Dry fodders refer to the estimated quantities of straw derived from rice, wheat, barley, *bajra*, and *juar*⁽²⁾. Green fodders have been calculated on the basis of an average yield of 200 maunds per acre and a total crop area (for all India) of 14,000,000 acres. The figures for concentrates and cottonseed are rough estimates⁽³⁾. The nutrients have been calculated from standard American tables⁽⁴⁾. It is probable that the quantity

(1) Royal Commission on Agriculture in India. Cmd. 3132 (1928), p. 201.

(2) Figures obtained from Agricultural Statistics of India, 1934-35. The following grain:straw ratios have been used :—for rice 1 : 1½, for wheat and barley 1 : 2, for *bajra* 1 : 2½, and for *juar* 1 : 3. In addition allowance has been made for straw obtained from pulses and certain unspecified grain crops. These occupy an area of about 66 million acres, and, allowing the low figure of ½ ton per acre, will provide about 16 million tons of coarse fodder.

(3) The estimates of individual oil-cakes in thousands of tons are linseed 99, groundnut 622, mustard and rape 516, coconut 60, miscellaneous (say) 200. Cottonseed, calculated on a production of 6½ million bales of cotton, will total 2,300,000 tons.

(4) W. A. Henry and F. B. Morrison. "Feeds and Feeding." The Henry Morrison Company, Wisconsin.

of dry fodder is seriously underestimated, since under Indian harvesting conditions the grain-straw ratio is likely to be abnormally low. There are also certain other natural fodder resources, such as natural grasses and certain edible shrubs and bushes, which are not included in the above estimate. It will, however, be of interest to determine how far the total nutrients shown in Table 34 would be adequate to meet the requirements for milk production alone, assuming for the moment that the requirements for growing stock and for working cattle could be met from grazing and from these other miscellaneous sources.

India's total output of milk has been estimated at 800 million maunds. The quantities of nutrients required to produce this amount of milk would be 29,550,000 tons of total digestible nutrients and 2,675,000 tons of digestible crude protein⁽⁵⁾. According to Table 34 the quantities available are 51,013,000 tons and 2,760,000 tons respectively. It will be noted that while there is an apparent surplus of total digestible nutrients, the quantities of digestible crude protein barely balance. Moreover, it is quite obvious that the assumption regarding the adequacy of grazing lands and other miscellaneous sources to supply sufficient nutrients for both growing stock and working bullocks is untenable. Young stock in particular require large quantities of protein as well as energy for growth. The requirements of working bullocks are also considerable. Estimates collected for the Royal Commission⁽⁶⁾ indicate that for about 200 days in each year working bullocks require (apart from grazing) an average of at least 20 lb. roughage per day, and that for half this period they require in addition a supplement of concentrates. It should be emphasised that the period during which there is any considerable growth of herbage on grazing lands is strictly limited: for 3 to 4 months such lands can only be looked upon as exercise grounds, providing indeed an excellent training ground for young draught cattle, but no source of nourishment. In this connexion I was struck by the almost universal demand of the villages for increased grazing land. I do not believe that the grant of such land would alleviate the present shortage of fodder, for the immediate tendency would be to over-graze the areas and leave them barren of herbage within a comparatively short period. Moreover, the provision of additional grazing land could not improve the food supply of the cattle during those months when drought prevents the growth of herbage. In any event grazing under Indian conditions cannot be looked upon as a source of nutrients for milking cattle.

If milk production is to be increased the provision of a very much larger food supply is essential. The problems involved are two-fold: first, to increase the supplies of fodder suitable for milk production; and second, to ensure that the available supplies are utilised economically. I propose to deal first with these two aspects of

(5) The requirements are calculated as follows:—for maintenance (700 lb. live weight), 0.35 lb. digestible crude protein and 5.6 lb. of total digestible nutrients; for milk production (8 lb.), 0.40 lb. digestible crude protein and 2.8 lb. total digestible nutrients.

(6) *Loc. cit.*, p. 697.

the subject, basing the discussion on the requirements of total nutrients and of protein. In addition the possibility of a shortage of mineral elements and of vitamins must be considered. This will be dealt with in a separate section.

During the past thirty-five years a very marked increase has taken place in the area devoted to green fodder crops, as shown in Table 35. Although the acreage has been more than trebled during this period there is still (as has already been noted) a serious shortage of fodder for cattle. It is significant to note that the present acreage under green fodder crops represents only about 4 per cent. of the total area sown. In Egypt the equivalent figure is over 16 per cent.

The first question which arises is the type of fodder which should be grown. It may be stated categorically that for the necessary increase in the supply of food for milking cattle it is useless to rely on coarse dry fodder. Such fodder contains too little protein in comparison with the total nutrients to be suitable for milk production. For milk production the nutritive ratio⁽⁷⁾ of the ration must not be wider than 1 : 10, and the higher the yield of milk the narrower should this ratio be. The nutritive ratio furnishes, in fact, an excellent index by which the suitability of various fodders can be judged. Dry fodders, such as rice straw, and wheat straw, have nutritive ratios of over 1 : 40 and are therefore obviously unsuitable for milk production. Grasses, such as Sudan grass, guinea grass, elephant grass and the spear grasses have nutritive ratios of between 1 : 12 and 1 : 10. These grasses are therefore reasonably good sources of nutrients for milch cattle⁽⁸⁾. But the fodder of outstanding value are the leguminous crops such as berseem (Egyptian clover), and lucerne (alfalfa). These fodders have nutritive ratios of 1 : 4 to 1 : 6, and are ideal for milk production. Moreover, they are of special importance to Indian agriculture by virtue of their ability to enhance the fertility of the soil, a point which has already been stressed in Chapter VII.

It is not easy to determine how far such fodders can be produced at a cost which would enable milk production to be profitably undertaken. Figures have been obtained from a large number of experimental and demonstration farms in an attempt to assess the yields and costs of production of typical green fodder crops. Unfortunately these figures not only vary from one locality to another, but differ markedly even in farms situated in the same locality. Moreover many of the crops have been grown on very small areas and under particularly good conditions, with ample manuring and irrigation. It would therefore be useless to attempt to arrive at any average figures for the yields and costs of production. It is, however,

(7) I.e., the ratio between the digestible crude protein and the combined digestible carbohydrates and fats.

(8) Other fodders grown on appreciable areas are *soy* (*Medicago sativiflora*) and shaftal (Persian clover). Green fodder is also obtained by cutting pulses green, and by cutting small quantities of the major crops green for feeding to cattle.

instructive to examine the collected results obtained from all reporting centres. It will be seen from Table 36 that the yields from crops of berseem and lucerne are at least as high as those from less-nutritious crops such as green *juar* and maize⁽⁹⁾. Further, Table 37 shows that the cost of production of lucerne does not differ materially from that of green maize, while berseem can be grown as cheaply as green *juar*. If such results can be taken as applicable to most fodder-growing areas in India, they constitute a very strong argument for encouraging the growth of these two leguminous fodder crops.

I have already stated that wide variations are found in the costs of production of green fodder crops. It might be supposed that such variations are due to differences in the methods of cultivation at the various centres. It is therefore interesting to note that similar differences are found in the costs of production of green fodders grown on Military Dairy Farms, where conditions of management and cultivation are very uniform. The average cost of production on such farms works out at $5\frac{1}{2}$ annas per 100 lb. (*i.e.*, $4\frac{1}{2}$ annas per maund), but the values vary from Re. 0-2-11 to Re. 1-1-9 per 100 lb., a range of 600 per cent.

These facts clearly indicate the need for more careful and extensive investigations into the factors responsible for variations in the yields and costs of production of cultivated fodder crops. It would, moreover, be desirable that any such investigations into crop yields and costs should be supplemented by parallel investigations into the value of the different fodders in the feeding of milking stock, particularly in regard to their influence on the cost of production of milk. In this connexion reference may be made to an attempt to determine the value of green fodder when utilised for milk production⁽¹⁰⁾. It was found that the addition of 40 lb. of green fodder per day to the rations of milking cows increased the milk yield by 45 per cent. (*i.e.*, by 750 lb. in a 300-day lactation). If the cost of production of the fodder was assumed to be 3 annas per maund (the nearest average figure which can be taken from Table 37), the added milk yield would have been obtained for an expenditure of Rs. 28, or just under 7 pies per lb. of milk⁽¹¹⁾. It is questionable whether this could be considered an economic figure. This example serves to emphasise the need for including in any future investigations not only the costs of cultivation of the fodder crops, but the effect of feeding these crops on the costs of production of milk.

During the two or three months immediately preceding the monsoon (and in some areas the period is very much longer) there is no fresh fodder or herbage available for cattle. Under present conditions the animals have to subsist during this period on inadequate

The conservation of fodder crops.

(9) The nutritive ratios of green *juar* and maize vary between 1 : 10 and 1 : 15 according to the age of cutting.

(10) Figures recalculated from brief.

(11) According to K. P. R. Kurtha's figures, the feed cost per lb. of milk on Military Dairy Farms varies between 4 and 6 pies.

supplies of coarse fodder. If the cultivation of green fodder crops is to be extended it will be necessary to convert part of the produce into a form in which it can be stored for use during the lean months. This point was recognised by the Royal Commission⁽¹²⁾, who stressed the value of silage making as a suitable means of conservation. It is disappointing to find that little or no progress has been made in this direction during the intervening ten years. Silage is frequently seen at Government demonstration and experimental farms, but its value appears to be practically unrecognised in the villages. There is an urgent need for popularising this method of fodder conservation among cultivators. If, as appears possible, there are unforeseen economic or practical difficulties in silage making under village conditions, these should be inquired into and where possible remedied. Silage is of such potential value in improving the nutrition of cattle (particularly of growing stock and milking cows) that every effort should be made to encourage its production. As the Royal Commission have stated, "small rations of silage fed to the hungry cows and young stock of the country during the season of fodder shortage would, we think, do more than anything else to bring about a rapid change in the quality of Indian cattle".

Silage making is not, however, the only feasible method of conserving green fodder. In the hot climate of India it should be possible to devise cheap methods of drying green crops. Such methods would be of special value in irrigated areas, where any surplus green fodder could thus be made available for transport to less fertile areas. Artificial drying is out of the question, not only on account of the high cost of machinery, but because of the heavy costs of maintenance and fuel. Moreover, in a hot and dry climate the employment of artificial methods of drying should not be necessary. There appears to be no reason why green crops should not be sun-dried by methods similar to those employed in Scandinavian countries, for example, by the use of tripods, wedge-shaped hollow frames or spaced poles. Drying under these conditions is extremely rapid, even with relatively 'stemmy' material such as coarse white clovers. The methods are, moreover, simple and inexpensive. There is no doubt that any substantial increase in the cultivation of green fodder crops will necessitate the introduction of improved methods of conservation, and I feel that this offers promising field for study⁽¹³⁾.

A further indirect method of conserving the feeding value of fodders (particularly of coarse fodders) is the cutting of the crop at the right stage of growth. This also formed the subject of a recommendation of the Royal Commission⁽¹⁴⁾ who stated "We are

(12) *Loc. cit.*, p. 206.

(13) It should be noted, however, that difficulty is likely to be met through the extreme brittleness of the leaves of crops such as berseem and lucerne. This is referred to in a paper by Wynne Saver entitled "Berseem as Green Fodder, Hay and Silage". (*Agric. and Animal Husbandry*, 4, 21 (1934).

(14) *Loc. cit.*, p. 209.

not satisfied that this subject has received enough attention from the agricultural departments, and we would suggest that, in districts in which cattle waste a considerable part of the coarse fodders to which they have access, the possibility of securing a better and more palatable straw by earlier harvesting should be considered, and that experiments should be made to determine the earliest stage at which the crops can be safely cut". These suggested experiments do not appear to have been carried out. Nor have any attempts apparently been made to improve natural herbage (either for grazing or for cutting) by the selection of suitable strains of indigenous grasses. Both these subjects warrant investigation.

It would be well at this point to emphasise the need for increasing the available supply of protein-rich concentrates such as linseed, cottonseed and earth-nut cakes.

Available supplies of concentrates. Such concentrates have nutritive ratios of from 1 : 1 to 1 : 3, and form by far the most valuable sources of nutrients for milk production. The total quantity of concentrates at present available for cattle feeding in India is estimated, according to Table 34, at about 3,800,000 tons. In addition to this about 325,000 tons of oilcakes are exported annually from India, while the quantity of oilseeds exported amounts to more than 1,000,000 tons. If the extracted cake from these two sources could be retained in India, it would result in a considerable increase in the available quantity of protein-rich concentrates. This subject was discussed by the Royal Commission⁽¹⁵⁾, who pointed out, however, that the only possibility of conserving this valuable potential supply of cattle food was by developing the Indian oil-crushing industry. In this connexion it would be a sound policy to give active encouragement to the export of vegetable oils, since this would indirectly increase the supply of oil-cake in the country. Improvement in the efficiency of the mills would also tend to lower the price of oil-cakes, and so make these products more readily available for the feeding of milch cattle.

There is little object in attempting to increase the fodder resources of the country unless the available supply can be utilised economically in the feeding of cattle. Indian

The rationing of milch cattle. milch cattle are seldom judiciously fed. On the one hand cows kept under village conditions are given entirely inadequate quantities of food, while the food used is of the wrong type for milk production. On the other hand in well organised city byres the quantity of food fed is frequently as much as 50 per cent. in excess of requirements. A proper rationing system would tend to correct both these tendencies.

It appears to be a fairly universal experience that Western rationing systems are not suitable for application to Indian cattle and buffaloes. This is partly due to the lack of information available regarding the composition and digestibility of Indian foodstuffs⁽¹⁶⁾.

(15) *Loc. cit.*, pp. 87—89.

(16) J. Matson, "Some Lessons learnt in regard to Cattle and Dairying, during 25 years' Farming in India." *Journ. Cent. L.A. Animal Husbandry and Dairying*, 2, 145 (1929).

It is also partly due to the fact that Indian cattle and buffaloes appear to have different requirements from European stock; in particular they are credited with a greater capacity for digesting coarse fodder⁽¹⁷⁾. In this connexion it has rightly been pointed out that whereas European cattle have been bred to digest and assimilate the largest possible quantity of food, Indian cattle possess characters which enable them to make the most efficient use of the smallest quantity of food. "The European animal extracting 60 per cent. from 30 lb. of dry matter is inferior in *India* to the Indian animal which can only digest 20 lb. dry matter but extracts 75 per cent.⁽¹⁸⁾." There is, therefore, a clear need for the formulation of independent rationing standards for Indian cattle.

What has been done to meet this need? Work has been chiefly confined to four centres. At Lyallpur⁽¹⁹⁾ an extensive series of investigations have been carried out to determine the digestibility of various Indian feeding stuffs. An attempt has also been made to find how far coarse fodders, hays and ensiled green crops (alone or in combination) can meet the maintenance requirements of cattle. At Bangalore⁽²⁰⁾ the work has been largely concerned with the mineral and sulphur metabolism of cattle on various rations including silage. Special attention has been given at this centre to the value of silage as a food for milking stock. At Coimbatore⁽²¹⁾ investigations have been made into the protein requirements of working bullocks, while preliminary experiments have been carried out in an attempt to determine the mineral requirements of young dairy stock. At Dacca⁽²²⁾ the work has so far been largely devoted to the formulation of a new method of determining the digestibility of foodstuffs by means of regression equations. The maintenance requirements of bullocks have also been investigated.

Most of these investigations have been carried out with obvious care and by sound methods, and the scientific value of the results cannot be questioned. The broad impression created is, however, that much of the work lacks a practical objective, and that there is a great need for better planned and co-ordinated methods of attack.

(17) See for example an article by Wynne Sayer [*Agric. and Live Stock in India*, 4, 107 (1934)] in which it is stated that "European equivalents have proved unsuitable for the Sahiwal herd to date, and the alterations in rations and the results achieved point to this fact being of far greater importance than is generally realised."

(18) J. Matson. "Cattle in relation to Agriculture in India." *Journ. Cent. Bur. Animal Husbandry and Dairying*, 2, 83 (1928).

(19) A series of papers by P. E. Lander and associates published as *Memoirs of the Department of Agriculture in India* and in the *Indian Journal of Veterinary Science and Animal Husbandry* and other journals, 1927-1936.

(20) Papers by F. J. Warth and co-workers in the *Indian Journal of Veterinary Science and Animal Husbandry*, and in *Agriculture and Live-Stock in India*, 1930-1935.

(21) Papers by R. B. Viswanath and P. V. Ramiah, *ibid*, 1933 to date.

(22) M. Carbery and co-workers. "Studies on the Determinations of Digestibility Coefficients." *Indian Journ. Veterinary Science and Animal Husbandry*, 4, 295 (1934) and 687 (1936), and other unpublished papers.

The ultimate objective should undoubtedly be the formulation of a satisfactory rationing system for Indian cattle and buffaloes. Before any such system can be worked out it is, however, essential to determine accurately the standard requirements for maintenance, growth, work and milk production. It is claimed that Indian cattle, and particularly buffaloes, can make better use of fodder than European cattle, but no quantitative data are available to show how far this difference depends on more efficient digestion and how far it is due to the better utilisation of the assimilated nutrients. Again, it is claimed (contrary to a widely accepted view) that work undertaken by draught cattle entails the utilisation of a considerable quantity of protein as well as of energy. Until points such as these have been more adequately investigated and elucidated, it will be impossible to formulate a satisfactory rationing system. Once, however, such basic information is available, rationing becomes relatively easy, since the feeding value of any given food can be determined by chemical analysis, supplemented (in certain instances) by digestibility determinations. In formulating rationing standards, the requirements for maintenance, growth, work and milk production will need to be determined in relation to both the energy, protein and mineral constituents of the food. Moreover, it is quite possible that the requirements will be different for cows and buffaloes, and they may even vary for different breeds of cattle. The supplementary study of the digestibility of various classes of feeding stuffs will also need to be undertaken on a fairly extensive scale if reliable average figures are to be obtained which can ultimately be applied throughout India. Here also it is likely that the digestibility coefficients will vary according to the type of animal used, *i.e.*, buffaloes or oxen.

This brief discussion will serve to show the necessity of formulating a careful programme of work and of ensuring close co-ordination between the various research centres if rapid progress is to be made in devising a satisfactory rationing system for universal application under Indian conditions. I would again stress the fact that it is only through the universal adoption of such a rationing system that proper use can ultimately be made of the food resources of the country.

I should add one further point. At present remarkably few analyses are available of the cattle foods commonly used in India. This applies particularly to the various types of dry and green fodder. It may be noted, too, that the feeding values of grasses show remarkable variations. Thus one authority writes "everything points to an extraordinary variation in the food values of Indian hay made from the same species of grass grown in different localities, and to the fact that grasses which have the best popular reputation have by no means the best feeding value"⁽¹⁶⁾. Side by side with the co-ordinated investigation of rationing standards efforts should, I consider, be made to obtain representative analytical figures of typical feeding stuffs from as many agricultural areas as possible.

Apart from lack of total nutrients and protein in the rations of cattle (which may be the cause of general undernourishment or even of semi-starvation), the lack of mineral constituents and of vitamins may cause pathological conditions in cattle. In some instances these conditions are clinically recognisable, as for example in the bone lesions associated with phosphorus or calcium deficiency. In other instances the abnormal condition is less obvious, and takes the form of a general stunting of growth or an appearance of unthriftiness. It may also result in sterility, or in the premature falling off of milk production.

Nutritional deficiency diseases. def-

Until recently very little attention had been paid to the possible existence of mineral and vitamin deficiencies among Indian cattle. During the past few years, however, instances of definite deficiency diseases have been recorded. In certain areas in H. E. II. the Nizam's Dominions, for instance, osteomalacia has been found⁽²³⁾. Again, a condition of blindness in calves has been attributed to lack of vitamin A⁽²⁴⁾. Less obvious effects of mineral deficiency have been observed in certain areas of the United Provinces, and have been remedied by the addition of a mineral supplement to the ration⁽²⁵⁾. It might be noted, too, that the analyses of fodders derived from different areas show marked variations in mineral content⁽²⁶⁾.

There is little doubt that such deficiencies are far more common than has been generally supposed and that they are a source of serious economic loss. Mineral and vitamin deficiencies are, however, relatively cheap to remedy, whether by the addition of mineral mixtures to the food or the soil or by the inclusion of small quantities of green fodder in the ration. It is, therefore, most desirable that extensive surveys of the incidence of deficiency diseases should be undertaken, so that mineral deficient areas can be located and their deleterious effects remedied. At the same time the information gained from such surveys could be usefully supplemented by accurate studies of mineral requirements (such as those noted in an earlier paragraph) and by extensive mineral analyses of fodders drawn from typical cattle breeding and milk producing areas.

(23) K. C. Sen. "The Nutrition of Indian Cattle. Part II. Malnutrition in relation to Health and Production Capacity of Animals." *Agric. and Live-Stock in India*, 5, 1 (1935).

(24) K. C. Sen. "The Nutrition of Indian Cattle. Part I. Some Nutritional aspects of Cattle Breeding." *Ibid.*, 3, 549 (1933).

(25) C. H. Parr. "Some Factors which affect the Supply and Efficiency of Cattle in the United Provinces." *Journ. Cent. Bur. Animal Husbandry and Dairying*, 4, 48 (1930).

(26) See, for example, A. R. Padmanabha and R. N. Kayasth "Mineral Composition of the Fodders of Central Provinces and its bearing on Animal Nutrition." *Agric. and Live-Stock in India*, 1, 526 (1931), and A. C. Roy and K. C. Sen, "The Seasonal Variation of Lime and Phosphoric Acid in some Hill Pastures." *Ibid.*, 3 (1933).

This might perhaps be a suitable point at which to make very brief reference to another set of pathological conditions which are undoubtedly responsible for the poor condition and high mortality of cattle in certain areas. I refer to parasitic infestations. Although such infestations are not directly related to the nutrition of cattle, they frequently lead to a condition of unthriftiness comparable to that found in cases of serious malnutrition. In view of the heavy economic losses attributable to such parasitic infestations their investigation is urgently called for.

CHAPTER XI.—Recommendations for the future development of dairy research, education and advisory work.

In Part I a general account has been given of the present state of the dairy industry in India. The outstanding impression created

Present position. by this survey is the entire absence of any systematic investigation of the numerous problems which face the industry, and the lack of a suitable organisation for developing its vast potentialities, either at the centre or in the provinces. Before turning to specific recommendations it is desirable to outline briefly the present organisation.

It may be said that the responsibility for the development of Indian dairying rests almost solely with the Imperial Dairy Expert. This officer, who prior to 1936 was attached to the Imperial Agricultural Research Institute, is now directly responsible to the Department of Education, Health and Lands. His duties, as laid down by the Department⁽¹⁾, include (a) the giving of advice to the agricultural and veterinary departments in the Provinces and Indian States and to private persons who are engaged in the production and utilisation of milk; (b) the training of post-graduate students and of students desiring to qualify for the Indian Dairy Diploma; (c) the testing of dairy products for the public where such tests are of a special nature not normally falling within the duties of public analysts and other similar officials; (d) the prosecution of research work into problems connected with the dairy industry, including the investigation of methods of handling and transporting milk and the utilisation of milk in the manufacture of milk products; and (e) the testing of new types of dairy machinery and equipment.

The office of the Imperial Dairy Expert is at Bangalore, where the Imperial Dairy Institute is situated. His permanent staff consists of two Class II Officers and four Class III Officers. One of these possesses a university degree; the remainder hold dairy diplomas. A farm of 198 acres is attached to the Institute at Bangalore, and there is a small sub-station at Wellington, Coonoor. The Institute itself is used chiefly as a teaching centre. There is somewhat inadequate hostel accommodation for the 24 students who take the dairying diploma, while suitable houses for the staff are lacking. The dairy is small and cramped. The laboratory (which is used for both chemical and bacteriological work) measures barely 20 feet square and possesses practically no equipment. This is supposed to serve for both teaching and research. A portion of an old barn was at one time in use as a laboratory for the physiological chemist⁽²⁾ and a suggestion has been made that this should be adopted as an extension of the existing laboratory. It is, however, quite unsuitable for this purpose and would not justify the necessary capital outlay. The annual budget of the Institute (*i.e.*, excluding the Imperial Dairy Expert's own budget) is roughly Rs. 1,30,000.

(1) These are contained in a letter from the Joint Secretary of the Department to the Director of the Imperial Agricultural Research Institute dated 6th April 1936 (No. F. 384/35-A.).

(2) This side of the work has since been transferred to Izatnagar.

Facilities in the provinces are even less adequate. Instruction in dairying is included in the courses run by provincial agricultural colleges, but this is of an elementary character. Only one institution⁽³⁾ has adequate facilities and teaching staff to provide instruction for the Indian Dairy Diploma. No provision is made for research into dairying problems. Any local advisory work in connexion with the production or utilisation of milk is undertaken by the Livestock Experts where provinces include such officers on their agricultural staffs. Otherwise advice has to be sought directly from the Imperial Dairy Expert.

It is obvious from this brief statement that the facilities and staff available at the centre and in the provinces is utterly inadequate to meet the needs of a branch of agriculture of the magnitude of the Indian dairy industry. This fact has recently been recognised by the Central Government, who have given their sanction to an expenditure of some Rs. 6 lakhs to provide additional buildings, equipment and staff. The provisional allocation of this sum allowed for the building and equipment of an Experimental Creamery at Anand (Bombay Presidency) at a cost of Rs. 3½ lakhs, and for additional accommodation at the Bangalore Institute at a cost of roughly Rs. 75,000. The remaining Rs. 2 lakhs was to be utilised in meeting the recurring expenditure at the Experimental Creamery during the first five years at a net cost of Rs. 40,000 per year. In addition a sum of roughly Rs. 1 lakh has been allocated by the Imperial Council of Agricultural Research for special investigations into problems connected with the manufacture of milk products. A small grant has also been made by the Council to the Allahabad Agricultural Institute for investigations into the chemical composition and physical properties of milk.

The present stock-taking provides an opportunity to re-examine these proposals in relation to the general development of organised dairying in India, and to bring them, if necessary, more into line with the needs of the industry. It would, I believe, be a grave mistake to attempt to meet these needs piece-meal : what is required is the formulation of a co-ordinated and progressive scheme of development which will embrace both research, education and advisory services, and in which both the central and provincial Governments can play their parts.

Since the results of research form the basis of both education and advisory work, this subject will be dealt with first.

I.—RESEARCH.

The number and complexity of the problems which face the dairy industry have been dealt with in the first six chapters of this report. It is obvious that under present circumstances the staff of the Imperial Dairy Institute is not in a position to undertake the scientific investigation of these problems. The

The need for an
Imperial Dairy Re-
search Institute.

(3) The Allahabad Agricultural Institute.

Institute is at present primarily a teaching centre and does not possess the scientific staff or the necessary laboratory accommodation or equipment for accurate research work. The provision of such accommodation and equipment would involve considerable structural alterations and extensions to existing buildings, but even so the result would not, I believe, be really satisfactory. There are, however, two more fundamental objections to the existing location of the Imperial Dairy Institute as a possible centre for dairy research. I understand that the site of the Institute was largely selected for two reasons: first, because the climate was more equable than in the dairying tracts of Northern India; and second, because there already existed a lucrative market for the milk in the form of the requirements of the military cantonment. Both these considerations adversely affect the value of Bangalore as a centre for research. In the first place the relatively temperate climate is not typical of India's most intensive dairying tracts, where the problems of the dairy industry are therefore of a very different character. In the second place the needs of the military are not representative of typical Indian dairying. At present the greater part of the output of milk at the Imperial Dairy Institute is either sold as pasteurised milk or is manufactured into butter or cheese. I have already pointed out that these products are not typical of Indian dairying. It has been urged in favour of Bangalore that the consumption of milk in South India is abnormally low, and that the presence of the Imperial Dairy Institute is of value in stimulating interest in milk production. The Central Government has, however, to consider the needs of India as a whole, and not the special needs of one locality, which is a matter for provincial action.

There is no doubt that the present location of the Institute is largely responsible for the fact that it is seriously out of touch with the real needs of the dairy industry. If (as I have suggested in Chapter II) organised dairying is in future to be largely concerned with the production and marketing of indigenous milk products, it is essential that a more suitable site should be found and that the Institute should be reconstituted as an Imperial Dairy Research Institute. In selecting such a site the following points should be taken into consideration:—

1. The Institute should be situated in a district which is representative of India's chief dairying tracts and of the centres of production of her major dairying product, namely, *ghee*. In practice this limits the site to an area running across the northern part of India and including the dairying belts of Bihar, the United Provinces, the Punjab and Bombay Presidency. The Royal Commission on Agriculture rightly emphasised the fact that the real index of milk production of a province is the number of she-buffaloes and not the number of cows. Table 38 shows the cattle densities of the typical dairying districts in the provinces mentioned above. This table shows clearly that the best site

for the new Institute would be somewhere within a triangle drawn through Delhi, Agra and Cawnpore.

2. I have considered the possibility of both New Delhi and Bareilly as sites for the Institute. Neither of these cities is, however, situated sufficiently close to the *ghee*-producing areas to warrant consideration. On the other hand the selection of a site within the area already mentioned would mean that the Institute could maintain close touch with the Imperial Agricultural Research Institute at New Delhi and with the sub-stations of the Imperial Veterinary Research Institute at Izatnagar. The Institute would also be conveniently near to Aligarh, one of the most important butter making centres of India. Further, the site suggested would be at the centre of the important dairy breeding tracts of India, which extend through the Punjab, Sind, Kathiawar, and the north of Bombay Presidency.
4. It is desirable that the Institute should be situated close to a town having a University or Agricultural College. In this connexion I should point out that the Indian Institute of Science has proved a valuable neighbour to the present Imperial Dairy Institute at Bangalore. It is most desirable that workers at the new Institute should have an opportunity of meeting colleagues of university standing.
5. In selecting the new site it is essential that undue attention should not be paid to the provision of a lucrative market for the milk produced on the Institute's farm. The Royal Commission have pointed out that farms which have been established solely for experimental work cannot be expected to pay their way⁽⁴⁾. If the Institute is to undertake the making of indigenous Indian milk products, it is almost inevitable that there will be a considerable financial loss in the running of the farm. Moreover, it is also desirable that the site should be selected solely on its merits and not because land is available in the vicinity which is already owned by Government.
6. Finally, if the Institute is to be located in a typical dairying tract, the climatic conditions will inevitably be exacting. There is, however, no reason why, with modern air conditioning systems, the staff of the Institute should not work under tolerable conditions.

At such a centre the staff would be closely in touch with the industry and with its major problems. There would probably be opportunities of working in collaboration with co-operative societies and other similar associations which might be attempting to improve the conditions of production and handling of milk and milk products

(4) Royal Commission on Agriculture in India, p. 150. Cmd. 3139 (1928).

in local villages. The Institute would also be in closer touch with the Central Government and with the Imperial Council of Agricultural Research at New Delhi⁽⁵⁾.

The success of the work of the Imperial Dairy Research Institute will depend very largely on the scientific and technical qualifications of the staff and on their ability to apply their training to the practical problems of the industry. I should perhaps clear up any misconception regarding the nature of the work to be undertaken at the Institute. It may be thought that this work is of a relatively simple character and that it will not require workers of marked ability. It has also been suggested that the dairy industry does not need fundamental research, as its needs are essentially practical. Both these views are founded on a complete misunderstanding of the complexity of the problems which await solution. I believe that progress in dairy research will only be made in India if it is clearly understood that men are required who, in the words of the Royal Commission "combine scientific knowledge and technique of the first order with the vision and creative power essential to the opening up of new and original lines of work". In staffing the Institute this consideration should be paramount. An honours degree in science at a university of repute should, I believe, be regarded as an essential qualification for any of the senior posts at the Institute⁽⁶⁾.

The first essential is to secure an able Director, since it is obvious that he will be in a key position in regard to the future development of Indian dairying. The Director must, therefore, be a man of outstanding ability. He should have had a wide experience in dealing with the general problems involved in the handling of milk and milk products; he should be capable of initiating and directing research and of relating the Institute's work to the practical problems of the industry. It is desirable that he should have had practical experience in the dairy industry as well as a sound knowledge of research methods. Above all, he should have the ability to visualise the requirements of the industry and to carry through his projects to a successful conclusion.

Under the Director the work of the Institute should, I consider, be divided into four sections, namely, dairy bacteriology, dairy chemistry, dairy technology and dairy husbandry. Responsibility for the development of each of these four branches of the work should be delegated to Heads of Sections who should be Class I Officers and who should be given adequate Class II assistants. It is possible that in the first instance one or more of these Heads of Sections might have to be recruited from outside India. If, however, my later recommendations are agreed to, it should be possible to find adequately qualified Indian workers to fill these posts within a few years.

(5) It may be mentioned that the existing institute at Bangalore is over 50 hours journey from New Delhi.

(6) *Loc. cit.*, p. 634.

As regards dairy bacteriology and dairy chemistry, the Heads of Sections should have had a sound fundamental training in the basic sciences underlying their work. It is essential that the Head of the Dairy Bacteriology Section should also have had a wide experience of the application of bacteriology to practical dairying problems. The Head of the Dairy Technology Section should be selected not so much on account of his knowledge of dairy technology as on his fundamental training in chemical technology and engineering. The future application to dairying of large and small-scale machinery, as well as of refrigeration, will largely depend on his knowledge and ability. He will also be responsible for the testing of dairy machinery and equipment. He should be provided with a capable assistant who has had specialised training in dairy technology.

It is desirable that the Head of the Dairy Husbandry Section should have a special knowledge of Indian dairy breeds as well as of Indian conditions of cultivation. Future policy regarding the breeding of Indian dairy cattle will largely depend on him, and he may also be needed on occasions to advise regarding the official registration of milking breeds. He should be provided with two special assistants, one of whom should be responsible for the accurate costing of both crop and milk production. The other should be a qualified veterinary assistant.

It has already been stated that the existing Institute at Bangalore possesses entirely inadequate buildings and equipment for research. The new Institute would need fully equipped chemical and bacteriological laboratories, since these sciences form a basis for adequate control in all other branches of the Institute's work. These laboratories would need to be built on a sufficiently generous scale to allow for the accommodation of post-graduate research students. As regards dairy technology, there should be accommodation for small-scale machinery and processing plant. I feel, however, that the arrangements should be as flexible as possible, since the object of this section will be to try out various types of plant and equipment under semi-commercial conditions. The basic needs of this section would be adequate boiler capacity and refrigeration. Some of the dairy plant could be of standard design. Much of it would, however, need to be constructed to meet special requirements. For this purpose it would be essential to have a well equipped engineering shop attached to the Institute. This would also be necessary in connexion with the testing of dairy machinery.

Apart from the above accommodation, the building would need to house offices, a library, and one or two lecture rooms. Separate housing accommodation would be needed for the staff and sufficient hostel accommodation for a small number of post-graduate research students.

As regards dairy husbandry, it is assumed that the herds at present stationed at Bangalore would be transferred to the new Institute. It would therefore be necessary to have sufficient acreage to supply fodder for roughly 472 cattle. Part of the land would

need to be irrigated, and it would be essential to have facilities for running the farm on a 'mixed-farming' system. Adequate store accommodation would also be needed for accurate rationing and similar experimental work. I do not, however, recommend that accurate metabolism studies should be carried out at the Institute. I anticipate that the greater part of the milk produced on the farm would be available for experimental work in connexion with methods of handling liquid milk and of manufacturing milk products. Apart from this supply it would be desirable to make provision for establishing one or more experimental depots for the collection and handling of milk under village conditions. It would thus be possible to compare the properties of milk produced under ideal conditions with those of milk produced under village conditions. This would be of great value in determining the feasibility of the adoption of new methods of processing and manufacture.

In considering the building and equipment of the new Research Institute, the question at once arises whether it would also be

The need for an experimental creamery. necessary to proceed with the building and equipment of the proposed experimental creamery at Anand. This scheme was

originally put forward for three reasons: first, to provide a centre for research and training in factory dairying; second, to enable such work to be carried out under the climatic conditions experienced in typical Indian dairying tracts; and third, to study the problems involved in the supply of liquid milk to large cities. So far as the first point is concerned, it is obviously unjustifiable, in view of the arguments put forward in Chapter II, to spend large sums on the manufacture of products which are of relatively little importance in India. Regarding the second point, if the new Institute is placed in the area which I have suggested, it will be subject to the same climatic conditions as at Anand. There remains the third point, namely, the supply of milk to large cities. I have already pointed out that only a very small proportion of India's population live in large cities. The provision of adequate supplies of milk to mofussil towns is, in practice, a more important subject for study. If, however, the problems involved in supplying milk to large cities are to be investigated, Anand would be an ideal sub-station for the purpose. But its establishment as a sub-station would result in considerable duplication of equipment and staff. Under the circumstances I suggest that the whole of the Anand proposals should be held over until the new Research Institute has been satisfactorily established and preliminary experiments have been carried out on the various problems involved in dealing with liquid milk. It will then be easier to determine whether or not a sub-station will be necessary at Anand.

It is not possible at this stage to suggest any definite figure for either the non-recurring or the recurring expenditure which is likely to be involved in the establishment of the proposed Imperial Dairy Research Institute. It is, however, desirable to give some general indication of the probable financial needs.

Expenditure involved.

As regards non-recurring (capital) expenditure, it may be noted that a sum of Rs. 6 lakhs has already been sanctioned in connexion with the Anand scheme, although only Rs. 4 lakhs were provisionally allocated for capital expenditure at Anand and Bangalore. I recommend that the whole of this sum of Rs. 6 lakhs should be allocated for capital expenditure in connexion with the new Research Institute. In addition any sum realised from the disposal of the Bangalore and Wellington farms [which were taken over from the Military Authorities at a total valuation of Rs. 2,84,000⁽⁷⁾] should be made available towards the purchase of land for the new Institute.

As regards recurring (annual) expenditure, it is extremely difficult to give even a rough estimate. It is probable that the pay of the senior staff would amount to roughly Rs. 1 lakh per year and on this basis it may be assumed that the total budget for the Institute would be between Rs. 2 and 2½ lakhs. It would probably be necessary to add a further sum in order to offset any losses incurred in the running of the farm. It may be noted that the annual sum spent on the running of the two national centres for dairy research in Great Britain is nearly double this sum⁽⁸⁾, although the British dairy industry handles only a quarter of the quantity of milk produced in India.

At present very few investigations into dairying problems are undertaken at provincial agricultural and veterinary colleges. This is perhaps partly due to the lack of adequate staff and facilities available at these provincial centres. But it is, I believe, largely the result of concentrating dairy education and advisory work at the central Institute at Bangalore: provincial Governments are apt to overlook their responsibilities in this direction, and this in turn means that no active encouragement is given to workers at provincial centres.

In a later section I recommend that advanced instruction in dairying should be given at the provincial colleges instead of at the central Institute, a recommendation which was indeed put forward by the Royal Commission on Agriculture, but which was not implemented⁽⁹⁾. It is, however, equally important that these colleges should be encouraged to undertake research into local dairying problems. A central research institute cannot undertake the study of problems of purely local interest, nor can such an institute investigate all the factors which may have to be taken into account in applying any new method under the wide variety of conditions existing in India. It is therefore essential that adequate research facilities should be provided at the various provincial colleges, and that one

(7) The amounts paid to the military authorities on the transfer of the Bangalore Institute to the Imperial Agricultural Department were as follows:—lands, Rs. 22,953; buildings, Rs. 1,36,773; plant and furnishings, Rs. 27,102; live-stock, Rs. 55,954; stocks, Rs. 41,344; total, Rs. 2,84,126.

(8) State grants to the two institutes total over Rs. 3 lakhs, while a further Rs. 1 lakh is received from other sources.

(9) *Loc. cit.*, p. 247.

or more specially qualified workers should be available to undertake the necessary investigations.

I consider that this is one of the directions in which valuable assistance might be given by the Imperial Council of Agricultural Research. The financial needs of the central institute should normally be met by direct grants from the Department of Education, Health and Lands, and the Institute should not need to seek financial assistance from the Council. The provision of grants from the Council would, however, form a useful means of encouraging the development of dairy research in the provinces and constituent states. As a first step the Council might consider making special grants to those provinces which are willing to provide facilities for advanced dairying instruction. A special grant to meet the cost of purchasing additional equipment and recurring grants towards the costs of special investigations into certain dairying problems have already been made to the Allahabad Agricultural Institute. This might be taken as a useful precedent. The nature of the problems to be investigated would, of course, depend on local requirements, though a number of suggestions have been put forward in Chapters III to VI. As the work of the central institute developed, it would obviously be desirable to arrange for close collaboration between workers at the centre and in the provinces. In this field also the Council could play a very useful part.

In the meantime the Council has (as I have already indicated) sanctioned a grant of Rs. 1 lakh for the study of problems concerned in the production of condensed and dried milks. If, as I have recommended, the Anand experimental creamery scheme is abandoned, this sum could be released for work along other lines. I do not think that it would be better utilised than in initiating research work at provincial centres along the lines just discussed.

II.—EDUCATION.

At present advanced courses in dairying are given at two centres, namely, at the Imperial Dairy Institute at Bangalore and at the Allahabad Agricultural Institute. The standard course is that leading to the Indian Dairy Diploma. This is a two-year course with a syllabus similar to that of the National Diploma in Dairying of Great Britain. It is designed to give the student sufficient knowledge and experience of practical dairying to enable him to undertake the responsibility of managing a dairy herd or of running a small dairy. Proposals are at present under discussion for making this course a more advanced one. These proposals include the provision of special instruction in dairy factory management, and necessitate the extension of the period of training by an extra year.

Apart from this course the Imperial Dairy Institute accepts post-graduate students for a 15-months' special course. This consists partly of training on the lines of the dairy diploma and partly of research, though the facilities for the latter are at present quite

inadequate. In addition occasional short courses of practical instruction and vocational courses for British troops are run at Bangalore.

At the provincial agricultural colleges there are no advanced courses in dairying. The college degree courses include instruction in dairying. Special short courses in elementary dairying are also run from time to time. At Lyallpur and Nagpur there is a six months' vernacular course. At Poona special courses are run wherever there is a demand for them; these are of variable length. At Coimbatore elementary dairying is included in a special short course in agriculture. At provincial veterinary colleges the instruction in dairying is (with one exception) meagre, and is usually limited to a short course in milk inspection. Most veterinary colleges are, however, handicapped by the lack of a milking herd or dairy, so that instruction is carried out under very unfavourable conditions.

As a result of my inquiries I consider that three types of dairy training are required, namely, instruction in general dairying, post-graduate training in research methods, and elementary courses in practical dairying.

There is no doubt that the existing I. D. D.⁽¹⁰⁾ course fills a definite need. This may be judged in two ways. In the first place there is an encouraging demand for admission to the course. The number of enquiries received at the Bangalore Institute during the past three years has been 128, 295 and 310 respectively, although only 45 could be admitted owing to the very limited accommodation. Similar figures are not available for the Allahabad Institute, but I am informed that the course is invariably full. In the second place I am told that successful students seldom fail to find employment. Unfortunately complete figures are not available on this subject. At least 63 students are known to be in employment⁽¹¹⁾. In view of these facts I consider that the course of training for the I. D. D. should be retained as the main course of instruction in general dairying. Two obvious questions arise: first, whether the syllabus of the course requires amendment, and second, what future provision should be made for the teaching of I. D. D. students.

(10) Indian Dairy Diploma.

(11) It is interesting to note the division of employment between government service and private dairies:—

			<i>Number.</i>	
Central Government	..	..	11	
Provincial and State Governments	..	..	26	
Military Dairy Farms	..	..	4	41
			—	
Private dairies, etc.	..	..	..	20
Higher studies	..	..	..	2
			—	63
			—	—

The proposal to increase the existing I. D. D. course from two to three years is based on two arguments ; first, that at their time of admittance many students are not sufficiently well educated to be able to complete the course satisfactorily in two years ; and second, that the course ought to include advanced instruction in dairy technology and factory management.

As regards the first point the official reports of examiners repeatedly stress the fact that many students show a very poor command of English. Under normal circumstances only matriculates are admitted to the I. D. D. course : exemption from matriculation is stated to be given only under exceptional conditions. Reference to the admissions to the Allahabad Agricultural Institute shows, however, that 10 per cent. of those accepted are non-matriculates. It appears, therefore, that the examiners' complaints regarding the lack of general education among students could be easily remedied by tightening up the standard of admission.

As regards the second point, namely, the inclusion of advanced instruction in factory management, this is based on the assumption that Indian dairying should be run on Western lines. I have already expressed the view that the adoption of the so-called factory system of dairying is not applicable to Indian conditions of production. I have also shown that even if it is feasible to establish large factories for the production of such products as condensed and dried milks, three or four such factories would be sufficient to provide for the full needs of the existing market. Openings for employment in such factories would therefore be very limited. Moreover, inquiries among firms who might ultimately establish factories in India reveals the fact that such firms invariably train their own employees in factory methods of production : what they require before engaging such employees is a general knowledge of dairying and of the sciences underlying dairy practice.

Under these circumstances I do not consider that any useful purpose would be served by lengthening the period of training for the I. D. D. or by including in the syllabus advanced training in factory processing or management. General information on this aspect of dairying can more readily be given in lectures, supplemented, if desired, by brief visits to modern butter-making creameries and other specially equipped centres.⁽¹²⁾

As regards other subjects included in the I. D. D. syllabus, I do not feel that any drastic alterations are called for. If candidates can answer satisfactorily the type of examination paper which I have been shown, they must have attained a satisfactory standard of both theoretical and practical training. I am somewhat apprehensive that too great stress is laid on butter and cheese-making. The value

(12) For example, visits might be arranged to such centres as the Dayalbag Dairy, the Military Ghee Heating Centre at Agra, and the Imperial Dairy Research Institute.

of the separator method of butter-making as against the 'country' method for the ultimate production of *ghee* has yet to be demonstrated. Cheese-making is of negligible importance in Indian dairying. I feel that more stress should be laid on the methods of production of indigenous milk products, on the need for devising cheap types of equipment, and on the improvement of methods of producing milk and milk products by co-operative enterprise and by the development of village industries. Instruction along these lines is at present handicapped by the lack of available knowledge on the subjects in question. This difficulty will disappear as further knowledge is acquired.

There is, however, one other aspect of the training which, I believe, requires special emphasis. The training should include adequate practice in the methods of imparting instruction in dairying in both English and the vernacular. Holders of the I. D. D. will probably be largely responsible for introducing improved dairying methods into village practice, either by the running of elementary dairy courses or by organising village collecting centres and other co-operative enterprises. In such work it is essential that the man in charge should be capable of presenting his subject in a clear and convincing manner. The I. D. D. course provides an excellent opportunity for instruction and practice in this subject.

I have been somewhat disturbed to find that a comparatively small number of graduates take the I. D. D. course. This is largely due to the fact that the Bangalore Institute run a so-called post-graduate course in addition to the I. D. D. course. Since 1924, 45 students have taken the post-graduate course, compared with 150 who have taken the I. D. D. course. It appears to me to be unnecessary to run a special course for post-graduates. The present post-graduate course is a combination of advanced instruction in dairying and training in research methods. I do not think that these two aspects of dairying can be satisfactorily included in a single course. As regards research, I am recommending the provision of suitable facilities at the new Research Institute. As regards advanced instruction in dairying, I consider that the present I. D. D. course should meet the normal requirement. It is, however, desirable to consider how far graduates in agriculture might be given special encouragement to qualify for the I. D. D. by exemption from some part of the two-year course. Under existing circumstances I do not think that this proposal would be feasible. But if (as I recommend) the I. D. D. course is to be included in the normal curricula of provincial agricultural colleges, there seems no reason why the dairying training for the agricultural degree should not be dovetailed with that for the I. D. D. An examination of the syllabuses of the I. D. D. and of typical agricultural degree courses shows, in fact, that there is already considerable duplication in the subjects studied. I do not consider that any similar exceptions could be given to veterinary graduates, whose training does not include subjects such as crop husbandry and farm management.

At present instruction for the I. D. D. is only given at two centres, namely, at Bangalore and at Allahabad. If my recom-

Centres of instruction.

mendations regarding the transfer of the Bangalore Institute to a new site and its establishment as an Imperial Dairy Research Institute are adopted, the question will arise whether I. D. D. courses should be run at the new centre. In this matter I strongly support the recommendation made by the Royal Commission on Agriculture⁽⁹⁾ that advanced dairying instruction should be undertaken at provincial agricultural colleges and not at the central institute. There are a number of reasons for this proposal. The present accommodation at Bangalore is entirely inadequate to meet the demand for admission to the course⁽¹³⁾. If the new Institute were to undertake the instruction of I. D. D. students, it would entail a very heavy capital expenditure on additional laboratories and equipment and on hostel accommodation. The staff would also need to be increased. On the other hand provincial agricultural colleges already possess teaching laboratories and equipment, and have, I understand, adequate hostel accommodation. They have a full complement of lectures on those general scientific and agricultural subjects which are included in the I. D. D. syllabus. The equipment of the dairy departments would undoubtedly need to be augmented, and increases would probably also be necessary in the dairy staffs. The provision of such additional equipment and staff would, however, tend to improve the dairying instruction for agricultural degree courses, in addition to catering for the I. D. D. course. I have already stressed the need for stimulating the interest of provincial Governments in the development of dairying. The transfer of the I. D. D. training to provincial colleges would, I believe, go far towards achieving this aim. There is, too, a further point. I have found that there is a definite tendency to discriminate between students trained at the Imperial Dairy Institute and those trained at the Allahabad Agricultural Institute, not on account of any difference in the efficiency of the training, but because training at the Imperial centre gives a better 'hall-mark' to the student. This attitude is unfortunate but, I believe, inevitable so long as the Central Government provides facilities for the course at its own institute.

It is very doubtful whether the training of I. D. D. students could meantime be satisfactorily undertaken at all provincial agricultural colleges. It is indeed questionable whether such a wholesale transfer of work would be desirable until more experience has been obtained regarding the possible difficulties involved. I suggest that under the circumstances the number of centres should meantime be limited. I assume that the Allahabad Agricultural Institute will remain as one centre. Geographically it would seem that at least two other centres would be required, one in Northern India (say Lyallpur) and one in Southern India (say Coimbatore). Such centres might be given financial aid by the Imperial Council of Agricultural Research on the lines already adopted in regard to the Allahabad Insti-

(13) As stated in a previous section, only 45 students have been admitted during the past 3 years, during which over 700 inquiries have been received.

tute. The possibility of extending the arrangements to include other provincial agricultural colleges should be considered in the light of the results achieved at these centres.

The transfer of instruction for the I. D. D. would, however, necessitate the adoption of certain safeguards. These may be summarised as follows :—

- (a) There should be not only a uniform syllabus for all centres, but a reasonable degree of uniformity in the methods of teaching. It would also be essential for the course to include adequate practical training in farm operations as well as in dairying. These points have been repeatedly stressed in examiners' reports.
- (b) The criticism has been made in examiners' reports that the present I. D. D. instruction at the Allahabad Agricultural Institute is handicapped by the lack of co-ordination between the teaching in the dairy department and that given in the pure science departments, the implication being that the teaching in pure science is not adjusted to the special needs of the I. D. D. course. This matter is obviously one which would need to be considered in drawing up the detailed scheme of training at each centre. It may be mentioned that in Great Britain it is the universal practice for N. D. D. students to receive part of their instruction in pure science departments, and the system works satisfactorily.
- (c) It would be necessary for the I. D. D. course to be run according to college sessions and not (as is done at present) by calendar years.
- (d) It is essential that the examination for the I. D. D. should be of the same standard at each centre. For this purpose a central examining board would be required.
- (e) For the appointment of the examining board, as well as to settle all points of common interest, such as the syllabus and methods of instruction, a special committee should be constituted under the Imperial Council of Agricultural Research. This committee would also be responsible for recommending new centres, and for reviewing the standard of teaching and the facilities available at existing centres. The committee should include one nominee from each recognised centre as well as members appointed directly by the Imperial Council. It should meet at least once each year, preferably immediately after the annual examinations, so that the examiners' reports could be submitted and any necessary action taken. The committee should be responsible

for printing and publishing the syllabus, which might also include brief notes on the facilities available at each centre.

At present there are two avenues open to graduates who require advanced training in dairying, namely to take the so-called post-graduate course at the Bangalore Institute, or to go to Great Britain in order to take the course for the National Diploma in Dairying.

Post-graduate training in research.

As regards the N. D. D. course in Great Britain, I consider that this is entirely unsuitable for Indian students. The N. D. D. course is based on a study of British farming conditions and of British dairy products such as butter and cheese. Indian students who qualify for the N. D. D. return to India with, I believe, entirely erroneous views regarding the possible application of Western dairying methods to Eastern conditions. This is likely to do the Indian dairy industry more harm than good.

As regards the existing post-graduate course, it has already been stated that this is largely a duplication of I. D. D. training, and could quite well be amalgamated with the I. D. D. course. The I. D. D. forms an excellent basis for practical dairy training, and if an agricultural graduate possesses the I. D. D. in addition to his degree he should be well qualified to fill any post in the educational or advisory services or in the commercial field. There are, however, very few Indian graduates who are qualified to undertake research work in dairy science. In such work a detailed knowledge of technical dairying is a secondary consideration. The research worker needs to have a thorough training in scientific methods of investigation and a fundamental knowledge of one or more branches of pure science. Such a man can readily acquire the necessary acquaintance with dairy practice without extensive practical training. It is significant to note that an essential qualification for agricultural research workers in Great Britain is an Honours degree in science, and that the Royal Commission on Agriculture recommended the adoption of this standard in the recruitment for research posts in the Indian agricultural services⁽¹⁴⁾.

I am convinced that little real progress will be made in the solution of Indian dairying problems until a nucleus of specially trained graduates is available to undertake the necessary scientific investigations. It is here that benefit should be derived from the establishment of a properly equipped Dairy Research Institute, since part of the work of such an institute should be the training of science graduates in research methods. Moreover, opportunity should be taken to encourage such graduates (preferably after a period of study at the central research institute) to gain further experience by studying at recognised research laboratories abroad. The objection to foreign training in dairying which was noted earlier in this section does not extend to training in research, since the latter involves a general study of the application of scientific principles and

(14) *Loc. cit.*, p. 634.

technique to the solution of dairy problems, and not merely a specialised knowledge of dairying practice.

If science graduates are to be encouraged to enter this field of study, certain incentives will, I think, be necessary. In the first place it is essential that such post-graduate research students should be able to work for higher university degrees at the Imperial Dairy Research Institute. This arrangement was suggested by the Royal Commission⁽¹⁵⁾ in regard to post-graduate students working at the Imperial Agricultural Research Institute. It should, I think, apply equally to the dairy research institute. In the second place it is desirable that funds should be made available to enable research scholarships to be awarded to promising science graduates to enable them to work at the central institute or to reside at a foreign research centre for an adequate period of training. The provision of such scholarships might be undertaken by the Imperial Council of Agricultural Research⁽¹⁶⁾. In the third place it will be valueless to give initial encouragement of this nature to promising students unless a real attempt is to be made to establish a research service for the dairy industry commensurate with its importance in Indian agriculture. I have already referred to the need for developing dairy research in the provinces. This will inevitably be a gradual process, but I anticipate that it should proceed with sufficient rapidity to absorb the specially trained scientific workers who will become available during the next ten or fifteen years.

If improved methods for the production and handling of milk and the manufacture of milk products are to be made use of in the villages, it will be essential to have available a large number of workers trained in certain elementary dairying practices. Such workers might be responsible for running village collecting or separating centres, for *ghee* or *khoa* making on a village industry basis, for the supervision of *mandies*⁽¹⁷⁾ or for running small retail milk shops. Such men would need elementary training in dairy hygiene and specialised training in the particular branch of work which they are to undertake. They would, in fact, correspond to the 'stockmen' who are already employed in certain branches of animal husbandry and veterinary work. Short vernacular courses would be necessary for the training of such men, but the syllabus of such courses should be elastic, being altered from time to time to meet the immediate needs of the dairy industry. The training would, of course, need to be undertaken at provincial centres, and successful trainees might be awarded a special college certificate. It would be desirable that the syllabus for such courses should be discussed with the Imperial Council of Agricultural Research, which could act as a valuable clearing house for information on the subject.

(15) *Loc. cit.*, p. 60.

(16) The scholarships offered by the Agricultural Research Council of Great Britain usually allow for two years work at home and a third year abroad.

(17) *i.e.*, *ghee* collecting depots.

In any such work I strongly recommend that serious consideration should be given to the provision of dairy training for women. Women have a natural aptitude for dairy work : moreover, they are already largely responsible for the handling of milk and the manufacture of milk products such as *ghee*. If improvements are to be effected in the handling of milk and milk products under village conditions, the cooperation of the women of the village is essential. In any attempt to provide special dairy training for women I suggest that collaboration should be sought with other agencies such as the health services, co-operative societies, and philanthropic and welfare associations.

The dairying instruction given at veterinary colleges is at present usually limited to a short course in milk inspection. It is very desirable that this instruction should be extended to include a knowledge of elementary dairying and of the principles involved in the production and handling of milk including the management of a dairy herd. The veterinary assistant is brought into close contact with the cultivator, and a better knowledge of dairying would frequently enable him to influence the latter in adopting improved dairying methods. The responsibility for this side of the work will tend to increase if, as I recommend later, the animal husbandry and veterinary services are unified. It is therefore all the more important that adequate instruction in dairying should be included in the syllabus of veterinary diplomas and degrees. The inclusion of such training will necessitate the provision of adequate accommodation for a small dairy herd and dairy at each veterinary college, and it is possible that the staff will also need to be augmented at some centres by the inclusion of a qualified instructor in dairying.

III.—ADVISORY SERVICES.

In Part I of this Report I have pointed out that very little is known regarding the best methods for the production and handling of milk and the manufacture of milk products under the tropical conditions of India. It might therefore appear doubtful whether the time is yet ripe for constituting dairy advisory services in the province. This would, however, overlook two facts.

In the first place the Imperial Dairy Expert is at present the only officer available in India to answer the large number of inquiries which come from all parts of the country. Owing to the time and expenditure involved in travelling, the Imperial Dairy Expert is only able to answer these inquiries by correspondence. He is, moreover, seldom in a position to know the local conditions of production and the local market requirements. Consequently he has to rely on the information—often incomplete or even misleading—which he is given by his correspondents. I found on more than one occasion that this had resulted in the installation of plant and equipment which was entirely unsuited to the local conditions.

and that in consequence there had been serious financial losses as well as loss of confidence. The Imperial Dairy Expert himself quoted an instance where a timely visit had put an entirely different complexion on a new dairying enterprise and had enabled him to reduce the proposed capital expenditure from a very large sum to a few hundred rupees. If a local advisory staff was available in each province, such difficulties would not arise.

In the second place it is clear that an officer such as the Imperial Dairy Expert cannot take any active part in stimulating the development of dairying in the provinces. Most provinces are at least as large as Great Britain and it will be readily understood that the services of a special provincial staff are essential if the needs of such large areas are to be explored and their potentialities developed. Such a provincial staff would, moreover, not only be in a position to give expert advice both to the provincial government and municipalities, but would be available as the medium for initiating any new schemes of development which might be planned.

Under these circumstances I strongly recommend that provincial governments should take the necessary steps to establish an

Need for a provincial advisory service. advisory service for the dairy industry. As a first step I consider that a specialist officer should be appointed in each province. This officer could undertake a preliminary survey of the needs of the province. Further development would depend on the results of his survey : whether, for example, progress could best be achieved by organising village milking centres, or by encouraging the co-operative production of milk products, or by the establishment of grading centres and other improved methods of marketing. It is essential that the specialist officer should not merely look on his post as that of an expert adviser. His major duty should be to initiate developments, and to take the lead in encouraging the adoption of improved dairying methods. For this reason I suggest that his official designation might be that of " Dairy Development Officer ".

The question at once arises as to the department to which this officer should be attached and as to the means which should be adopted for keeping him in touch with the

Methods of securing co-ordination. centre. In this connexion I have been greatly impressed with the organisation of the agricultural marketing staff. Provincial Marketing Officers, while nominally attached to agricultural departments, actually work under a small committee representative of the various departments and interests concerned. As regards contact with the centre, arrangements are made by which close touch is maintained with the Agricultural Marketing Adviser to the Government of India, and all marketing surveys are co-ordinated through this channel. I consider that a somewhat similar arrangement might be adopted in regard to the administrative position of the Provincial Dairy Development Officers.

The development of dairying is closely related to many other branches of government activity. I suggest that the committee under which the Dairy Development Officer should work should include the Director of Agriculture, the Director of Veterinary Services, the Director of the Public Health Department, the Registrar of Co-operative Societies, the Provincial Marketing Officer, and not more than three other members who should be nominated on account of their special interest in some aspect of dairying⁽¹⁸⁾. One of these should be a member of the dairy staff of the provincial agricultural college. This arrangement would ensure the co-ordination of dairy developments with Government activities in closely allied fields, and would provide the Dairy Development Officer with a valuable source of advice and assistance in the planning of his work*.

Co-ordination with the central Government involves a more complex problem. The development of dairying in India is primarily the concern of provincial Govern-

Co-ordination with the centre. Owing to the very undeveloped condition of the industry it is, however, essential that the central Government should take a prominent part in initiating and co-ordinating any developments. I have already recommended the establishment of an Imperial Dairy Research Institute as the main contribution which the central Government can make to the development of the dairy industry. It is, I believe, equally important that the central Government should encourage the exchange of ideas and experiences among Provincial Dairy Development Officers and also between such officers and the staff of the central Research Institute. The obvious channel for such co-ordination is the Imperial Council of Agricultural Research. One method of achieving this aim would be to attach a specialist officer to the Council whose duties would include the co-ordination of dairy developments and of dairy research in the provinces. I believe, however, that the purpose in mind could be achieved more efficiently and economically by combining these duties with those of the Director of the Imperial Dairy Research Institute. The Director should be the best qualified worker in this field in India. He will be in intimate touch with the latest research work at his own institute as well as at other research centres in India and overseas. For the successful planning of the Institute's programme of work he should, moreover, be kept closely in touch with the needs of the Indian dairy industry, and this could be assured if he has facilities for maintaining personal contact with the Provincial Dairy Development Officers.

For administrative reasons it is, however, essential that the actual channel of communication should be through the Imperial Council of Agricultural Research. I suggest, therefore, that the

(18) See, however, the suggestions put forward in Appendix VI.

*The actual executive control of the Dairy Development Officer might be entrusted to the Head of the Department responsible for animal husbandry development.

Director of the Institute should not only be appointed a member of the Council, but that he should act as part-time Dairy Expert to the Council in so far as his duties include those of advising and co-ordinating work in the provinces and constituent states. The transfer of the Institute from Bangalore to a site nearer to New Delhi will facilitate this arrangement. I should make it clear that this proposal is not intended to prejudice the ultimate appointment of a full-time Dairy Expert to the Council if the growth of organised dairying should justify this step.

I should perhaps state at this point that I feel that the relationship between the Imperial Council of Agricultural Research and the three Imperial Research Institutes⁽¹⁹⁾ requires clarification. The functions of the Council are not limited to the promotion, guidance and co-ordination of agricultural and veterinary research. The Council is also designed to act as a clearing house of information in regard to agricultural and veterinary matters generally⁽²⁰⁾. In this respect it stands in a unique relationship to provincial Governments, and it is therefore the obvious body through which co-ordination and the exchange of ideas and experiences should be secured. But I believe that it is equally important that the Council should be able to make full use of the special facilities available at the Imperial Research Institutes, and that the programme of work of these Institutes should be subject to periodic review by the Council. Ultimately it may be desirable to establish a more direct relationship between the Council and the Imperial Research Institutes on the same broad lines as that which exists between the Council and the recently established Imperial Institute of Sugar Technology. In the meantime the appointment of the Director of the Imperial Dairy Research Institute as part-time Dairy Expert to the Council will ensure a very close measure of collaboration between these two bodies.

If this additional duty is to be undertaken by the Director of the Institute it is essential that he should be provided with a special officer who can relieve him of much of the detailed work involved, and who can act as a personal liaison officer between the centre and the provinces. Such work will probably involve considerable travelling, since one of its objects will be to assist Provincial Dairy Development Officers in the initiation and development of new methods of handling milk and milk products. It is obvious that the Director cannot undertake this work personally. It is desirable that, in addition to an extensive knowledge of the dairy industry, the officer appointed should have had experience in similar organising work, preferably in connexion with the supervision of provincial marketing inquiries. The establishment of this post will supersede the present position of Imperial Dairy Expert.

(19) i.e., the Imperial Agricultural Research Institute, the Imperial Veterinary Research Institute, and the Imperial Dairy Research Institute.

(20) Memorandum of Association of the Imperial Council of Agricultural Research.

I should, perhaps, refer briefly to the probable costs involved in the establishment of dairy advisory services in the provinces. The initial expenditure should not exceed, say, Rs. 25,000 per year in each province, which would meet the salary and expenses of the Provincial Dairy Development Officer, with perhaps one or two assistants. The ultimate expenditure would considerably exceed this sum, but would probably not be in excess of Rs. 1 lakh per year. It is instructive to compare this with the expenditure involved in the dairy advisory services of Great Britain. The total number of county instructors and other advisory officers employed is 125, and the expenditure *on salaries alone* is roughly £30,000 (Rs. 4 lakhs). Yet the value of Great Britain's output of milk is only about a quarter of that of India. Moreover, in India the provision of Government assistance is far more urgently required than in great Britain, owing to the backward state of the Indian dairy industry. If the establishment of provincial advisory services resulted in an increase in the value of milk products by only one-tenth of one per cent. of its present value, the sum realised (Rs. 30 lakhs) would be far more than sufficient to justify the whole of the administrative expenses involved.

CHAPTER XII.—Recommendations for the future development of Research, Education and Advisory services in connexion with cattle improvement.

In Part II a description has been given of the efforts which are being made to improve the general standard of Indian cattle, and attention has been directed towards some of the major problems to be solved and some of the more urgent difficulties to be overcome in achieving this end. The present chapter will be devoted to specific recommendations in connexion with the future development of the cattle industry. As in the previous chapter, the subject will be dealt with under three heads, namely research, education and advisory services.

I.—RESEARCH.

The existence of a number of large Government breeding farms in India offers unique facilities for the study of problems of inheritance in cattle. It is therefore somewhat surprising to find that no notable contributions to existing knowledge have been made in this field by workers in India. I believe that this is largely due to the fact that there has in the past been no focussing point for such work. The breeding farms have been run on strictly utilitarian lines; unsatisfactory animals have been "culled" and no serious attempt has been made either to record the full breeding data of the herds or (where such data have been recorded) to analyse the results systematically. Thus the opportunity of collecting and analysing information of great potential value has been neglected. As a first step in remedying this position it is, I believe, essential that a first-rate geneticist should be recruited for service in India. I have been particularly struck by the valuable results achieved by geneticists in plant breeding, and I do not doubt that equally valuable (though less rapid) results might be achieved in the field of animal breeding. I understand that proposals are already under discussion for the establishment of an animal genetics section of the Imperial Veterinary Research Institute at Izatnagar. I believe that such a section would prove to be a great asset in the future development of cattle breeding in India⁽¹⁾.

Work in this field may be classed under three heads: problems associated with inheritance, problems involving a study of the physiology of reproduction (including endocrinology), and problems connected with management and constitution.

As regards problems of inheritance, there is no doubt that these can best be investigated in collaboration with existing cattle breeding farms. In the study of the inheritance of milking capacity, the lack of any uniform system of milk records—indeed the

(1) The Royal Commission on Agriculture in India (Cmd. 3132, p. 242) expressed the view that the time was not ripe for the establishment of an animal genetics institute in India, and stated that much valuable work in cattle breeding might be done without such a centre. Their arguments apply, however, only to research into specific problems of inheritance; they do not apply to the relatively modern developments which are now included under the general heading of genetics, namely endocrinology and the physiology of reproduction.

lack of breeding herds in general—has in the past been a serious handicap. The only data at present available are those which have been specially collected at a few agricultural centres and on Military Dairy Farms. As the breeding of milking strains extends this position will gradually be remedied. In the meantime, however, much useful data can be accumulated regarding the inheritance of milk yield in stock whose milking potentialities have so far remained relatively undeveloped. Breeding studies should not, however, be limited to milking stock. There is little information available regarding the inheritance of draught qualities and conformation. There is, too, the vexed question of the feasibility of breeding for draught and milk. Cross-breeding with European stock also offers scope for investigations by the geneticist*. The study of these subjects could most easily be undertaken by co-operation between the genetics section at Izatnagar and the various Government breeding farms.

The second group of problems, namely those concerned with the physiology of reproduction and endocrinology are, however, best studied on a relatively small scale, at any rate in the earlier stages of the work. The feasibility of artificial insemination would, for example, need to be tried out under experimental conditions before it could be tested in the field. Hormone therapy would also require to be carried out on a scale permitting careful control and in collaboration with workers in other branches of animal husbandry and veterinary pathology. For such work Izatnagar itself would form an excellent centre.

The third group of problems, which are concerned with the relation of constitution to management, have been discussed in some detail in Chapter VIII. The study of these problems has so far been limited to two main centres, namely the Imperial Agricultural Research Institute and the Military Dairy Farms. I consider that such problems are of great significance in relation to the improvement of milking capacity in cattle kept under the tropical conditions of India, and that their investigation should be continued and if possible extended. In particular, attention should be given to the influence of feeding and of climatic conditions on constitution (preferably measured by some objective physiological response) as well as on the rate of growth and age of maturity. I suggest that this work should include not only Indian milk cattle, but buffaloes and European cross-breeds. Such work will probably be continued at the Imperial Agricultural Research Institute, but I consider that it is of sufficient importance to be undertaken at other centres, particularly at Izatnagar and at the new Dairy Research Institute.

I have already indicated that nutritional research problems fall into three groups: first, problems connected with the production and conservation of fodder suitable for milch cattle; second, the formulation of a system of rationing suitable for Indian cattle;

Nutritional problems.

pro-

blems.

*i.e., as part of a study of the inheritance of milk yield. This does not affect the general conclusions regarding cross-breeding which are outlined in Chapter IX.

and third, the detection and remedy of specific forms of nutritional deficiency attributable to the lack of adequate minerals and vitamins in the diet.

The first group of problems requires widespread field-work in order to determine the feasibility of the growing of fodder crops in different localities and under varying climatic conditions. As indicated in Chapter VII this does not only involve the study of yields and costs of production, but necessitates the investigation of the influence of such crops on soil fertility. Briefly the general problem involved is that of establishing a system of 'mixed-farming' suitable to Indian conditions. In order to determine the feasibility of such a development it is obvious that the centres for investigation should be as numerous as possible. There are at present throughout India some 200 Government farms distributed as shown in Table 39⁽²⁾. Of these only 40 are cattle breeding farms; the remainder are experimental and demonstration farms which are primarily utilised for crop production. Such farms usually possess only a few bullocks, which are used for cultivation. If (as I recommend later) small dairy herds could be attached to each of these farms, admirable facilities would be available for the investigation of 'mixed-farming' methods under a wide variety of conditions. The effect of mixed farming on the yield of cash crops and food crops, as well as on the yield and cost of production of milk, could thus be investigated on a practical scale and at centres which are already recognised as the main sources of information to the progressive cultivator. Side by side with such investigations, practical observations would need to be made into the effect of different qualities and quantities of fodder on the health, growth, maturity and milk yields of cattle. It is desirable that part of this work should, however, be carried out on 'country' cattle and not on improved breeds, since it is important to ascertain what would be the economic effect of the adoption of 'mixed-farming' *under existing village* conditions.

The second general subject for investigation, namely rationing, requires a very different type of organisation. The ultimate formulation of satisfactory feeding standards entails exact scientific experiment, and this is only possible at centres which possess special equipment and a staff of trained scientists. The sub-division of this subject has been dealt with in Chapter VIII; it only remains for me to suggest a suitable allocation of the work between the various existing centres. The recent establishment of an Animal Nutrition Section of the Imperial Veterinary Research Institute at Izatnagar fundamentally affects the allocation of work⁽³⁾. Although full use should obviously be made of the facilities available at the three provincial centres (*i.e.*, Lyallpur, Coimbatore and Dacca), it is inevitable that much of the funda-

(2) "Agriculture and Animal Husbandry in India, 1933-35", Part II, pp. 54-63.

(3) This takes the place of the Physiological Chemist's section at Bangalore.

mental work of all-India importance should now tend to be centred at Izatnagar.

Bearing in mind the ultimate objective, namely the formulation of a rationing system, the work may be divided in one of two ways. It may be divided according to function, that is, in terms of requirements for maintenance, growth, work, reproduction or lactation. Alternatively it may be divided according to the food constituents studied, namely the energy, the protein or the mineral constituents. In practice it is more economical to allocate investigations according to function, since food and excreta from a single animal can be used for a number of different analyses. The investigation of energy requirements is an exception to this generalisation, since such work requires a specially constructed calorimeter and a very highly trained staff.

Under these circumstances I suggest that the energy requirements for all functions should be studied at a single centre, and that the central laboratory at Izatnagar should be provided with the necessary equipment and staff for this purpose. The remaining work could be allocated among the three provincial centres. From geographical considerations it would seem that requirements for milk production should be studied at Lyallpur, requirements for work at Coimbatore (where special facilities already exist) and requirements for growth and reproduction at Dacca. The study of mineral requirements is particularly important at the two latter centres, which are situated in areas where stunted growth is not uncommon. At all centres the work should be carried out on both Indian cattle and buffaloes, since the efficiency of digestion and utilisation of food appears to differ for these two types of bovine.

This provisional allocation of work is not meant to be mutually exclusive. Success in research depends largely on the initiative and keenness of individual workers, and it would be unfortunate if any scheme of co-ordination were to have the effect of discouraging workers in the prosecution of promising lines of work. On the other hand the subject is such a large one, and the means at the disposal of each centre are so limited, that it is most desirable that unnecessary overlapping of work should be avoided. I consider that in order to assist in co-ordinating the work of the various centres, a small committee of those concerned should be set up under the Imperial Council of Agricultural Research. This would also form a valuable medium for discussion and for the exchange of information and experience.

I have mentioned in Chapter X that, apart from the determination of the nutritional requirements of cattle, it is most desirable that representative analytical figures should be obtained for the large variety of feeding stuffs available in different parts of India. I understand that suitable facilities for such analyses are already available at the Imperial Agricultural Research Institute, New Delhi, where investigations are in progress into various branches of crop production. I therefore recommend that the Institute should be responsible for undertaking the comprehensive fodder and feeding

stuffs analyses which will be necessary in connexion with the ultimate formulation of a rationing system.

The third general group of problems requiring investigation is that concerned with mineral and vitamin deficiency diseases.

Deficiency diseases. Here there are three methods of approach. One method, namely the accurate determination of mineral requirements, has already been dealt with. The second is the correlation of these requirements with the mineral composition of herbage. In this work, which is of a purely routine nature, the adequate equipment and staffing of a central analytical laboratory would prove the cheapest and most convenient means of undertaking the large number of analyses required. I suggest that the Nutrition Section at Izatnagar should include such a laboratory, and that where mineral deficiencies are suspected, arrangements should be made to send typical samples of fodder to this laboratory for analysis. The third method of approach is the recognition of the clinical signs of nutritional deficiency disease. At present the Disease Investigation Officers⁽⁴⁾ are largely responsible for this branch of the work. The first cases of osteomalacia reported in India were, in fact, discovered as a result of the work of one of these officers. I consider that such work is of very great importance and would alone warrant the continuation of the appointments of Disease Investigation Officers. It is, of course, essential that in any suspected cases of nutritional deficiency disease the co-operation of the Nutrition Section at Izatnagar (and where necessary of other sections) should be enlisted on the lines suggested above.

II.—EDUCATION.

Facilities for the training of students in cattle breeding, feeding and management are at present altogether inadequate. Apart from instruction included in the syllabus of agricultural degrees and veterinary diplomas, there are only two courses open to students, namely, special training given at the Imperial Agricultural Research Institute and the instruction included in the I. D. D. syllabus. Yet the future development of the cattle and dairying industries must depend largely on the supply of well trained men capable of supervising the work of government breeding farms and similar centres. The provision of suitable training will be all the more important if a determined effort is to be made to improve the standard of Indian cattle. As a result of my inquiries I consider that training is required in four directions : first, improved teaching in existing agricultural and veterinary courses ; second, post-graduate experience in cattle breeding and management ; third, post-graduate research training in genetics and animal nutrition ; and fourth, elementary courses of instruction for so-called ' stockmen '.

I should make it clear at the outset that in breeding and live stock management generally, theoretical teaching cannot replace practical demonstration and experience. It is essential therefore that agricultural and veterinary colleges should possess both farm land and live stock. Table 40 shows the

Instruction at agricultural and veterinary colleges.

(4) Appointed through the Imperial Council of Agricultural Research.

present facilities available at the various provincial centres. It will be seen that on the whole the facilities at agricultural colleges are reasonably satisfactory. During my visits of inspection it was made clear that students had ample opportunities of handling stock and of taking part in the various farm operations. At all centres stock-judging is taught, both on the college farm and during visits to other breeding farms. It is unfortunate to find that two of the agricultural colleges rely on cross-bred European stock for their own dairy herds. This is apt to give students a false impression of the potential value of Indian breeds of cattle. It may also be mentioned that there is a tendency to instruct in stock-judging from diagrams of European breeds. This will probably be remedied when the details of Indian breed types are published by the Imperial Council of Agricultural Research.

At veterinary colleges, on the other hand, facilities for practical training are lacking, except at one recently established centre⁽⁵⁾. The actual handling of live stock is, of course, included in the students' ordinary routine. But the stock handled are mainly in a diseased condition: no practical instruction is given in the management of healthy stock, nor in day-to-day farming operations, nor in milking or practical dairying. There is, of course, theoretical teaching in animal husbandry at all the veterinary colleges, but at two centres this does not include practical experience in such subjects as stock-judging. At the remaining centres reliance for such training is placed on very occasional visits to breeding farms and cattle shows. I consider that it is essential that this lack of practical training should be remedied. As a minimum, each veterinary college should possess a small herd of milking cows, with accompanying bulls and young stock, and sufficient land to demonstrate agricultural operations and to produce fodder for the herd. This would, of course, also entail the keeping of one or two pairs of draught bullocks. A suitably equipped dairy would also be needed to demonstrate the essentials of dairy hygiene. Without these facilities no improvement can be anticipated in the present level of animal husbandry instruction in the veterinary colleges, which is of a definitely low standard.

The ordinary student who has taken a degree or diploma at an agricultural or veterinary college should be sufficiently well qualified to be able to handle, manage, and judge cattle. But this training is, of course, quite inadequate to qualify the student for a responsible post in a large cattle breeding farm. For such a post a student would require advanced training and experience in cattle breeding and management. In the past reliance has been chiefly placed on the recruitment of Europeans to fill important cattle breeding posts. There is no reason why such work should not be undertaken by qualified Indians, provided that facilities for training are improved.

It has been aptly stated that the true stock breeder is born and not made, but there is also considerable truth in the contention that

(5) i.e., at the Patna Veterinary College.

'an eye for stock' can be cultivated by continued contact with animals, provided that the student has sufficient guidance from a first-rate practical breeder. The potentialities of a student for live stock work will usually become apparent during his college course, and every effort should be made to pick out such students for further training. This should be along two lines: first, actual experience on an approved breeding farm (such as a provincial cattle breeding farm), and second, an advanced course in animal husbandry at a central institution. Until the details of the various developments at Izatnagar have been decided (including the facilities for teaching in connexion with the proposed central veterinary college, and the establishment of a genetics section of the Imperial Veterinary Research Institute), I cannot do more than recommend in general terms the institution of such a course of training as that outlined above. I feel, however, that in view of the urgency of ensuring an adequate supply of trained breeders for the responsible posts which will fall vacant within the next few years, a provisional scheme of training should be arranged at a very early date*.

The provision of post-graduate research training in animal nutrition should not prove difficult. There are already three provincial centres at which research into animal nutrition is studied, and the Nutrition Section at Izatnagar is in course of erection. No facilities at present exist, however, for research training in animal genetics. This position will be remedied with the establishment of a Genetics Section at Izatnagar. In the meantime students who require such training will need to be sent to research centres overseas. The demand for workers with research qualifications in genetics will never be large. There are, however, few if any Indian students who possess such qualifications at present. If a Genetics Section is to be established at Izatnagar, it is essential that this position should be remedied. I suggest that the Imperial Council of Agricultural Research should consider the establishment of one or two special scholarships to enable promising post-graduate students to obtain the necessary research training overseas.

As in dairying, the ultimate dissemination of knowledge acquired at research centres and elsewhere depends on the employment of a large staff of trained men who can work among cultivators in the villages. This fact has led to the proposal that special elementary courses should be instituted for the training of 'stockmen' who can assist the provincial veterinary staffs in such activities as vaccination, castration and general live stock improvement work. This subject was discussed in detail at a recent meeting of the Animal Husbandry Wing⁽⁶⁾, when it was suggested that such a course might occupy 6 months and that the subjects taught should be dressing and compounding and the treatment of simple and minor

*I suggest that as an interim measure advantage might be taken of the personnel and facilities available at the Imperial Agricultural Research Institute, New Delhi, and at its sub-station at Karnal.

(6) Report of the Sub-Committee on Veterinary Education.

ailments, castration, the registration of pedigree stock (including the tattooing and branding of animals), rendering assistance in vaccination and inoculation work, dipping operations, and other miscellaneous duties of a simple character. I am strongly in favour of the institution of such courses of training. I do not consider that any substantial progress can be made in improving the live stock of the country without a large increase in the personnel of the provincial veterinary departments. Since much of the work is of an elementary and routine character, it could however quite well be performed by less highly trained men than veterinary assistants. Moreover, the employment of such 'stockmen' will, I believe, have the indirect effect of raising the standard of training and efficiency of veterinary graduates, a direction in which there is undoubtedly room for improvement.

III.—ADVISORY SERVICES.

In the previous chapter it was pointed out that no provincial services existed for advisory work in relation to the dairy industry. The provision of advisory services for animal husbandry and veterinary work and the responsibility for live stock improvement have long been recognised as falling within the duties of provincial governments. In most provinces, however, such work has been under dual control, veterinary departments being responsible for the control of disease and for castration, and agricultural departments for the breeding and distribution of pedigree and approved bulls. There is no doubt that this dual control has been detrimental to cattle improvement. I propose, therefore, to deal with this general question in some detail. I shall then outline certain supplementary recommendations.

During my tour I had ample opportunity of discussing the control of cattle improvement with directors of agriculture, directors of veterinary services, and live stock experts, as well as with independent persons connected with cattle breeding. As a result of my inquiries and of the examination of a number of other relevant considerations, I consider that the unification of live stock improvement and veterinary work into a single department of animal husbandry will ultimately* be essential for the successful development of the cattle industry. The chief considerations which have led me to this conclusion may be summarised as follows :—

The control of cattle improvement.

(1) The whole tendency in modern medicine is to substitute preventive for curative treatment. This is equally true of both human and veterinary medicine. Adequate nutrition, sound breeding and a favourable environment are held to be as important as preventive vaccination and inoculation. The linking of all such preventive measures is specially necessary in a country like India,

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*I recognise that for local and personal reasons immediate unification may not be desirable or possible in all provinces. This does not affect my view that unification is the *ultimate* goal to be aimed at if the best use is to be made of the personnel of the live-stock and veterinary departments.

where, as a result of the lack of adequate communications and of the extreme poverty of the cultivator, curative treatment of individual animals is seldom possible.

- (2) Any attempt to improve the standard of cattle by the distribution of pedigree or approved bulls is of little value unless it is accompanied by the castration of inferior males and the inoculation of improved stock against contagious disease. The two latter measures are already under the supervision of the provincial veterinary departments. It is clear that the dual control of live stock improvement under village conditions is fraught with difficulty, and it would obviously facilitate such work if the distribution of bulls and the castration and inoculation of stock was placed under the same supervision⁽⁷⁾. Moreover, by utilising trained stockmen for all three duties (as well as for the registration of progeny, the need for which has been stressed in Chapter VIII) considerable economy should be effected.
- (3) In general, the training of a veterinarian should give him special qualifications for the care of stock. Regarding these qualifications the Royal Commission on Agriculture⁽⁸⁾ have stated that "Where the knowledge and instincts of the farmer and cattle breeder are combined with the professional training of the veterinary surgeon the position is ideal".
- (4) The provincial agricultural departments already have a very wide field of work. They are responsible for demonstrating and advising on the methods of cultivation of a great variety of crops. They have charge of all improvements in crop production and undertake the distribution of improved seed. In addition they are responsible for the control of plant diseases. Under these circumstances their interest in cattle improvement is bound to be a very minor one.
- (5) This fact accounts for the small proportion of the agricultural staffs who are used for live stock improvement work. Table 41 shows the number of gazetted and non-gazetted officers attached to the agricultural and veterinary departments. It will be seen that the total numbers are very similar, especially in the non-gazetted posts. But special inquiries which I made during my tour showed that out of roughly 2,000 agricultural officers only some 80 (or 4 per cent.) were actually engaged in live stock improvement. On the other hand the whole of the veterinary staffs (namely,

(7) It may be noted that in most provinces the veterinary staffs are already responsible for the health of pedigree bulls distributed to villages.

(8) *Loc. cit.*, p. 239.

1,800 officers) are already engaged in one branch of this work, namely, castration and inoculation.

- (6) A similar position is also found in regard to the relative expenditures of the departments on live stock improvement. Table 42 shows that only 6 per cent. of the expenditure included in the agricultural budgets is allocated to cattle improvement. Such work must obviously take a minor place in the departments' activities. The whole of the expenditure of the veterinary departments is, on the other hand, already devoted to live stock work, and it is significant that in the Punjab (where animal husbandry work is under veterinary supervision) 18 per cent. of the expenditure is used directly in the breeding and distribution of pedigree bulls.

These facts appear to me to provide a very strong case for unifying animal husbandry and veterinary work into a single department of animal husbandry, and I strongly recommend that in the interests of both efficiency and economy this policy should ultimately be adopted by provincial governments. Certain safeguards will, however, be necessary. These may be summarised as follows :—

- (a) It is probably inevitable that the Director of the unified department should be a qualified veterinary surgeon. While the Director must obviously retain general control over all sides of the work, it is, I believe, essential that he should have on his staff a Live Stock Expert with special knowledge and experience of cattle breeding. This officer should not only be available to give expert advice on breeding matters, but should be given full responsibility for the running of provincial cattle breeding farms and for selecting and purchasing pedigree and approved bulls. He should also be responsible for any work arising in connexion with the institution of herd books and milk records. For such an officer a veterinary diploma should not be an essential qualification: he should be selected primarily on account of his knowledge and experience of practical cattle breeding. At the same time every effort should be made to improve the training of veterinary graduates in all branches of animal husbandry.
- (b) The unification of animal husbandry and veterinary work will not eliminate the need for close co-operation between the agricultural and veterinary departments. This is particularly true if 'mixed-farming' is to be attempted on any considerable scale in the future. In some provinces the two departments are not under the same Minister, a position which calls for immediate remedy. But it will be necessary for co-ordination to be effected not only through official channels but through personal contact between the Directors concerned⁽⁹⁾. If my

(9) See, however, the suggestions outlined in Appendix VI.

suggestion regarding the appointment of Provincial Fodder Specialists is adopted, I anticipate that there will be very close collaboration between these officers and Provincial Live Stock Experts. This should also provide a valuable connecting link between the two departments.

- (c) In certain provinces the veterinary assistants are not under the direct control of the Director of Veterinary Services, but are employed by District Boards. If maximum efficiency and economy are to be achieved in live stock improvement, it is essential that all such assistants should work directly under the provincial government's veterinary staff.

I should perhaps refer briefly to the expenditure involved in live stock improvement. I have already pointed out that the unification of animal husbandry and veterinary work should result in a better return for existing expenditure. It is, however, inevitable that if substantial progress is to be made in cattle improvement, the total funds for animal husbandry work should be augmented. This is true whether live stock improvement is under the agricultural or the veterinary department.

The Royal Commission pointed out that in 1926 there was only one veterinary assistant to every 100,000 head of cattle but stated that the actual requirement was one assistant to every 25,000 head. Since 1926 the position has not improved appreciably, the present figure being one veterinary assistant to every 85,000 head of cattle. The number of assistants varies, however, from province to province. Table 43 shows that the suggested ratio of 1 : 25,000 has only been approached by two provinces, *i.e.*, the North-West Frontier Province and the Punjab, where incidentally live stock improvement is already controlled by the veterinary departments. This table also shows the expenditure on veterinary services and live stock improvement per head of cattle. It is significant to note that the number of pedigree and approved bulls at stud and the number of castrations performed (as shown in Tables 24 and 26) run roughly parallel with this expenditure. It is obvious, therefore, that further cattle improvement cannot be effected without increased expenditure, whether the control of such improvement is under the agricultural or the veterinary departments. Consequently the unification of animal husbandry and veterinary work should not be looked upon as a means of reducing expenditure on cattle improvement: rather is it a means of making the best use of any funds available for live stock improvement and of ensuring that such improvement is effected under the most favourable conditions.

In Chapter VIII, I discussed the measures which are being taken to effect a general improvement in the standard of Indian cattle. These measures are largely concerned with cattle of draught type. I have, however, indicated that there is an urgent need for developing the milking potentialities of in-

Supplementary
agencies for cattle
improvement.

digenous Indian breeds of cattle and that every opportunity should be taken to augment the number of agencies which can be employed in such work. Among these agencies I consider that three are of such importance as to warrant special mention in this Report.

Gowshalas and *pinjrapoles*⁽¹⁰⁾ were originally established as homes for ailing, maimed or economically useless cattle. They form a concrete example of the Indian reverence and affection for animals, and particularly for the cow. During recent years, largely as a result of the efforts of the Imperial Dairy Expert and of the Animal Husbandry Expert to the Imperial Council of Agricultural Research, an attempt has been made to direct the work of these institutions into more constructive channels, and particularly to use them as a means of improving the milking capacity of Indian breeds of cattle. Among the pioneer institutions which have adopted progressive methods of management may be mentioned those at Calcutta, Karachi, Bombay, Delhi and Cawnpore.

The activities of the Karachi Pinjrapole Association may be taken as typical of those of the best managed *pinjrapoles* and *gowshalas*. In 1926 this association was granted over 800 acres of land on permanent tenure and about 4,000 acres on lease from the Bombay Government on condition that the association established a dairy farm, a scientific breeding department, and a veterinary dispensary for the treatment of sick animals. At the present date there are 135 milking cows in the dairy herd, giving about 12 maunds of milk daily. Breeding bulls are kept by the association and can be requisitioned by the public of Karachi. In addition an average of about 100 animals are given free of charge to zamindars each year. The association runs two veterinary dispensaries, at which more than 1,000 animals are treated each year. These activities are carried on in addition to the ordinary work of the association, which is responsible for the maintenance of a total of nearly 3,000 head of cattle. Similar progressive methods are adopted at the other institutions mentioned.

The financial resources of such institutions are very considerable. They are maintained by charity or by a cess levied on commercial transactions which pass through the hands of those interested, or, in some cases, on all commercial transactions in the market. A special inquiry made during the course of my tour showed that the *gowshalas* of seven large cities were able to collect sums varying from 3 pies to 9 annas annually per head of population (Table 44). In Bombay, for example, the annual expenditure on *gowshalas* is over Rs. 3 lakhs, in Karachi it is just under Rs. 1½ lakhs, and in Delhi it is over Rs. 1 lakh. Taking the lowest *per capita* contribution, *i.e.*, 3 pies, and applying this to the total population of India, it may be assumed that the total annual contributions to *gowshalas* and *pinjrapoles* exceed Rs. 50 lakhs. This is a very conservative estimate, but

(10) At *gowshalas* only cattle are accepted and maintained. *Pinjrapoles* will accept and maintain all kinds of animals and birds.

is sufficient to indicate the very considerable sum involved⁽¹¹⁾. It is obvious that every effort should be made to encourage the expenditure of part of this sum in constructive breeding work such as that described above.

The question arises as to whether any assistance in this direction can be given by Government. It is, I believe, essential that there should be no interference with the internal administration of such institutions. One direction in which provincial governments might help is by the grant of land on favourable terms to *gowshalas* and *pinjrapoles* at which breeding work is undertaken. I found, moreover, during my tour that there was considerable ignorance among those responsible for the management of such institutions regarding the aims and methods employed at the more progressive centres. I suggest that this might be overcome by the appointment of a special officer whose duties would include the stimulation of local interest at the various centres and the giving of expert advice to institutions which desire to improve their methods of management and to adopt a constructive breeding policy. Such an officer would best be attached to the staff of the Animal Husbandry Expert of the Imperial Council of Agricultural Research. He should, of course, have had experience in this type of work and it is essential that he should also have the confidence of the Hindu community.

Throughout this Report I have made frequent reference to the excellent work carried out by the Military Dairy Farms. There are 33 such farms in India, with an adult cattle population of over 5,000 head. The work of these farms is characterised by the most careful supervision of breeding, feeding and management. The general policy of the farms has, however, been to rely on cross-breeding with European stock to improve the milk yields of Indian cattle. It is probably true that such cross-bred stock are particularly suited to meet the special requirements of the army authorities, which include the provision of large quantities of milk for liquid consumption at military centres. It is, however, unfortunate that this prevents the Military Dairy Farms from playing any part in the improvement of the milking stock of the country. Complaints have indeed been made in the past that the sale of cross-bred animals from such farms has led to deterioration in the quality of local stock. At one farm⁽¹²⁾, however, the policy of improving the milk yields of Indian cattle by the selection and breeding of high milking strains has been outstandingly successful, and the stock from this farm is, I understand, in great demand by progressive breeders. In view of the unique opportunities which are available at Military Dairy Farms to undertake controlled breeding, I feel strongly that the possibility of undertaking similar breeding work at all such farms should be seriously considered.

(11) According to one authority the figure should be very much higher than that quoted, namely about 18 crores of rupees.

This would, however, correspond to a yearly *per capita* contribution of 9 annas, which is the maximum contribution noted in Table 44. It is extremely unlikely that this figure could be taken as representative of India as a whole.

(12) Ferozepore.

I have already suggested that district and demonstration farms should, as far as possible, be used as centres for the experimental production of fodder crops, particularly in connexion with the investigation of 'mixed-farming' systems. This would entail the running of a small dairy herd at each farm. There are over 150 such farms throughout India, and the establishment of small pedigree herds at each farm would provide valuable nuclei for the breeding and distribution of improved milking stock in the provinces.

District and demonstration farms. These three agencies alone, namely, *gowshalas* and *pinjrapoles*, the Military Dairy Farms, and district and demonstration farms, would probably add 400 to 500 breeding centres to those at present available for the production and distribution of pedigree milking stock. Their use in this connexion would, I believe, prove invaluable as a means of raising the general level of milk production among Indian cattle.

In order to make full use of such breeding centres, it is, however, essential to devise a suitable system for the registration of pedigree stock. The opening of herd books and the establishment of a system of milk records has been referred to in Chapter IX, where it is stated that the characteristics of six milking breeds have already been defined. In view of the importance of this scheme in stimulating interest in the breeding of milking stock, I consider that it should be proceeded with as quickly as possible. The approval and registration of stock, the recording of milk yields and the general supervision of the scheme in the provinces should obviously fall within the duties of the Provincial Live Stock Experts. It is, however, essential that a register of stock and of milk records should be kept centrally. The Royal Commission on Agriculture recommended⁽¹³⁾ that this part of the work should be undertaken by the Imperial Council of Agricultural Research, a recommendation which I strongly endorse. The Council stands in a unique position in relation to the provinces. It has, moreover, been largely responsible through its Cattle Breeding Committee for the present development of the scheme. The existence of such a clearing house of information regarding the available milking breeds of the country should prove to be of great value in shaping future policy as well as in providing a record of the location and milking capacity of the best dairy stock of India.

The opening of herd books. There is one further point in connexion with live-stock improvement which requires emphasis. I refer to the need for providing a more adequate supply of fodder for cattle. I have already stressed the great importance of increasing the quantity and improving the quality of such fodder particularly in the feeding of milch cattle. A proposal has recently been put forward that each province should constitute a grazing and fodder committee (linked up with a sub-committee of the Imperial Council) in order to develop the fodder resources of the country. I strongly support

The provision of increased supplies of fodder.

this proposal. The consequent pooling of the ideas and experiences of the various officials in each province should ensure that full use is made of all possible means of increasing the supply of fodder. I feel, however, that it will be necessary to go a step further in this direction, namely, to appoint an officer in each province who can act as a fodder specialist. The activities of a committee are deliberative rather than executive, and I feel that a committee's efforts might be largely abortive unless there is available a specialist officer who can initiate schemes of development and carry out the various recommendations of the committee. I have been much impressed with the value of the work carried out by Provincial Live-Stock Experts, and I believe that a parallel service which would be concerned with the provision of adequate grazing and fodder resources would prove to be of real service in improving the condition of India's live stock*.

*The Central Fodder and Grazing Committee to be established by the Imperial Council of Agricultural Research as a result of the recent recommendation of the Board of Agriculture and Animal Husbandry may reach the conclusion that a central specialist officer is also necessary.

SUMMARY OF PRINCIPAL CONCLUSIONS AND RECOMMENDATIONS.

Chapter I.

1. The total output of milk in India is exceptionally large, being between 700 and 800 million maunds or 5,500 and 6,500 million gallons per year. Compared with other countries, India stands second in volume of milk production. She produces over four times the output of Great Britain, over five times that of Denmark, over six times that of Australia and over seven times that of New Zealand.

2. Owing to the density of India's human population the *per capita* consumption of milk is, however, extremely low. Estimates indicate that the average consumption per head per day does not exceed 7 to 8 oz.

3. According to existing dietary standards the quantity of milk required for the maintenance of satisfactory growth and health lies between 15 and 30 oz. per head daily. The output of milk in India would therefore need to be at least doubled in order to meet even the minimum requirement.

4. The consumption of milk is shown to vary according to income level. If consumption is to be increased it is essential that the price of milk should be within the purchasing power of the majority of the population. It is therefore not only necessary to increase the existing output of milk, but to effect all possible economies in the costs of production of milk and the manufacture of milk products.

Chapter II.

5. In planning the development of the dairy industry it is essential to ensure that it caters for the existing taste and dietary habits of the population. Marketing surveys show that, of the total output of milk, roughly one-third is consumed as liquid milk. Of the remainder over 76 per cent. is converted into *ghee* and over 22 per cent. into *khoa*, *dahi* and other indigenous products. Western products such as creamery butter and cheese are scarcely used except by Europeans and a small number of Indians who have acquired a taste for them.

6. The relative unimportance of Western products is also apparent from an examination of the quantity of milk products imported into India. These represent less than half of 1 per cent. of the total value of the milk products produced in India. An increase in the value of *ghee* by only 1 per cent. would add more to the wealth of the dairy industry than the replacement of the whole of the imported milk products by Indian produced articles.

7. There is little doubt that the evolution of the indigenous milk products which are peculiar to India (*i.e.*, *ghee*, *khoa*, *dahi*, and related products) has been largely due to the fundamental difficulties involved in handling milk under tropical conditions and to the special problems associated with the lack of adequate communications and transport facilities.

8. The fact that 90 per cent. of the population live in rural areas introduces a further obstacle to the introduction of Western methods into Indian dairying practice. In particular it appears that the widespread adoption of a large-scale factory system of dairying in India would involve almost insuperable difficulties.

9. These facts indicate that what is needed in Indian dairying is a new outlook and a new technique ; an outlook which recognises the special nature of India's problems, and a technique which is designed to solve these problems.

10. Among the more important considerations which should be taken into account in the formulation of such a technique the following may be mentioned : first, attention should be concentrated on the production of indigenous milk products and not on products of Western origin ; second, steps should be taken to ensure that an adequate supply of milk and/or milk products is available for consumption by the rural population ; third, any attempt to introduce improved methods should be effected by evolutionary rather than revolutionary changes of technique ; fourth, the combination of producers on a village industry basis (as distinct from a factory basis) should prove the most effective form of dairy organisation in India ; and fifth, any improvements in production should be supplemented by the provision of improved marketing facilities.

Chapter III.

11. Consideration of the methods of producing and distributing milk for liquid consumption should not be limited to the supply of milk to large urban centres, which include only some 3 per cent. of the population. Nevertheless, in view of the abnormally low milk consumption in large cities and of certain special difficulties involved in the provision of adequate supplies of milk in such densely populated areas, a separate section of the present Report has been devoted to problems connected with city milk supplies (Appendix II).

12. As regards the general problems of milk production and distribution, these are partly associated with the lack of knowledge of hygienic methods of handling milk, and partly with the difficulties inherent in the tropical nature of the climate, the poverty of the Indian cultivator, and the lack of adequate communications and transport facilities.

13. On account of these special difficulties the methods of producing and handling milk in India may have to be greatly modified from those employed in temperate zones. Extensive investigations will require to be carried out on this subject. Such investigations should not be limited to laboratory studies, but should be tried out in practice under village conditions.

14. Some form of heat treatment will probably prove the best and most economical method of prolonging the keeping quality of milk under tropical conditions. Such treatment should be applied as soon as possible after production. Refrigeration also offers great scope for development in relation to the transport of milk to large

cities, but the costs involved are considerable and will need to be greatly reduced if the method is to be capable of widespread adoption.

15. The distribution of milk not only introduces the risk of re-contamination but offers unlimited opportunity of adulteration. As regards re-contamination, it is extremely doubtful whether the introduction of modern Western methods, such as pasteurisation and bottling, could ever be employed on any considerable scale in India. For the mass of the population some form of 'loose' milk distribution is inevitable. It is suggested that cheap methods of 'loose' milk delivery, such as those largely employed in rural areas in Great Britain, should be investigated under Indian conditions, and if necessary modified to suit local needs.

16. As regards adulteration, figures collected from provinces show that from 20 to 65 per cent. of samples are watered or otherwise adulterated. Assuming that milk is, on the average, adulterated to the extent of 10 per cent. of added water, the financial loss to the dairy industry amounts to over 10 crores of rupees. Legislation exists for checking adulteration, but this is not applied effectively.

17. A second essential in checking adulteration is the formulation of reliable methods of analysis and satisfactory standards of purity. As regards methods of analysis, it is recommended that standardised apparatus should be employed and that revised conversion tables should be worked out. As regards standards of purity, extensive investigation is still required to enable the fairness of existing standards to be assessed. It is also suggested that the feasibility of allowing the 'standardisation' or 'toning' of milk should be considered.

Chapter IV.

18. There is no doubt that the production of *ghee* must be looked upon as the most important single factor in any scheme of development of the dairy industry. This product is of special value in Indian dairying economy, since it not only provides the cultivator with a cash sale, but leaves with him the greater and more valuable part of the milk, *i.e.*, the non-fatty solids contained in the *lassi* or butter-milk. This also applies to the production of 'country' butter.

19. The first direction in which improvement might be effected in the production of *ghee* is in the total outturn. But it is equally essential that quality should not be sacrificed in efforts to obtain higher yields of *ghee*. The whole subject of the relationship of out-turn to quality of *ghee* requires thorough investigation.

20. Figures collected from provinces show that up to 65 per cent. of the samples of *ghee* which were examined were adulterated. A calculation of the total quantities of adulterants available in India indicates that these amount to roughly 6 per cent. of the total output of *ghee*. It is found, however, that there is a difference of opinion

among authorities regarding the analytical standards for the detection of adulteration. These require re-investigation. In addition it is most desirable that a cheaper and quicker method for detecting adulteration should be devised.

21. It is suggested that the difficulties involved in the sale of *banaspatine* under the term (vegetable) *ghee* could be met by the adoption of legislation similar to that which governs the sale of margarine in Great Britain.

22. It is urgently necessary that facilities should be provided for the improved marketing of *ghee*. Additional markets should be established in those *ghee*-producing areas which are not at present adequately provided for. In addition, an attempt should be made to establish grading centres, preferably under the Agricultural Produce (Grading and Marking) Act, 1937. The value of advertisement as a means of popularising improved grades of *ghee* should be explored.

23. 'Creamery' butter constitutes only about 0.1 per cent. of the total output of milk products in India. There are, however, indications that the demand for such butter is increasing and the needs of this branch of the dairy industry should not therefore be entirely neglected. The most important direction in which improvement should be sought is in the quality (flavour and texture) of the product.

Chapter V.

24. Apart from liquid milk and *ghee* the most important dairy products produced in India are *khoa*, *dahi* and certain other indigenous milk products. The quantity of milk utilised in their manufacture approximates 95 million maunds (760 million gallons), which is more than twice that utilised for the whole of the production of manufactured milk products in Great Britain. It is also significant to find that the indigenous Indian milk products realise more per maund of milk than liquid milk itself. This is contrary to the experience of practically all Western countries, but re-emphasises the importance of these products to the Indian dairy industry.

25. Certain of these products are manufactured by a process of partial desiccation, while others are produced by the souring of the milk. The processes of manufacture are, however, primitive and crude, and urgently call for improvement. Attention should be given to better methods of packing and marketing and to the provision of standards of quality. It is also suggested that the manufacture of indigenous milk products might provide a useful outlet for separated milk, where this is available.

26. It is desirable that the nutritive value of the various indigenous milk products should be carefully investigated in view of their widespread consumption.

27. The production of cheese in India is negligible, and imports of cheese are equivalent to only 0.002 per cent. of India's total milk production. Nevertheless the manufacture of European varieties of cheese (to replace imports) might be encouraged at hill stations (Appendix III).

Chapter VI.

28. The amount of separated milk produced in India is small and little if any of it is wasted. A considerable quantity is, however, made into casein; and this is lost as a source of nutriment. The question arises as to whether it would be justifiable to attempt to establish milk condensing and drying factories.

29. The present market for condensed milk in India is relatively small. There is a considerable market in South and East Africa, in Malaya, and in other Far-Eastern countries, but the possibility of building up an export trade from India is open to considerable doubt. Very little milk powder is consumed in India, but there is some indication that the market for this product might be expanded. Consideration of a number of relevant factors indicates that the feasibility of establishing condensing and drying factories in India would depend largely on whether the requisite quantities of milk could be collected at convenient centres, and whether such milk would be of sufficiently good quality to be capable of conversion into condensed milk and milk powder.

Chapter VII.

30. India possesses the largest number of cattle of any country in the world. Out of the world's cattle population of about 690 million animals, 215 million (or just under one-third) are located in India. Owing to adverse climatic and economic conditions the productive value of the cattle industry is not commensurate with its size. Nevertheless the actual and potential value of cattle products is very great.

31. Milk and milk products may be valued at about 300 crores of rupees. This is roughly equivalent to the value of India's total output of rice, and is three to four times the value of the output of wheat. India is also the largest exporter of hides and skins in the British Empire, her yearly output of this group of products being valued at roughly 40 crores of rupees, or more than the value of the total Indian production of sugar. Cattle labour also represents an important contribution of live-stock to Indian agriculture, the monetary value calculated on the basis of cultivation costs being estimated at between 300 and 500 crores of rupees.

32. The value of cattle as a means of raising the fertility of the soil cannot be readily computed. One estimate places the cash value of cattle manure at 270 crores of rupees. There is no doubt that the widespread adoption of 'composting' would greatly enhance the value of this manure. But the potential value of cattle as a means of introducing a 'mixed-farming' system in India, and thus of improving crop yields, is incalculable. In any such system of 'mixed-farming' the introduction of leguminous fodder crops would still further increase soil fertility, while the improvement in crop yields would off-set any apparent increase in the cost of milk production.

Chapter VIII.

33. Comparatively slow progress is being made in the distribution of pedigree and approved bulls ; the number of bulls at present at stud represents only one per cent. of India's requirement. There is little doubt that material progress will only be achieved by increasing the number of approved and registered stock raised in villages and by private breeders. The purchase of such bulls for distribution provides a most valuable stimulus to improved cattle-breeding in selected areas and gives encouragement to progressive breeders. At the same time it is essential that ' type ' should be preserved within each breed, and this will necessitate the continued maintenance of Government breeding farms where the methods of breeding can be more accurately controlled.

34. It is difficult to assess the value of the present castration policy in eliminating the scrub bull. Progress in the number of castrations performed varies from province to province. There is still considerable difficulty in getting young stock castrated at a sufficiently early age. One direction in which future action should be concentrated is the intensification of castration measures in selected breeding areas, combined, if possible, with the inoculation of all local stock against rinderpest.

Chapter IX.

35. There is probably no single measure which would do more towards increasing and cheapening milk production in India than an improvement in the milk yields of Indian cattle. At present the yields of village cattle average only about 600 lb. per year. An increase in yield would lower the cost of milk production by spreading maintenance costs and costs of depreciation and labour over a larger output of milk.

36. In formulating breeding policies two essentials must be kept in mind : first, the necessity for adopting a policy which will meet local requirements ; and second, the need for continuity in the programme of breeding and the urgency of ensuring that the programme is not prematurely interrupted.

37. Certain breeders have tended to rely on cross-breeding with sires of high-yielding European breeds to raise the productivity of their stock. The immediate beneficial results of such cross-breeding on milk yield are striking, but they have invariably been obtained in herds where exceptional facilities for the control of breeding, as well as of feeding and general management, have been available. In the hands of *gowalas* and similar uneducated owners of milking stock the results have frequently been disastrous. There is no doubt that the general adoption of a policy of cross-breeding to improve the milk yields of country stock would be fatal to the development of sound dairying in India.

38. Breeding experiments carried out at various centres show that by careful selection indigenous strains of Indian cattle can be built up which are capable of giving milk yields comparable with

those found among average European stock. It is essential that the breeding of high yielding strains should be greatly extended. In order to encourage such breeding the establishment of herd-books and of a system of milk record should be proceeded with as soon as possible.

39. There is no doubt that she-buffaloes must be looked upon as the premier milk-producing stock in India. Their growing popularity is reflected in the census statistics, while marketing surveys indicate that they already provide nearly half of India's total milk supply.

40. With intensive milk production there is inevitably a constant rivalry between constitution and economic performance. Management is therefore an extremely important factor, particularly under the exacting conditions of climate experienced in the Indian plains. The relation of management to the maintenance of a sound constitution should be looked upon as one of the major subjects for investigation in connexion with the breeding of improved stock.

Chapter X.

41. The majority of Indian milch cattle are seriously underfed. This is apparent not only from a superficial inspection of stock, but from the slow rate of growth, the late maturity and the long dry periods of cattle kept under village conditions.

42. Estimates of the total quantities of nutrients available for the feeding of cattle in India show a marked deficiency, especially in the amount of protein. If milk production is to be increased the provision of a very much larger food supply is essential.

43. Coarse fodders are relatively valueless for milk production. Cultivated grasses are reasonably satisfactory, but the fodders of outstanding value are the leguminous crops such as berseem (Egyptian clover) and lucerne (alfalfa). It has already been noted that these are of special importance to Indian agriculture by virtue of their ability to enhance the fertility of the soil. Wide variations in the yields and costs of production of these fodder crops have, however, been recorded. Careful and extensive investigations into the factors responsible for these variations are urgently needed. Such investigations should include a study of the effect of the leguminous crops on the subsequent growth of cash and food crops. They should also include a study of the value of different fodders in the feeding of milking stock and on the costs of milk production. The conservation of such fodder crops also requires investigation.

44. Efforts should be made to increase the available supply of protein-rich concentrates such as linseed, cottonseed and earth-nut cakes. This might be achieved by encouraging the export of vegetable oils and by improving the efficiency of the mills.

45. It appears to be a fairly universal experience that Western rationing systems are not suitable for application to Indian cattle and buffaloes. It is therefore desirable that a suitable system of rationing should be devised for the guidance of milch cattle owners. In

addition it will be necessary to obtain representative analytical figures of typical feeding stuffs for as many agricultural areas as possible.

46. During the past few years instances of mineral and vitamin deficiency diseases have been recorded in India. There is little doubt that such deficiencies are far more common than has been generally supposed, and that they are a source of serious economic loss. It is desirable that extensive surveys of the incidence of such deficiency diseases should be undertaken, and that the information so obtained should be supplemented by accurate studies of mineral requirements and by mineral analyses of fodders drawn from typical cattle breeding and milk producing areas.

Chapter XI.

47. In order to provide an adequately staffed and equipped centre for research into the many problems which face the dairy industry, it is recommended that the existing Imperial Dairy Institute should be transferred to a more suitable site and should be reconstituted as an Imperial Dairy Research Institute. Under the Director the work of the Institute would be divided into four sections, namely, dairy bacteriology, dairy chemistry, dairy technology and dairy husbandry. Details are given regarding the buildings, equipment and staff required for such an institute.

48. If such an institute is established, the need for a separate experimental creamery (such as that proposed at Anand) will not arise. The Anand Creamery would, however, provide an ideal sub-station for the study of problems involved in the supply of milk to large cities, should such a sub-station ultimately be required. It is suggested that the whole of the Anand Creamery proposals should be held over meantime until the new Research Institute has been established and preliminary experiments have been carried out on the various problems involved in dealing with liquid milk.

49. Side by side with the development of the new Research Institute, efforts should be made to encourage the investigation of dairying problems at provincial agricultural colleges. The Imperial Council of Agricultural Research might give valuable assistance in this direction.

50. The course for the Indian Dairy Diploma provides a valuable basis of instruction for students who desire general training in dairying. The proposal to extend the period of instruction from two to three years is shown to be unnecessary, though certain alterations in the syllabus are desirable. In particular, more stress should be laid on the methods of production of indigenous milk products, on the need for devising cheap types of equipment, and on improvement in the methods of producing milk and milk products by cooperative enterprise and by the development of village industries. The course should also include practical training in methods of imparting instruction.

51. Training for the I. D. D. should be given at provincial agricultural colleges and not at the central institute. It is doubtful,

however, whether such training could at present be satisfactorily arranged in all provinces. It is therefore suggested that the number of centres should meantime be limited. The transfer of instruction would necessitate the provision of certain safeguards, including the adoption of a uniform syllabus and of a reasonable degree of uniformity in the methods of instruction at all centres and the establishment of a central examining board. The appointment of a special committee under the Imperial Council of Agricultural Research is recommended.

52. As regards post graduate training, the course for the National Diploma in Dairying of Great Britain is entirely unsuitable for Indian students. For graduates who require training in technical dairying, the I. D. D. course provides adequate instruction. For graduates who require training in research methods facilities should be provided at the Imperial Dairy Research Institute. Opportunity should also be taken to encourage such graduates to gain further experience by studying at recognised research laboratories abroad. For this purpose scholarships might be provided by the Imperial Council of Agricultural Research.

53. If improved methods for the production and handling of milk and the manufacture of milk products are to be made use of in the villages, it will be essential to have available a large number of workers trained in certain elementary dairying practices. Courses of training for such workers should be provided at provincial agricultural colleges. It is recommended that serious consideration be given to the provision of dairy training for women.

54. It is desirable that dairying instruction at veterinary colleges should be extended to include a knowledge of elementary dairying and of the principles involved in the production and handling of milk, including the management of a dairy herd.

55. It is strongly recommended that provincial governments should take the necessary steps to establish an advisory service for the dairy industry. As a first step it is suggested that a Dairy Development Officer should be appointed in each province. The major duty of such an officer would be to initiate dairying developments and to take the lead in encouraging the adoption of improved methods. The Dairy Development Officer should work under a special committee representative of the various branches of government activity concerned.

56. In order to secure co-ordination between the central and provincial governments, it is recommended that the Director of the Imperial Dairy Research Institute should act as part-time Dairy Expert to the Imperial Council of Agricultural Research, and that in this capacity he should be responsible for maintaining contact with provincial dairy developments. He should be provided with a special officer who could relieve him of much of the detailed work involved and who could act as a personal liaison officer between the centre and the provinces.

Chapter XII.

57. The solution of problems connected with the breeding of cattle requires the appointment of an animal geneticist. Work in this field would include the investigation of problems of inheritance, of problems involving a study of the physiology of reproduction (including endocrinology), and of problems connected with management and constitution. In the investigation of problems of inheritance full use should be made of records available at the various Government breeding farms.

58. Greater use should be made of existing experimental and demonstration farms (of which there are some 200 in India) in studying problems of fodder production. Such farms should be equipped with small herds of pedigree milch cattle. They could thus fulfil a dual function by acting as centres for the study of 'mixed-farming' methods and by providing valuable nuclei for the breeding and distribution of pedigree milking stock.

59. In devising a rationing system suitable for Indian cattle and buffaloes, full use should be made of existing provincial research centres (*i.e.*, Lyallpur, Dacca and Coimbatore) as well as of the newly established Animal Nutrition Section of the Imperial Veterinary Research Institute at Izatnagar. A provisional allocation of work is suggested in the Report. The Imperial Agricultural Research Institute at New Delhi should undertake such comprehensive fodder and feeding stuffs analyses as are required.

60. As regards mineral and vitamin deficiency diseases, the Disease Investigation Officers who have been appointed in each province through the Imperial Council of Agricultural Research should be responsible for field surveys, while facilities should be provided at the Nutrition Section at Izatnagar for the mineral analyses of suspected pastures.

61. Adequate facilities for instruction in breeding and live stock management are available at most provincial agricultural colleges. At veterinary colleges, however, facilities for practical instruction are lacking. It is recommended that, as a minimum, each veterinary college should possess a small herd of milking cows, with accompanying bulls and young stock, and sufficient land to demonstrate agricultural operations and to produce fodder for the herd.

62. There is urgent need for securing suitable men who can be specially trained in cattle breeding and management. The potentialities of a student for live stock work will usually become apparent during his college course, and every effort should be made to pick out such a man for further training. This training should include experience on an approved cattle breeding farm and an advanced course in animal husbandry at a central institution.

63. In connexion with the ultimate establishment of a Genetics Section at Izatnagar a small number of trained geneticists will be

required. It is suggested that the Imperial Council of Agricultural Research should consider establishing one or two special scholarships to enable promising post-graduates to obtain the necessary research training overseas.

64. The effective dissemination of knowledge acquired at research centres, as well as the control of breeding and live stock improvement, will ultimately depend on the employment of a large staff of trained men who can work among cultivators in the villages. For such 'stockmen' it is desirable that special elementary courses of instruction should be instituted.

65. It is strongly recommended that, in the interests of both efficiency and economy, live stock improvement and veterinary work should be unified under a single department of animal husbandry. It is recognised that for local and personal reasons immediate unification may not be desirable or possible in all provinces. But it is suggested that unification should be looked upon as the ultimate goal.

66. If unification is adopted, it will be essential for the Director of the unified department to have on his staff a Live Stock Expert with special knowledge and experience of cattle breeding. It will also be essential to ensure close cooperation with the Department of Agriculture. This would be facilitated by the appointment of a Fodder Specialist, who would normally work in close touch with the Live Stock Expert.

67. Further cattle improvement cannot be effected without increased expenditure, whether the control of such improvement is under the agricultural department or is unified with the veterinary department. Existing figures show clearly that the extent of live stock improvement in the different provinces runs roughly parallel with expenditure. The unification of animal husbandry and veterinary work should not therefore be looked upon as a means of reducing expenditure on cattle improvement: rather is it a means of making the best use of any funds available for live stock improvement and of ensuring that such improvement is effected under the most favourable conditions.

68. The present measures which are designed to improve the general standard of Indian cattle are largely concerned with draught breeds. Every effort should be made to augment the number of agencies which can be used for developing the milking potentialities of indigenous Indian breeds of cattle. Such agencies should include the Military Dairy Farms, district and demonstration farms, and *gowshalas* and *pinjrapoles*. It is suggested that a special officer should be appointed under the Imperial Council of Agricultural Research whose duties would include the stimulation of interest in milch cattle breeding at various centres and the giving of expert advice to *gowshalas* and *pinjrapoles* which desire to improve their methods of management and to adopt a constructive breeding policy.

69. In order to maintain close cooperation between all departments concerned with rural development, it is suggested that a Board of Rural Development should be constituted in each province. This Board would include the directors of the departments of agriculture, forestry, veterinary services and public health, a representative of the irrigation and revenue departments, and the Registrar of Co-operative Societies. Specialist officers would attend the meetings of the Board. The Chairman would be a non-technical officer of the rank of Commissioner and with a special knowledge of and interest in rural conditions. The Board would act solely as a coordinating and advisory body, but would be in a position to make direct representations to the responsible minister in regard to any controversial matters (Appendix VI).

APPENDICES.

APPENDIX I—Terms of Reference for the Expert Scientific Adviser (Dairying).

1. In view of the economic importance and value to general agricultural development of improved production and handling of milk and milk products, keeping in view the requirements of cattle for agriculture, to advise as to the lines to be followed in order to secure (a) increased and more economical production, and (b) improved collection handling and disposal of milk and milk products.

2. To advise as to the main lines of research which require to be taken up in relation to (a) the composition and physical properties of the various milks available in India, (b) the industrial processing of such milks, and (c) the manufacture of by-products.

3. To advise as to what facilities should be provided by Government for testing new plants and machinery, in order to take advantage of recent advances in dairy science.

4. To advise as to what additional technical and scientific staff and facilities are required for the above purposes.

5. To advise on the policy to be followed regarding research schemes now in operation, and which of them should be renewed at the end of their term.

6. To comment on the present working of individual research schemes (or groups of schemes) and to suggest improvements.

7. To report how far dissemination of scientific and technical information, not only in regard to research but also in regard to animal husbandry matters in general with special reference to dairy science, is being applied in practice and to advise what further steps are desirable for more extensive and speedier application.

APPENDIX II.—Special Considerations relating to City Milk Supplies.

Reference has already been made to the small proportion of India's population who reside in cities. It may be assumed that the special difficulties associated with city milk supplies only arise in urban centres with populations exceeding 100,000. Less than 3 per cent. of the population of India live in cities of this size. Between 1921 and 1931 the number of such cities only increased by three (namely, from 35 to 38), while the population increased by 18 per cent. In comparison the population of towns of 50,000 to 100,000 increased by 30 per cent. and of towns of 20,000 to 50,000 by 36 per cent.

Nevertheless the supply of milk to large cities justifies special consideration by virtue of two facts : first, because the *per capita* consumption of milk is particularly low in such cities ; and second, because certain special difficulties are involved in the provision of adequate supplies of milk in densely populated areas. The problems involved are, however, somewhat difficult to discuss, since conditions of production and distribution vary markedly at different centres. This fact is illustrated in Table 45⁽¹⁾. It will be seen, for instance, that only 5 per cent. of the Hyderabad milk supply is drawn from areas situated more than 5 miles from the municipality, while nearly 40 per cent. of the Lahore supply comes from such areas. The remaining cities show intermediate figures. Again in Madras and Bangalore most of the milk is sold through milk vendors and there are few milk shops. In Hyderabad and Lahore the position is reversed, most of the milk being disposed of through milk shops. Other differences are associated with local conditions of collection and transport. Thus the lack of railway and road facilities in the country districts outside Calcutta makes the collection and transport of milk from outlying areas peculiarly difficult. Under these circumstances it is obviously impossible to make any detailed recommendations regarding the supply of milk to individual cities. There are, however, certain general problems which are common to all urban centres. I propose to deal with these in the present Appendix.

One feature which is shown in Table 45 to be characteristic of all the cities is the large cattle population which is housed within the municipal boundaries. This is, of course, undesirable on hygienic grounds alone. But there is a more fundamental objection to the housing of cattle in urban areas. The production of milk under such conditions is extremely expensive. Rents are high, the cost of accommodation for cattle in Bombay being as much as Rs. 10 per head per month. The cost of feeding stuffs is also inevitably high, since these have to be transported into the cities from rural areas. Again the depreciation of stock is very considerable. In most cities the practice is adopted of purchasing cattle in full milk and disposing of them (usually to slaughter houses) as soon as the milk yield becomes uneconomic. In Bombay alone some 16,000 buffaloes are slaughtered each year⁽²⁾. It is obvious that under such conditions milk cannot be produced cheaply.

In Western countries the tendency has been for city stables to be eliminated as a result of economic pressure. In Edinburgh, for example, the cattle population within the city boundaries has fallen from 4,300 in 1925 to roughly 1,600 in 1936.—a reduction of nearly two-thirds in only twelve years. It is stated that "economic factors are slowly obliterating the city stables. . . . The cost and difficulty of obtaining labour, the high

(1) Information collected from municipalities.

(2) A. Olver "Salvage of Dry Cows from City Dairies". Second Animal Husbandry Wing Meeting, Madras (1936).

reals and high rates, the cost of transporting feeding stuffs from the country, and still more the competition of the more cheaply produced country milk which is rendered possible by modern transport, are the chief factors contributing to make the production of milk within the city boundaries unprofitable" (3). If this statement is true for Western countries, why does it not apply equally to conditions in Indian cities? The answer is, I believe, two-fold. In the first place India lacks facilities for transporting milk from country districts to urban areas. Milk can be purchased in villages at 6 to 9 pies per lb. In cities it is sold at 18 to 34 pies per lb. (4), an increase in price of 300 to 400 per cent. In the second place the lack of adequate control of adulteration permits the dishonest city milk producer to water his milk, and thus to compensate for his higher costs of milk production. These two facts are undoubtedly responsible for the major difficulties associated with the supply of cheap milk to Indian cities. In order to overcome these difficulties action by both provincial governments and municipalities will be necessary.

The action of provincial governments should be mainly concerned with the provision of land and transport, and if necessary of facilities for the collection of milk produced in rural areas. As regards land, it will, I believe, be useless to establish new dairy farming enterprises so long as cattle are kept in the existing city stables (5). But by offering suitable land to the owners of such milch cattle it should be possible to persuade them to transfer their stock from city stables to rural areas, where milk can be produced under more economic conditions (6). At the same time it would, of course, be essential to make adequate provision for either road or rail transport into the cities. This might be achieved by arranging for concession rates on milk carried by rail, by establishing suitable sidings at selected points, by arranging for special milk trains to be run at convenient hours, and if necessary by arranging some suitable form of road transport. It might, too, be necessary to organise collecting depots in country districts, particularly where it is desired to use village milk for transport to cities. Careful investigation of methods of processing and refrigeration (as outlined in Chapter III) would, however, have to precede the establishment of such collecting depots.

These concessions should not be granted by provincial governments unless an assurance is given that milk production will be carried out by approved methods and under hygienic conditions, the provincial government to have rights of entry and inspection at all times. It was pointed out in a report on this subject (7) that the mere transfer of milk production from city stables to outlying areas might do more harm than good, since the municipalities would no longer be able to supervise the conditions of housing and management of the cattle. An arrangement by which the requisite control could be exercised by provincial authorities would avoid this danger. I should mention, too, the need for selecting land in rural areas which are sufficiently far removed from the city boundaries. Owing to the relatively rapid growth in city populations, these boundaries are being continually extended, and rural areas are quickly urbanised.

(3) Personal communication from the Medical Officer of Health for Edinburgh.

(4) Figures obtained from Provincial Government Reports.

(5) An important point in this connexion is that owners of cattle which are at present housed in city stables have an assured market for their milk.

(6) This is the principle adopted in the scheme sponsored by the Government of Bombay for the transfer of cattle at present in city stables to good farming land at Palghar, some 50 miles from the city.

(7) Dr. H. H. Mann. Report on the Milk Supply of Bombay.

This was, for example, particularly noticeable in the rural areas around Bombay, which were being rapidly absorbed into the suburban districts. It would obviously be a short-sighted policy to establish dairying enterprises in such districts.

Turning next to the action which should be taken by municipalities, I consider that this might be along three lines. In the first place it will be essential, if milk is to be supplied from rural areas, to exercise proper control over that produced within the city so that country milk is not placed at a disadvantage through having to compete with adulterated milk. Such control should also include the adequate inspection and licensing of premises within the city and the supervision of methods of production. As regards adulteration, it is, I believe, essential that an efficient system of licensing should be introduced in order to facilitate the identification of offenders⁽⁸⁾. In the second place it is desirable that municipalities should provide suitable accommodation for milk markets. In some cities (for example, Calcutta) the wholesale milk market is run under filthy conditions, and the milk is sold side by side with other perishable commodities such as fish, vegetables and fruit. There is consequently no incentive to handle the milk hygienically. The provision of sanitary milk markets by municipalities would, I believe, be essential if large quantities of milk were to be brought into cities from long distances and would also do much to encourage the adoption of better methods of handling this product. In the third place municipalities could give active encouragement to the production of milk in rural areas by allocating hospital and similar contracts to those who produce milk outside the city boundaries. In the past the tendency has been for municipalities to accept milk which is offered at the cheapest rate, irrespective of its quality. In this matter I feel strongly that municipalities have a unique opportunity not only of encouraging the adoption of better methods of production but of giving indirect assistance to those who agree to remove their cattle to rural areas.

As regards the actual processing and distribution of milk in cities, I have laid down certain principles in Chapter III which should provide a basis for effecting improvement. I should however stress one point. It has been suggested that municipalities might themselves undertake the running of milk depots and the distribution of milk. I am definitely opposed to any such scheme. Such a step could only be justified if it were found impossible to ensure the provision of a cheap and pure supply of milk through ordinary commercial channels. It is true that milk retailed in cities is at present relatively expensive and that much of it is of poor hygienic quality and frequently adulterated. This is, however, largely attributable to lax administration on the part of municipalities. Adequate legislation exists for dealing with the abuses found in city stables, for the hygienic control of the production and handling of milk, and for the prevention of adulteration. But under present conditions of municipal administration such legislation is entirely ineffective. It is, I think, clear that if municipalities are unable to apply existing legislation effectively, it is useless to anticipate that any greater success could be achieved by a system involving municipalisation of the milk supply.

(8) At the Second Animal Husbandry Wing Meeting held at Madras in 1936 it was suggested that licences to sell milk should only be given to men of substance and that hawkers licences for the sale of milk should be discontinued. For milk contractors the standard suggested was not less than 200 lb. of milk per day and for *bona fide* producers 100 lb. per day. It was also suggested that milk vendors should be required to register their servants and provide them with badges so that they could be held responsible in cases of adulteration. I consider that these suggestions offer a most useful basis for a more efficient licensing system.

There is one further point. Schemes for effecting improvement in a city milk supply cannot be formulated without a very thorough survey of the existing channels of marketing. I only found one instance in which a really comprehensive inquiry on these lines had been undertaken, namely, at Lahore⁽⁹⁾. It is essential that similar surveys should be undertaken in other cities if their milk supplies are to be reorganised on sounder lines.

(9) R. Lal Anand and A. C. Aggarwala "The Milk Supply of Lahore in 1930". Punjab Board of Economic Inquiry, Publication No. 28, 1935. Two papers by Z. R. Kothavalla have also been published regarding the Bombay milk supply, but these do not give adequate details of the existing channels of marketing.

APPENDIX III.—Special Considerations relating to Hill Dairying.

In a pamphlet dealing with the syllabus for the Indian Dairy Diploma⁽¹⁾ special emphasis is laid on the need for instruction in hill dairy farming. While it is true that this branch of dairying involves special problems, it would be a mistake to over-emphasise its importance. The winter population of hill stations in India only amounts to some 600,000. The population may be doubled or even trebled⁽²⁾ in the summer season, but even so it constitutes only about 0.5 per cent. of India's total population. Moreover many of those who reside in hill stations are drawn from the wealthier classes, who can afford to pay a fairly high price for their milk. It should be noted, too, that the climate of hill stations is more suitable for the handling of milk than that of the plains: at Darjeeling, for example, the mean monthly temperature seldom exceeds 62°F., while at Mussoorie the highest mean monthly temperature recorded is 72°F.⁽³⁾

The special problems of hill dairy farming are three-fold: first, the seasonal variation in the demand for milk; second, the provision of cattle of a suitable breed to withstand the cold climate and high altitude; and third, the supply of adequate fodder.

As regards the seasonal variations in the demand for milk, this is inevitable in centres where the populations show large fluctuations. The variation in sales of milk by dairies at two well-known hill stations are shown in Table 46⁽⁴⁾. It will be seen that the summer demand is from five to six times as high as the winter demand. This fact introduces a difficult problem for hill dairies, since if their summer production is adequate to meet the demand, their winter production is apt to be greatly in excess of the demand. One method of meeting this difficulty is to alter the size of the herd according to the season. This policy is, for example, adopted by one firm, who move milk cattle from the plains to the hill stations in the summer months. An alternative method is to manufacture the surplus winter milk into milk products. There is no doubt that indigenous milk products could not be manufactured economically from milk produced under hill conditions, and it is questionable whether even the manufacture of high grade creamery butter would yield a profit. I believe, however, that the production of cheese could be undertaken on a limited scale. It has been stated in Chapter VI that the market for cheese is very small. But nearly 10,000 cwt. are imported into India each year (chiefly for the use of the European population) at a total value of just over Rs. 8 lakhs. The cool conditions at hill stations are, moreover, favourable to cheese production and storage, which would be extremely difficult under plains conditions. Imported cheese is valued at Rs. 80 per cwt.^{*}, which would give a gross return of 17 to 18 pies per 1 lb. of milk. I was informed that milk could be purchased wholesale at hill stations for 10 to 12 pies per lb. It appears therefore that the manufacture of cheese (of European varieties) might offer a possible outlet for surplus milk produced during the winter months. It is interesting to note that limited quantities of such cheese are already successfully produced at certain hill dairies.

(1) Z. R. Kothavalla. "A Note on the Course of Training for the Indian Dairy Diploma." The statement reads "The factory system of dairying and hill dairy farming should form two of the most important items of training for the dairy diploma".

(2) The Census of Population, 1931 shows, for instance, that the population of Simla increased from 18,144 in the winter season to 52,187 in the summer season.

(3) Annual Report of the Public Health Commissioner, New Delhi, 1935.

(4) Personal communication.

* Calculated from the average declared value as given in the Annual Statements of Sea-borne Trade of British India.

The provision of milch cattle suitable for hill districts does not involve any serious difficulty. It is found that European breeds thrive well under the temperate conditions of climate. Indigenous Indian breeds are also found in some districts,—for example the Siri breed in Darjeeling and the Lohani breed in the North-West Frontier Province. European cross-breeds are commonly found, but it is stated⁽⁵⁾ that this is having a detrimental effect on the draught qualities of local stock. Scindi cattle and buffaloes also appear to thrive well. I should, however, mention that in certain areas there is a high incidence of hamaturia among cattle, which is a source of considerable loss to owners of stock.

A more difficult problem is the provision of an adequate supply of fodder for milch cattle. It is impossible to generalise on this subject, owing to the wide variations in climate, elevation and contour at different hill stations. At Coonoor and Ootacamund, in the Nilgiri Hills, the cattle are able to graze on the rolling down-land which forms the main plateau. Green crops such as oats can be grown successfully in such localities. On the other hand in the more typical hill stations such as Simla and Darjeeling, fodder has to be obtained from forest areas. In these districts there is a serious shortage of fodder suitable for milking stock and particularly of grazing land. Cattle owners are therefore encouraged to stall-feed their stock, the Government having, for example, built cattle sheds at Darjeeling for the purpose⁽⁵⁾. While certain crops such as maize can be grown, reliance has to be largely placed on the use of local shrubs and scramblers for fodder. Efforts are being made to develop the planting of fodder trees which stand annual or periodic lopping. It is claimed that such trees produce more leaf fodder than could be produced from the same area of fodder grasses⁽⁶⁾. Experience shows, however, that the control of such lopping is essential in order to prevent permanent damage through injudicious lopping by ignorant *gujars*. It is interesting to note that, where uncontrolled lopping has been permitted, the deterioration has been so serious that the local inhabitants have petitioned for control by the Forest Department or have introduced their own methods of control in order to conserve the available supplies of fodder. It is clear from these brief notes that forest departments are already taking active steps to augment the supplies of fodder in hill areas. I consider that such work is of great value not only in improving the condition of the cattle but in cheapening and increasing milk production.

(5) F. Canning. "Notes on the Better Utilisation of Forest Areas for Grazing." New Delhi, 1936.

(6) E. A. Smythies, Conservator of Forests, Western Circle, U. P. (quoted by F. Canning).

APPENDIX IV.—The Provision of Milk for Children of School Age.

I have already referred in Chapter I to the very low level of milk consumption in India, and to the urgent need for increasing the consumption of this valuable food. In this connexion I outlined the results of experiments which had been made to determine the effect of adding a supplement of milk to the diets of children of school age. Briefly these results showed that children who received the milk supplement increased in weight and height far more rapidly than those who received no supplement, while they also showed a marked improvement in general health.

It is obviously desirable that steps should now be taken to put into effect a more general scheme for the provision of milk to children of school age. The original experiment was carried out by the Municipality of Simla, but already a number of other municipalities have given consideration to the adoption of similar schemes. The difficulty is, however, to raise sufficient funds to meet the very considerable expenditure involved. As is stated in the report of the Simla experiment, "the urgent need for the expansion of the scheme is clear; the means to do so are not so obvious" (1).

In the original Simla experiment, one pound of whole milk was given daily to each of 120 children. The milk for the experiment was purchased at 2 annas per lb. For a full school year of 200 days this would involve an expenditure of Rs. 25 per child. It is very doubtful whether any municipality could afford to allocate such a large *per capita* sum for the provision of milk to school children. Two alternatives appear to be open, namely, to reduce the cost of the schemes or to secure additional financial assistance from outside the municipalities. In practice I think that both these measures would need to be adopted.

As regards reduction of cost, the first step would be to limit the scope of the scheme to certain selected groups of children. It would probably be desirable to confine the scheme to children attending primary schools, and within these schools to select only such children as are underweight, neglected or indigent. This would probably include 30 per cent. of the primary school population (2). The second step would be to effect a reduction in the cost of the milk. The milk used in the Simla experiment was pasteurised and bottled. This is an ideal method of supply for schools, but is far too expensive to be practicable on a large scale. The alternative, namely, to purchase 'loose' milk, is open to some objection on hygienic grounds, but appears inevitable. In any event it seems preferable to adopt this alternative than to abandon all attempts to initiate a scheme. 'Loose' milk can be purchased at Rs. 4 per maund (3). This would reduce the cost per child per year from Rs. 25 to Rs. 10. A still further reduction could be effected by using separated milk in place of whole milk. It appears from experiments carried out at the Nutrition Institute, Coonoor, that separated milk is as valuable a supplement for the feeding of school children as whole milk (4). Liquid skimmed milk can be obtained in cities at Rs. 1½ per maund (3), which would involve a cost of Rs. 3¾ per child

(1) W. H. Crichton. Second Report of the Milk Scheme sanctioned by the Simla Municipality.

(2) Personal communication from the Medical Officer of Health, Simla.

(3) This figure refers to milk purchased in Delhi. Whole milk could probably be bought in villages at very much lower prices, say 6 pies per lb. or Rs. 2½ per maund. All such loose milk would need to be boiled before being consumed by the children.

(4) W. R. Aykroyd and B. G. Krishnan. "The Effect of Skimmed Milk, Soyabean and other Foods in supplementing typical Indian Diets." *Ind. Journ. Med. Res.* 24, 4 (1937).

per year. An alternative source would be to use reconstituted skimmed milk powder. This can be purchased at Rs. 36 per cwt., the annual *per capita* cost on this basis being Rs. 5. These figures are, however, calculated on a supplement of 1 lb. of milk per school day. The English milk-in-schools scheme only allows for one-third of a pint per day, *i.e.*, just under half a pound. While a full pound would be desirable under Indian conditions, half this quantity of milk would be preferable to none at all.

Turning to the provision of financial assistance from outside sources there are, I think, three possibilities. In the first place the system might be adopted of providing the milk cheap but not free, except in cases of obvious under-nutrition. This is the basis of the English milk-in-schools scheme, and although it might not be workable under Indian conditions, its possible application should at least be explored. In the second place provincial governments might be invited to assist in initiating the scheme by making suitable grants-in-aid to municipalities and district boards. The direct expenditure incurred by the latter would thus be substantially reduced. In the third place, efforts might be made to obtain voluntary subscriptions from the wealthier sections of the population, a method which has, I understand, met with considerable success in Delhi. In this connexion, too, I suggest that the interest of the supporters of *goushalas* and *pinjrapoles* might be enlisted, with the object of obtaining cheap or even free milk for school children from such institutions. I am convinced that the inclusion of such philanthropic work among the beneficent objects of *goushalas* and *pinjrapoles* would add to the interest and support given to them by all classes of the community.

The above suggestions are intended to be illustrative rather than exhaustive, but they serve to show that with suitable organisation some form of school milk scheme should be feasible. The subject is obviously one of great difficulty. In British India alone there are over ten million scholars in primary schools, and the provision of a daily supply of milk for even a fraction of these would inevitably involve very considerable expenditure. The whole question is, however, of such potential importance to the future health of the population that I believe it merits most careful and serious consideration.

APPENDIX V.—The Importance of Goats as Milch Animals.

So far as India's total output of milk is concerned, the goat contributes only a very small proportion, a recent survey showing the following figures⁽¹⁾ :—

	Quantity of Milk (thousands of maunds).	Percentage of total.
Cows	378,730	54.7
Buffaloes	300,090	43.6
Goats	10,785	1.6
Others	324	0.1
	<hr/> 689,929	<hr/> 100.0

Moreover from marketing reports it appears that goats are generally kept not so much for the production of milk as for meat and incidentally for hides and skins. The number of goats in India is, however, very large. There are more than 38 million in British India, and nearly 16 million in Indian States. An increase in the *per capita* milk yield of goats would therefore markedly increase the quantity of milk available in the country.

According to recent surveys, the average lactation yields of goats vary from 45 lbs. to 276 lbs., the mean value being 160 lbs. The daily milk yield varies from 2 ozs. in Bihar and Orissa to 12 ozs. in south-western Punjab and Sind, the average for India being about 7 ozs. The lactation periods vary from 120 to 150 days. These figures refer to goats kept under village conditions. Under such conditions they are seldom stall-fed, and they may have to roam for many miles in search of food. The low milk yields of village goats are therefore not surprising. Under more favourable conditions goats may give very much higher yields, and may kid more frequently. Thus the milk yields of goats at the Mission Farm at Etah, U. P., have been increased by better management and selection from 1.1 lb. per day to 2.3 lbs. per day for the Jumna Pari breed, from 1.5 lbs. to 2.0 lbs. per day for the Bar-bari breed, and from 1.1 lbs. to 2.6 lbs. for the local village type⁽²⁾. At the same time the kidding interval has been reduced from an average of 360 days to an average of about 260 days. Both at Etah and at the Government Cattle Breeding Farm, Hissar, Punjab⁽³⁾, remarkably high yields have been obtained with some animals, yields of 600 to 1,200 lbs. being not unfrequently recorded, with one exceptional figure of 1,713 lbs. The maximum daily yields of such goats varied from 3½ to 7 lbs., and the average daily yields from 1¼ to 4½ lbs.

These figures show the potentialities of Indian breeds of goats as milking animals. As with village cattle, there is no doubt that better feeding and management alone would markedly increase the milk yields of country goats. Work such as that proceeding at Etah and at Hissar is, however, of great importance in demonstrating the value of selective breeding, combined with better feeding and management, in improving the milking capacities of indigenous stock.

(1) Provisional figures from Provincial Marketing Surveys.

(2) Annual Reports of Mr. A. E. Slater's Goat Breeding Scheme. Imperial Council of Agricultural Research, Simla, 1932-1936.

(3) Punjab figures obtained from brief.

APPENDIX VI.—A Note on the Need for the Co-ordination of Rural Services.

During my tour I was concerned to find a very general lack of co-ordination between the work of the different government departments in the field of rural development. This applies not only to the isolation of departmental activities. It was equally apparent in the lack of co-ordinated and long-range schemes of development and in the piecemeal methods adopted in establishing new enterprises. This cannot be better illustrated than in the words of a prominent member of the Indian Forestry Service :—“ The revenue department is anxious to collect its revenue, the forest department to grow trees, the agricultural department to cultivate better paying crops, the veterinary department to rear more stock, the local land owner to keep a stud bull, the irrigation department to find more canal water, the public health authorities to improve the drinking water. These are all competing for the areas which should be the natural fodder reserves of the province. ”(1). This statement, which refers to the foothills of the northern provinces, applies with equal force in other areas : there appears to be no means of bringing together those responsible for the various branches of rural development and ensuring that their interests should be complementary rather than competitive.

The need for such co-ordination in rural development is particularly apparent in relation to cattle breeding and dairying. Cattle breeding necessitates the closest co-operation between the veterinary, agricultural and forestry departments(2). Dairying involves in addition a number of problems connected with marketing and co-operation, as well as certain public health considerations. No authority at present exists through which these various interests can be co-ordinated. It may be argued that all such activities are under the control of a single minister. This is not true for all provinces. Moreover the responsible minister can seldom give to the questions at issue that detailed consideration which is essential in harmonising conflicting interests.

After considering various alternatives, I feel that the difficulty could best be met in most provinces by constituting a Board of Rural Development(3), which would include the directors of the departments of agriculture, forestry, veterinary services and public health, a representative of the irrigation and of the revenue departments, and the Registrar of Co-operative Societies. Specialist officers, namely, the provincial live stock expert, the provincial marketing officer, the provincial dairy development officer and the fodder specialist (if appointed) should attend meetings of the Board in an advisory capacity. The Chairman of the Board would hold a key position, and the success of the Board's work could depend largely on his tact and personality. I consider it essential that he should be a non-technical officer of the rank of Commissioner and with

(1) R. M. Gorrie. “ Notes on the Conservation of Hill Grazings. ” Paper presented at the Second Animal Husbandry Wing Meeting, Madras, 1936.

(2) The irrigation department ought also to be included. On several occasions I was informed that irrigation developments had adversely affected the cattle in what had previously been excellent breeding tracts.

(3) A proposal to constitute such a Board was considered by the Government of Bombay in 1934. This proposal included, however, the unification of the departments of agriculture, veterinary services and co-operation into a combined department, with the director of agriculture as head. The scheme therefore differed fundamentally from that now put forward, since it included the appointment of a technical officer as head and the loss of administrative independence by the departments of veterinary services and co-operation. Under these circumstances it is not surprising that the proposal was abandoned.

special knowledge of and interest in rural conditions. Whether the post of Chairman should be a whole-time or a part-time one would depend on individual circumstances. Such a Board should, I believe, act solely as a co-ordinating and advisory body, and should not curb the initiative nor limit the responsibilities of the directors of individual departments, nor interfere with the internal administration of such departments. On the other hand the Board might, on occasion, have to recommend the abandonment of projects which, though good in themselves, failed to fit in with the general scheme of rural development. It should, therefore, be in a position to make direct representations to the responsible ministers in regard to any controversial questions relating to rural development and the co-ordination of rural services. The Board could appoint committees to deal with specific problems or with the development of such activities as marketing or dairying. One of the first duties of such a Board would, I suggest, be to carry out a survey of the agricultural resources of the province in order that any subsequent schemes could be properly related to a long-range policy of rural development.

I am strongly of opinion that the constitution of such a Board would do much towards ensuring inter-departmental co-operation and the direction of departmental work along the most productive lines.

APPENDIX VII.—Conversion Tables.

For these tables the following typical analyses of mixed milk of Indian cows and buffaloes⁽¹⁾ have been used : for whole milk, 15.45 per cent. total solids containing 6.13 per cent. fat ; for skimmed milk, approximately 9.3 per cent. total solids. The English equivalents have been taken from the Report of the Reorganisation Commission for Milk, 1933.

Conversion Tables for Imported Milk Products.

				To make one cwt. there are required.	
				gallons of English milk.	maunds of Indian milk ⁽²⁾ .
Butter	..	..	..	264	20.0
Cheese	..	..	..	112	11.4
Condensed milk (whole)	..	..	..	27	2.8
Milk powder (whole)	..	..	..	78	8.0
Condensed milk (skimmed)	..	..	..	32	3.7
Milk powder (skimmed)	..	..	..	118	14.0
Cream	..	..	..	68	7.0
Sterilised milk	..	..	..	11	1.0

Conversion Tables for Indigenous Milk Products.

				Out-turn of product per 100 lb. of Indian milk.	Quantity of Indian milk required to produce 1 lb. of product.
				lb.	lb.
<i>Ghee</i>	..	..	..	6	16.0
'Country' butter	..	..	..	7	14.0
<i>Dahi</i>	..	..	..	85	1.2
<i>Khoa</i>	..	..	..	25	4.0
<i>Channa</i>	..	..	..	20	5.0
<i>Mallai</i>	..	..	..	20	5.0
<i>Rabree</i>	..	..	..	40	2.5

(1) Weighted according to the relative quantities of milk produced by cows and buffaloes in India. The average composition of milk has been taken as : for cows, 13.9 per cent. total solids containing 5.2 per cent. fat, and for buffaloes, 17.4 per cent. total solids containing 7.3 per cent. fat. It is estimated that 378.7 million maunds of milk are produced by cows, and 300.1 million maunds by buffaloes.

(2) One maund equals approximately 80 lb.

APPENDIX VIII.—ITINERARY.*

November, 1936.—

- 4th Landed at Bombay.
- 6th Arrived at Delhi.
- 7th to 11th *Delhi*.—Interviews with H. E. the Viceroy, the Hon'ble Member for Education, Health and Lands, the Secretary of the Department of Education, Health and Lands, the Public Health Commissioner to the Government of India, the Director of Supplies and Transport, Army Headquarters, the Officiating Vice-Chairman and the Animal Husbandry Expert of the Imperial Council of Agricultural Research, the Agricultural Marketing Adviser to the Government of India, and other officials. Visits to the Imperial Agricultural Research Institute, Edward Keventer's Dairy Farm, the Delhi Cattle Breeding Farm, and the Delhi *Pinjrapole*.
- 12th *Karnal*.—Visits to the Nagloi, Bahadurgarh, Rohtak, Sonapat, Sisana and Panipat Veterinary Hospitals and the Imperial Cattle Breeding Farm, Karnal.
- 13th and 14th *Hissar*.—Visits to the Government Cattle Breeding Farm.
- 15th, 16th and 19th *Lahore*.—Interviews with H. E. the Governor of the Punjab, the Officiating Director of Agriculture and the Director of Veterinary Services. Visits to Keventer's Sales Depot, the Military Dairy Farm, the Public Analyst's Laboratory, the University Chemistry Laboratories, the Punjab Veterinary College, the Lahore *Gowshala*, and to *gujar's* premises and milk shops.
- 17th *Ferozepore*.—Visits to the Military Dairy Farm and to the Kahna-Kachha and Lulani Veterinary Hospitals.
- 18th *Lyalpur*.—Visits to the Vegetable Ghee Factory and the Agricultural College and Dairy.
- 20th and 21st *Khazewal*.—Visits to Grantee Farms in the Montgomery area.
- 22nd and 23rd *Karachi*.—Interviews with H. E. the Governor of Sind, the Officiating Director of Agriculture, the Director of Veterinary Services, and the Director of the Public Health Department. Visits to the Military Dairy Farm, the English Dairy, the Karchi *Pinjrapole* and cattle stables and dairies.
- 25th and 26th *Ahmedabad*.—Visits to Lord's Dairy, the Dudhia Dairy, the Changodar herd, and local cattle stables and milk shops.
- 27th *Chharodi*.—Visit to Government Cattle Breeding Farm.
- 28th *Anand*.—Visits to Polson's Dairy and separating stations, and to the Government Creamery.
- 29th *Baroda*.—Interviews with H. H. the Gaekwar of Baroda and with the Commissioner for Agriculture. Visits to the Palace Dairy, the Australian Dairy Co., the Niyampura Producer's Co-operative Society, and the Alembic Chemical Works.

*Visits to local villages are not detailed, but frequent opportunities were taken to inspect village conditions in various parts of the country.

- 30th November to 4th December, 1936. *Bombay*.—Interviews with H. E. the Governor of Bombay, the Secretary to Government, Revenue Department, the Municipal Commissioner, the Public Health Officer and others. Visits to the Byculla Dairy, the Parisian Dairy, the Infants and Public Milk Supply Company, the Municipal Cold Stores, the Municipal Public Laboratories, the Bombay *Pirajpole*, the Borivli, Kandivli and Mulund *Gowshalas*, the Bandra slaughter house, the Bombay Veterinary College, the Haffkine Institute, and typical buffalo stables and milk shops.
- 5th and 6th .. *Poona*.—Interviews with the Director of Agriculture, the Director of Veterinary Services, and the Provincial Live-Stock Expert. Visits to the Agricultural College and Dairy, the Government House Dairy, and the Military Dairy Farm.
- 7th to 12th .. *Bangalore*.—Interviews with the Dewan of Mysore, the Director of Agriculture, the Director of Veterinary Services and the Live-Stock Expert. Visits to the Imperial Dairy Institute, Hosur Cattle Breeding Farm, the Hebbal Agricultural and Live-Stock Farm, the Indian Institute of Science, the Civil Veterinary Hospital, the Military Dairy Farm, the Lakeview Dairy, the City Milk Supply Co., and local cattle stables and milk shops.
- 13th to 17th .. *Madras*.—Interviews with H. E. the Governor of Madras, the Director of Agriculture, and the Officiating Director of Veterinary Services. Visits to Madras University, Madras Veterinary College, the Garrison Dairy Farm, the Madras Co-operative Milk Supply Union, the local *gowshala*, and cattle stables and milk shops. Attended the Second Animal Husbandry Wing Meeting.
- 18th *Katpadi*.—Visit to the Mission Goat Breeding Farm.
- 19th and 20th .. *Coimbatore*.—Visits to the Agricultural College and Dairy and to the Pattagar of Palayankottai's Farm.
- 21st to 27th .. *Coonoor*.—Visits to the Nutrition Laboratory at the Pasteur Institute and to Wellington Dairy Farm.
- 28th and 29th .. *Mysore*.—Interview with the President of the Municipal Committee. Visits to the Rayankere Dairy Herd, the Chatanhalli Cattle Breeding Farm and the Yellandihalli Sheep Breeding Farm.
- 30th December to 2nd January, 1937. *Bangalore*.—Interviews with the Imperial Dairy Expert. Visits to the Irwin Canal Farm, the Mandya Sugar Factory, the Devidan Farm, and the Laboratory of the Agricultural Department.
- 3rd to 6th .. *Hyderabad*.—Interviews with the Chief Minister of H. E. H. the Nizam's Dominions, and with the Director of Agriculture and the Director of Veterinary Services. Visits to the Himayatsagar Dairy and Poultry Farm, the Secunderabad Military Dairy Farm, the Veterinary Hospital, the Deccan Dairy, and typical *gowshala*'s premises. Attended the Indian Science Congress.
- 7th and 8th .. *Nagpur*.—Interviews with H. E. the Governor of the Central Provinces, the Director of Agriculture and the Director of Veterinary Services. Visits to the Agricultural College and Dairy, the Telankheri Farm and Co-operative Dairy, the Veterinary Hospital, and various *gowshala*'s premises.

January, 1937—*contd.*

- 10th to 13th and 16th to 19th. *Calcutta.*—Interviews with H. E. the Governor of Bengal, the Director of Veterinary Services and the Public Health Officer. Visits to the Bengal Veterinary College, the Municipal Laboratories, the Co-operative Milk Union, Keventer's Dairy, the Express Dairy, the Milk Market and Hogg Market, the Sodepur *Gowshala*, and cattle stables and milk shops.
- 14th and 15th .. *Dacca.*—Interviews with the Officiating Director of Agriculture and the Provincial Live-Stock Expert. Visits to the Agricultural Farm and Dairy, to *Dacca University*, and to local milk shops.
- 20th and 21st .. *Darjeeling.*—Visits to the Co-operative Milk Union's premises, Keventer's Dairy Farm and typical hill areas.
- 23rd to 24th February *Delhi.*—Meetings of the Advisory Board of the Imperial Council of Agricultural Research. Collection of statistical data and discussions with officials of the Council and others.
- 25th *Aligarh.*—Visit to Keventer's Dairy Farm.
- 26th to 28th .. *Agra.*—Visits to the Military *Ghee* Heating Centre and *Ghee* Testing Laboratory, the Dayalbagh Dairy, the Agricultural Farm at Bichpuri, Singhal's Dairy, and a typical *mandi* at Kasta Fatehabad.
- 1st March, 1937 .. *Etah.*—Visit to the Mission Goat Breeding Farm.
- 2nd *Muttra.*—Visit to the Government Cattle Breeding Farm.
- 4th *Allahabad.*—Visit to the Farm and Dairy of Allahabad Agricultural Institute, the Katra Co-operative Dairy, Mahabir's Dairy, the *khau* market, the Indalpur and Geneshgunj milking stations, and local *gowshalas'* premises.
- 5th to 7th .. *Lucknow.*—Interviews with H. E. the Governor of the United Provinces, the Director of Agriculture, the Deputy Director in charge of Live-Stock Improvement, and the Director of Veterinary Services. Visits to the Parbatpur Co-operative developments, the Makdumpur grazing areas, the Government Cattle Breeding Farm at Kheri, the Military Dairy Farm, and the Diamond Dairy.
- 8th and 9th .. *Cawnpore.*—Visits to the Agricultural College and Dairy, the Military Dairy Farm, the Cawnpore *Gowshala*, the *Ghee* Testing Laboratory of the Cawnpore Pure *Ghee* Association, and Messrs. Spencer's Dry Ice Factory.
- 12th *Meerut.*—Visit to the Military Grass Farm.
- 14th to 16th .. *Simla.*—Visits to Keventer's Dairy Farm, the Simla Veterinary Hospital, and typical hill areas.
- 17th *Kasauli.*—Visits to the Military Food Laboratory and the Pasteur Institute.
- 18th to 23rd .. *Delhi.*—Interviews with H. E. the Viceroy, the Hon'ble Member for Education, Health and Lands, the Quartermaster General, Army Headquarters, the Joint Secretary of the Department of Education, Health and Lands, the Education Commissioner to the Government of India, the Vice-Chairman and other officials of the Imperial Council of Agricultural Research, the Public Health Officer of New Delhi, and others.
- 23rd Left Delhi.
- 25th Sailed from Bombay.

T A B L E S.

153-154

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TABLE I.—*Estimated total production of milk, and estimated production and consumption per head of twenty countries (*).*

Country.	Total production of milk 1930-34.	Human population.	Daily production per head of population.	Daily consumption† per head of population.
	(Million gallons.)	(Thousands.)	(Oz.)	(Oz.)
New Zealand ..	870	1,559	244	56
Denmark ..	1,200	3,551	148	40
Finland ..	620	3,666	74	63 ✓
Sweden	980	6,233	69	61
Australia	1,049	6,630	69	45
Canada	1,580	10,377	66	35
Switzerland ..	607	4,066	65	49
Netherlands ..	970	7,935	54	35
Norway	290	2,814	45	43
U. S. A.	10,380	122,775	37	85
Czechoslovakia ..	1,200	14,730	36	36
Belgium	651	8,092	35	35
Austria	545	6,760	35	30
Germany	5,096	66,030	34	35
France	3,150	41,835	33	30
Poland	1,990	31,948	27	22
Great Britain ..	1,474	45,266	14	39
Italy	1,050	41,177	11	10
Roumania	382	19,033	9	9
India	6,400†	352,838	8	7

* The first and fourth columns are taken from the *Problem of Nutrition. Volume IV. Statistics of Food production, Consumption and Prices* (League of Nations Publication). The second column is from latest Census figures. The third column is calculated from the figures in the first and second columns.

† Includes both liquid milk and milk products, expressed in milk equivalents.

‡ Assuming India's total production to be 800 million maunds.

TABLE 2.—*Milk production and consumption by provinces.*

Province.	Production per head (a).	Consumption per head (b).
Assam	1.4	2.2
Bengal	3.1	1.9
Madras	3.6	1.6
Bombay	4.7	4.0
United Provinces	4.7	5.0
Central Provinces	6.1	0.8
Bihar and Orissa	6.4	3.2
Punjab	18.3	9.9

(a) Provincial Marketing Surveys.

(b) Sir John Megaw's figures.

TABLE 3.—*Milk consumption in certain municipalities.*

Province.	Municipality.	Consumption per head per day (oz.).		
		Milk.	Ghee.	Other milk products.
Bengal	Kharagpur	3.1	0.24	0.29
Madras	Madras	1.4	0.18	0.10
Bombay	Surat	6.1	0.75	0.35
United Provinces	Lucknow	1.4	0.35	0.27
	Agra	2.6	0.42	0.67
Central Provinces	Jubbulpore	0.9	0.28	0.01
Bihar	Bhagalpur	0.5	0.08	0.19
Punjab	Lahore	2.0	0.40	0.01
	Amritsar	7.3	1.25	2.61

TABLE 4.—*Effect of a supplement of whole milk on the growth of school children.*

Groups.	On Milk.				Control.			
	Average gain in three months.				Average gain in three months.			
	Boys.		Girls.		Boys.		Girls.	
	Weight.	Height.	Weight.	Height.	Weight.	Height.	Weight.	Height.
	Lb.	In.	Lb.	In.	Lb.	In.	Lb.	In.
Group I (First Report) ..	3.92	0.8	5.35	0.78	1.6	0.6	1.1	0.18
Group II	3.9	0.7	4.33	0.38	1.56	0.46	1.1	Nil.
Group III	3.7	0.53	3.0	0.19	1.9	0.42	1.0	0.07
Group IV .. ..	..	..	5.5	0.29	..	..	0.5	Nil.
Average ..	3.84	0.67	4.54	0.41	1.6	0.49	0.92	0.06

TABLE 5.—*Effect of a supplement of skimmed milk on the growth of school children.*

			Average increase in weight in three months.	Average increase in height in three months.
			Lb.	In.
Hostel 1 (Boys)	..	Group A (receiving milk) ..	4.77	0.61
		Group B (not receiving milk) ..	2.13	0.35
		Group B (receiving milk) ..	3.07	0.69
		Group A (not receiving milk) ..	1.10	0.43
Hostel 2 (Girls)	..	Girls receiving milk ..	4.8	0.80
		Girls not receiving milk ..	0.8	0.53
Hostel 3 (Boys)	..	Boys receiving milk ..	4.57	0.67
		Same boys receiving no milk ..	0.84	(?)

TABLE 6.—Amount spent on food and proportion spent on milk products (per family per month).

Inquiry.	Bombay (1922).	Bombay (1932).	Sholapur (1925).	Ahmeda- bad (1924).
	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.
Total expenditure on food	27 2 11	21 6 10	18 10 5	22 12 7
Expenditure on milk	0 13 9	1 3 9	0 15 7	0 13 10
Expenditure on <i>ghee</i>	0 9 11	0 5 0	0 5 1	2 8 3
Total expenditure on milk products ..	1 7 8	1 8 9	1 4 8	3 6 1
Percentage of food expenditure spent on milk products	5.4%	7.2%	6.9%	14.8%
Number of families	2,473	1,469	1 055	872
Average size of family	4.8	4.4	4.7	3.9

TABLE 7.—Influence of income level on milk consumption (Bombay 1922*).

Income Groups (Rs. per mensem).	Consumption of		Expenditure on		Percentage† expenditure on milk and <i>ghee</i> .
	Milk.	<i>Ghee</i> .	Milk.	<i>Ghee</i> .	
	(Lb.)	(Lb.)	Rs. a. p.	Rs. a. p.	
Below 30	1.0	0.3	0 3 1	0 4 6	3.0
30 to 40	2.0	0.2	0 6 7	0 3 10	3.2
40 to 50	2.2	0.3	0 7 10	0 5 10	3.7
50 to 60	4.0	0.5	0 14 6	0 9 8	5.8
60 to 70	5.2	0.8	1 2 9	0 12 7	6.3
70 to 80	7.3	1.1	1 9 10	1 5 9	8.1
80 to 90	7.9	1.5	2 1 4	1 10 7	9.1
90 and above	13.6	2.0	3 2 0	2 7 3	11.2
All incomes	3.9	0.5	0 13 9	0 9 11	5.4

*All values given per family per month.

†These figures refer to the proportion of total food expenditure spent on milk and *ghee*.

TABLE 8.—*Influence of income level on milk consumption (Lahore 1930).*

Income groups. (Rs. per mensem).	Daily consumption per head. (Oz.)
Up to 25	2·8
26 to 50	9·2
51 to 100	12·0
101 to 200	13·6
201 to 500	16·0
501 to 1,000	20·0
1,001 to 1,500	31·2
1,501 to 2,000	31·2
2,001 and more	31·2
Average for Lahore	4·0

TABLE 9.—*Utilisation of milk in India.*

Total production of milk	Million Maunds.	As percentage of total milk production.
.. .. .	690*	
Utilised—		
(a) as liquid milk	215·0	31·2
(b) for manufacture	475·0	68·8
Manufactured products :		As percentage of total milk manufactured.
<i>Ghee</i>	364·0	52·7
<i>Khoa</i>	52·2	7·6
Other indigenous milk products†	16·7	2·4
<i>Dahi</i> (curds)	28·2	3·8
Butter‡	10·3	1·5
Cream	2·8	0·4
Ice-cream	2·8	0·4
Cheese	(negligible).	..

*While the total production of milk in India (including Burma) is estimated at about 690 million maunds, estimates of utilization are only available for areas producing about 460 million maunds. In the above table these utilization estimates have been arbitrarily applied to the full production figures.

†This includes products such as 'mallai,' 'rabree' and 'khurchan' which are obtained by evaporating the milk to a less degree than 'khoa'.

‡Including both 'country' and 'creamery' butter.

TABLE 10.—Total value of milk and milk products produced in India.

Product.	Maunds of milk equivalent (millions).	Retail value per maund of milk.	Value (crores of rupees).
		Rs.	
Liquid milk	215.0	5	107.5
<i>Chee</i>	364.0	2½	100.0
<i>Khoa</i>	52.2	7½	39.2
Other indigenous milk products ..	16.7	13	22.3
<i>Dahi</i> (curd)	26.2	7½	19.7
Butter	10.3	3	3.0
Cream	2.8	3	} 1.7
Ice-cream	2.8	3	
	690.0	..	293.4

NOTE.—Liquid milk has been valued at 1 anna per lb., the cost of production working out at 9-10 pies per lb. This may be too high a value to place on the milk. On the other hand the *ghee* has been valued at its retail price, no allowance being made for the value of the butter-milk (*tassi*) consumed by the cultivator and his family.

TABLE 11.—The urban and rural populations of India.

	Number of towns.	Population (in millions).	Percentage of population.
Total Population .. .. .	..	352.8	100
Urban Areas .. .. .	..	39.0	11.0
Towns having :—			
100,000 and over	38	9.7	2.7
50,000 to 100,000	65	4.6	1.3
20,000 to 50,000	268	8.1	2.3
10,000 to 20,000	543	7.4	2.1
5,000 to 10,000	987	7.0	2.0
Under 5,000	674	2.2	0.6
Rural Areas .. .. .	..	313.8	89.0
Villages having :—			
5,000 and over .. .. .	..	5.3	1.5
2,000 to 5,000 .. .. .	..	38.7	11.0
500 to 2,000 .. .. .	..	139.0	39.4
Under 500 .. .. .	..	130.8	37.1

TABLE 12.—Adulteration of milk in different provinces during 1933-1935.

	1933.			1934.			1935.		
	No. of samples examined.	No. of samples adulterated.	Percentage of samples found adulterated.	No. of samples examined.	No. of samples adulterated.	Percentage of samples found adulterated.	No. of samples examined.	No. of samples adulterated.	Percentage of samples found adulterated.
Bombay ..	5,646	1,477	26.2	6,289	1,420	22.6	6,583	1,800	27.3
Bengal ..	4,387	1,662	37.9	5,088	1,850	36.4	5,278	1,866	35.3
Madras ..	1,078	647	60.0	1,458	933	64.0	1,798	1,182	65.7
Assam ..	274	98	35.8	369	175	47.4	359	156	43.4
United Provinces ..	1,428	381	26.7	1,581	418	26.4	1,901	410	21.6
Punjab ..	2,377	452	19.0	1,531	342	22.3	1,016	332	32.7
Bihar ..	204	106	52.0	226	139	61.5	269	146	54.2
Sind ..	681	295	43.3	526	206	39.1	447	224	50.1
North-West Frontier Province.	60	31	51.7	23	10	43.5	28	18	64.4
Total ..	16,135	5,149	31.9	17,091	5,493	32.1	17,679	6,134	34.7

TABLE 13.—*Percentage of added water in typical samples of milk.*

Percentage of water added.							Number of samples.	
0	..	..	..	..	..	..	22
6 to 15	..	..	..	..	..	..	29
16 to 25	..	..	..	..	..	..	23
26 to 35	..	..	..	..	..	..	16
36 to 45	..	..	..	..	..	..	7
46 to 55	..	..	..	..	..	..	3
Total							..	100

TABLE 14.—*Acidities of samples of ghee.*

Reading point.						Number of samples examined.	Percentage of total examined.	
2.0—2.9	..	..	..	..	..	2	..
3.0—3.9	..	..	..	..	..	144	3.1
4.0—4.9	..	..	..	..	..	154	3.5
5.0—5.9	..	..	..	..	..	243	5.6
6.0—6.9	..	..	..	..	..	567	13.0
7.0—7.9	..	..	..	..	..	997	22.8
8.0—8.9	..	..	..	..	..	1,600	36.6
9.0—9.9	..	..	..	..	..	606	13.9
10.0—10.9	..	..	..	..	..	65	1.5
11.0—11.9	..	..	..	..	..	2	..
Total						..	4,380	100.0

TABLE 15.—*Adulteration of ghee in different provinces during 1933-1935.*

	1933.			1934.			1935.		
	No. of samples examined.	No. of samples adulterated.	Percentage of samples found adulterated.	No. of samples examined.	No. of samples adulterated.	Percentage of samples found adulterated.	No. of samples examined.	No. of samples adulterated.	Percentage of samples found adulterated.
Bombay	1,522	198	13.0	2,354	155	6.6	1,796	165	9.2
Bengal	3,247	607	18.7	4,013	1,091	27.1	4,634	1,586	34.2
Madras	1,189	402	33.8	1,651	747	45.2	1,548	686	44.3
Assam	78	43	55.1	92	55	59.8	164	85	51.8
United Provinces	3,022	266	8.8	3,746	842	22.5	4,556	904	19.8
Punjab	115	25	21.7	107	47	43.9	206	92	44.7
Mhar	359	168	46.8	506	327	64.7	801	473	59.2
Sind	770	291	37.7	774	356	45.9	1,581	632	39.9
North-West Frontier Province ..	95	56	59.0	104	44	42.3	105	43	41.0
Total	10,397	2,056	19.8	13,347	3,664	27.4	15,391	4,666	30.3

TABLE 16.—Frequency distribution of butyro-refractometer readings and Reichert-Meissl values of ghee.

Range.	Butyro-refractometer readings.			Range.	Reichert-Meissl values.		
	Percentage of readings falling within range.				Percentage of readings falling within range.		
	Sunawala and Kothawalla.	Godhole and Sadgopal.	Military Food Laboratory.		Sunawala and Kothawalla.	Godhole and Sadgopal.	Military Food Laboratory.
40.0—40.9 ..	..	6.7	1.4	Below 23.0 ..	4.9	..	..
41.0—41.9 ..	..	24.4	96.0	23.0—24.9 ..	2.4	3.2	..
42.0—42.9 ..	14.6	62.2	2.6	25.0—26.9 ..	48.7	16.2	..
43.0—43.9 ..	65.9	6.7	..	27.0—28.9 ..	9.8	19.3	..
44.0—44.9 ..	14.6	..	..	29.0—30.9 ..	9.8	32.2	7.1
45.0—45.9 ..	4.9	..	..	31.0—32.9 ..	14.6	16.2	66.0
				33.0—34.9 ..	9.8	12.9	26.9
	100.0	100.0	100.0		100.0	100.0	100.0

TABLE 17.—Exports of ghee from India and imports of ghee into Malaya.

Year.	Total exports from India.	Value of total exports.	Value of exported ghee per maund.	Indian imports into Malaya.	Percentage of Indian exports going to Malaya.	Percentage of Malaya's imports obtained from India.
	(Cwt.)	(Rs. lakhs.)	(Rs.)	(Cwt.)		
1928-29	38,605	37.9	70	27,400	71.0	95.5
1929-30	35,579	35.1	71	24,580	69.1	93.7
1930-31	31,123	28.5	66	20,260	65.0	96.3
1931-32	27,294	22.2	58	13,900	51.0	95.2
1932-33	21,837	15.9	52	12,960	59.3	94.1
1933-34	24,418	13.3	39	13,620	55.8	95.4
1934-35	25,526	14.6	41	13,900	54.5	96.8

TABLE 18.—Quantities and value of butter imported into India.

Year.						Quantity.	Value
						(Cwt.)	(Rs.)
1926-27	..	..	..	..	..	1,091	2,25,247
1927-28	..	..	..	..	..	1,590	2,78,253
1928-29	..	..	..	..	..	1,335	2,51,959
1929-30	..	..	..	..	..	2,255	4,08,360
1930-31	..	..	..	..	..	2,625	4,70,391
1931-32	..	..	..	..	..	3,570	5,42,397
1932-33	..	..	..	..	..	3,772	5,23,500
1933-34	..	..	..	..	..	5,106	5,78,346
1934-35	..	..	..	..	..	6,265	6,23,654
1935-36	..	..	..	..	..	7,708	

TABLE 19.—Returns from various milk products.

Product.	Out-turn per 100 lb. milk.	Retail price per lb.	Gross return per maund of milk.		Relative return per 100 lb. milk.
			Rs.	as.	
	Lb.	As.	Rs.	as.	
<i>Ghee</i>	6	9	2	11	54
'Country' butter ..	7	9	3	2	63
Liquid milk ..	100	1	5	0	100
<i>Dahi</i>	85	1½	7	7	149
<i>Khoa</i>	25	6	7	8	150
<i>Channa</i>	20	8	8	0	160
<i>Mallai</i>	20	10	10	0	200
<i>Rabree</i>	40	8	16	0	320

TABLE 20.—Imports of cheese into India.

Year.			Quantity.	Year.			Quantity.
			(Cwt.)				(Cwt.)
1926-27	..	..	11,258	1931-32	..	..	7,349
1927-28	..	..	11,507	1932-33	..	..	8,858
1928-29	..	..	11,121	1933-34	..	..	9,871
1929-30	..	..	10,876	1934-35	..	..	10,924
1930-31	..	..	10,443	1935-36	..	..	10,546

TABLE 21.—Imports of milk products.

Nature of Product.				Approximate quantity imported.	Milk equivalent of imports.
				(Cwt.)	(Maunds.)
Unsweetened condensed milk, whole	..	..	..	25,000	70,000
Sweetened condensed milk, whole	..	..	..	25,000	70,000
Sweetened condensed milk, skimmed	..	..	..	150,000	550,000
Dried milk powder, whole	..	..	..	25	200
Dried milk powder, skimmed	..	..	..	250	3,500
Preserved cream	..	..	..	50	350
Sterilised milk	..	..	..	150	150
Total				200,000	694,200

TABLE 22.—Imports of condensed and dried milks into India.

Year.			Quantity.	Year.			Quantity.
			(Cwt.)				(Cwt.)
1926-27	..	..	182,845	1931-32	..	..	185,925
1927-28	..	..	224,036	1932-33	..	..	172,332
1928-29	..	..	245,153	1933-34	..	..	171,870
1929-30	..	..	242,611	1934-35	..	..	180,942
1930-31	..	..	226,853	1935-36	..	..	209,214

TABLE 23.—*Number of bulls issued annually from Government farms in certain provinces (average figures).*

	1923-24 to 1925-26.	1929-30 to 1931-32.	1932-33 to 1934-35.	1935-36.
Assam	7	15	36	42
Bengal	5	13	30	33
Bombay	30	17	28	23
Central Provinces	52	41	62	36
Madras	20	74	69	103
Punjab	320	336	551	616
United Provinces	75	145	142	141
Total ..	509	641	918	994

TABLE 24.—*Number of approved bulls at stud in certain provinces (average figures).*

	1929-30 to 1931-32.	1932-33 to 1934-35.	1935-36.
Assam	32	115	200
Bengal	79	360	487
Bombay	102	227	289
Central Provinces	73	104	132
Madras	104	124	181
Punjab	3,579	4,323	5,035
United Provinces.. .. .	2,696	3,245	3,448
North-West Frontier Province ..	170	233	234
Total ..	6,835	8,741	10,006

TABLE 25.—*Number of castrations performed in veterinary hospitals and dispensaries and during district work (British India).*

Year.	Castrations performed in hospitals and dispensaries.	Castrations performed in district work.	Total number of castrations performed.
1928-29.. .. .	206,941	303,958	510,899
1929-30.. .. .	243,562	353,628	597,190
1930-31.. .. .	284,968	415,126	700,094
1931-32.. .. .	337,957	463,297	801,254
1932-33.. .. .	380,880	512,184	893,064
1933-34.. .. .	430,675	575,456	996,131
1934-35.. .. .	497,111	612,034	1,109,145

TABLE 26.—*Bovine castrations performed in British India during 1934-35.*

Province:	Total bovine castrations.	Total male bovine population.	Percentage castrated.	Index* number.
Assam	21,843	3,068,042	0·69	10·8
Bengal	4,120	13,497,435	0·03	0·4
Bombay	35,379	4,868,561	0·72	11·3
Central Provinces ..	156,795	7,073,711	2·21	32·9
Madras	51,812	11,550,103	0·45	7·5
Punjab	441,787	6,914,964	6·38	100·0
United Provinces ..	22,374	15,813,997	0·14	2·1
North-West Frontier Province.	32,834	476,751	6·80	107·8
Bihar and Orissa ..	110,034	11,006,149	0·99	15·5
Sind	2,968	990,192	0·29	4·5

*In this the Punjab percentage, i.e., 6·38 is taken as equal to 100.

TABLE 27.—*Influence of milk yield on cost of milk production.*

Breed.	Average. lactation yield.	Feed cost per lb. of milk.	Labour cost per lb. of milk.	Total cost per lb. of milk.
		(Pies.)	(Pies.)	(Pies.)
Half-bred	6,500	3.55	0.83	6.49
Ferozepore Sahiwal	5,717	3.88	0.94	7.16
Scindi	4,150	4.48	1.51	9.42
Ordinary Sahiwal ..	3,864	4.45	1.29	9.18
Buffaloes	4,000	5.68	1.29	11.14

TABLE 28.—Average lactation yields of European cross-bred cows.

Breed.	Average lactation yields.						Average number of days in milk.					
	1931-32.	1932-33.	1933-34.	1934-35.	1935-36.	Mean.	1931-32.	1932-33.	1933-34.	1934-35.	1935-36.	Mean.
Pure Indian	4,092	3,678	3,065	2,130	3,272	3,247	296	274	251	265	282	273
‡ European	4,202	3,874	6,662	5,445	4,514	4,939	308	256	316	301	292	295
‡ European	4,837	5,389	4,966	4,954	5,247	5,078	319	310	302	297	321	310
‡ European	5,957	6,665	7,129	6,509	10,030	5,252*	313	337	347	307	392	321
‡ European	6,409	6,855	7,985	6,908	7,040	6,859	338	315	331	315	322	324
‡ European	6,272	6,831	6,494	6,873	7,505	6,817	340	310	310	312	331	321
‡ European	6,140	6,885	7,283	7,002	6,580	6,778	329	335	335	327	317	329

* Omitting the exceptional value of 1935-36.

TABLE 29.—Progressive increase in milk yield shown by herds at Lyallpur, Karnal, Pusa and Ferozepore from the date of their establishment.

	Average daily yield in lbs.				Overall.*
	Lyallpur Agricultural College Dairy.	Karnal.	Pusa.	Ferozepore.	
First year	5.60	8.8	5.8	11.3	4.6
Second year	5.40	7.1	7.6	11.6	5.9
Third year	6.80	8.4	8.3	12.9	8.6
Fourth year	7.18	8.6	6.6	12.9	9.2
Fifth year	7.45	10.2	6.8	12.6	9.8
Sixth year	8.60	10.0	6.1	14.8	10.6
Seventh year	9.31	9.9	7.4	14.7	11.3
Eighth year	7.27†	12.2	8.2	15.0	11.1
Ninth year	9.10	12.9	8.0	16.2	11.9
Tenth year	9.30	13.2	9.4	16.4	11.7
Eleventh year	9.03	13.2	10.8	17.4	12.5
Twelfth year	9.80	14.1	12.0	16.4	12.1
Thirteenth year	11.28	..	12.3	15.3	9.9
Fourteenth year	10.73	..	11.7	18.0	12.5
Fifteenth year	11.97	..	12.7	17.0	12.5
Sixteenth year	11.40	..	14.3	15.4	12.0
Seventeenth year	11.67	..	12.4	16.9	12.9
Eighteenth year	12.82	..	13.0	17.7	12.8
Nineteenth year	11.43	..	13.6	20.3	17.0
Twentieth year	15.05	..	18.5	22.6	16.8
Twenty-first year	16.54	..	..	18.3	13.7
Twenty-second year	17.15	..	..	16.5	11.1

* NOTE.—Karnal herd (Hariana and Tharparkar) was started in 1923 and Pusa and Ferozepore (Sahiwal) in about 1912, and the Lyallpur herd (Sahiwal) in 1914.

* These are overall averages, i.e., averages computed over milking and dry stock, whereas those shown in other columns are milking averages. Further the progressive increase of the Ferozepore herd is often masked by the influx of fresh cows which are purchased in the market for meeting the requirements of trade. These are not separately shown in administration reports.

† Fall due to severe attack of Foot-and-mouth disease.

TABLE 30.—*Distribution of milk yields in three Sahiwal herds.*

Name of farm.	Number of cows yielding.						
	Below 3,000 lb.	3,000 to 4,000 lbs.	4,000 to 5,000 lbs.	5,000 to 6,000 lbs.	6,000 to 7,000 lbs.	7,000 to 8,000 lbs.	8,000 lbs. and over.
1. Montgomery Dairy Farm ..	32	41	6	3	5	0	0
2. Jehangirabad Cattle Farm ..	48	82	95	37	11	0	2
3. Allahdad's Farms Jahanian ..	17	27	45	44	20	10	3

TABLE 31.—*Typical yields of improved cattle (average values).*

—	Pur- chased.	Farm- bred.	—
Amrit Mahal .. ..	..	..	Ajjampur, Madras.
Hissar .. ..	..	..	Hissar, Punjab.
Kangayam	1,493	1,615	Hosur, Madras.
Kankrej	932	1,936	Charodi, Bombay.
Gir	2,052	2,500	Charodi, Bombay.
Ongole	2,674	3,526	Chintaladevi, Madras.
Haryana	2,379	3,634	Karnal, Punjab.
Tharparker	2,294	3,791	Karnal, Punjab.
Scindi	3,572	4,137	Hosur, Madras.
Sahiwal .. ..	..	7,000	Ferozepur, Punjab.

TABLE 32.—*Comparison of number of cows and she-buffaloes at successive five-year periods.*

—	Population Cows.	She-Buffaloes (in thousands).	Percentage changes.*	
1915-16	37,697	13,629	100	100
1920-21	37,083	13,312	98	98
1925-26	37,961	14,205	101	104
1930-31	37,994	14,707	102	108
1934-35	38,696	15,438	103	113

* 1915-16 taken as 100.

TABLE 33.—Relative importance of cows and buffaloes in relation to milk production.

Province.	Bovine population.		Average lactation yields (in lb.).		Total milk production* (in thousand maunds).		Proportion of milk contributed by buffaloes.
	Breeding cows, i. e., cows over 3 years old kept for breeding or milk production.	Breeding buffaloes, i. e., buffaloes over 3 years old kept for breeding or milk production.	Cows.	Buffaloes.	Cows.	Buffaloes.	
Assam	1,305,188	112,781	170	430	2,771	628	18.4
Bengal	7,673,067	236,669	420	960	40,283	3,080	7.6
Bihar and Orissa	5,792,528	1,635,792	440	1,770	31,913	37,166	53.9
Bombay	1,796,896	1,153,869	500	885	11,135	12,035	51.9
Central Provinces	3,216,893	830,084	500	700	19,745	7,221	26.8
Madras	4,280,661	2,395,870	430	775	23,112	23,175	50.1
North-West Frontier Province	206,974	137,648	800	1,200	2,069	2,164	51.2
Punjab	2,549,778	2,873,692	1,400	2,160	44,745	78,040	63.6
Sind	761,107	339,573	1,000	1,500	9,513	6,350	40.0
United Provinces	5,726,249	4,060,877	800	1,000	57,262	50,760	46.9

* Excluding goat's milk. It should be noted that in calculating total milk production allowance has been made for the fact that many of the animals in the first two columns will not be in milk.

TABLE 34.—Total available feeding stuffs.

	Available quantity (1,000 tons).	Digestible crude protein (1,000 tons).	Calculated Nutrients.		Total digestible nutrients (1,000 tons).	Nutritive Ratio.
			Digestible carbohydrates (1,000 tons).	Digestible fats (1,000 tons).		
Dry fodders ..	111,000	1,010	34,580	383	36,480	1 : 36.0
Green fodders ..	100,000	1,000	10,000	250	11,562	1 : 10.6
Concentrates ..	1,500	450	375	180	1,163	1 : 1.6
Cottonseed ..	2,300	800	690	367	1,818	1 : 5.1
Total ..	214,800	2,760	45,645	1,150	51,013	1 : 17.5

TABLE 35.—*Acreage under fodder crops.*

Year.			Area (million acres).	Year.			Area (million acres).
1901	..	..	2·9	1920			8·1
1905	..	..	3·9	1925			8·9
1910	..	..	4·8	1930			9·3
1915	..	..	7·1	1935			10·2

TABLE 36.—*Distribution of yields of certain fodder crops.*

Yield (maunds per acre).	Percentage giving yields within limits shown in first column.					
	Juar.	Maize.	Oats.	Berseem.	Lucerne.	Grasses.
0—199 ..	37	61	35	22	26	17
200—399 ..	52	36	56	35	40	24
400—599 ..	7	3	9	19	23	36
600—799 ..	4	0	0	9	4	5
800—999 ..	0	0	0	9	7	6
over 1,000 ..	0	0	0	6	0	12
Total ..	100	100	100	100	100	100

TABLE 37.—*Distribution of costs of certain fodder crops.*

Cost (per maund).		Percentage giving costs within limits shown in first column.					
		Juar.	Maize.	Oats.	Berseem.	Lucerne.	Grasses.
As. pies.	As. pies.						
Below 1—11 ..		52	18	22	50	20	40
2-0 to 3-11 ..		34	40	43	18	37	28
4-0 to 5-11 ..		8	18	14	16	7	17
6-0 to 7-11 ..		2	18	0	3	6	7
8-0 to 9-11 ..		0	3	0	6	13	2
10-0 to 11-11 ..		0	0	4	3	3	0
Over 12-0 ..		4	3	17	3	13	3
Total ..		100	100	100	100	100	100

TABLE 38.—*Density of cows and she-buffaloes and of human population in various districts in India.*

Province.	District.	Per square mile.		
		Number of cows.	Number of buffaloes.	Human population.
United Provinces ..	Allahabad	64	41	524
	Etawah	48	55	441
	Agra	39	63	567
	Muttra	45	63	461
	Etah	42	81	501
	Aligarh	24	83	602
	Bareilly	45	49	679
Punjab	Hissar	23	17	172
	Rohtak	35	37	326
	Karnal	45	49	273
	Lahore	26	55	514
	Lyallpur	22	62	357
Bihar	Purnea	96	22	440
	Bhagalpur	85	28	529
	Darbhanga	96	41	946
	Muzaffarpur	80	44	969
	Champanan	90	34	603
	Saran	67	52	927
Bombay	Ahmedabad	19	25	259
	Kaira (Anand)	16	79	453
South India	Bangalore	59	18	311
	Coimbatore	36	13	345

TABLE 38(a).—*Density of cows and she-buffaloes and of human population in British Provinces.*

Province.	Per square mile.		
	Number of cows.	Number of buffaloes.	Human population.
United Provinces	60·1	42·6	508·2
Punjab	26·3	29·7	243·7
Bihar and Orissa	59·9	18·7	453·6
Madras	30·0	16·8	328·5
Bombay	23·2	14·9	232·9
North-West Frontier Province ..	15·3	10·1	179·3
Central Province and Berar ..	32·1	8·3	155·2
Sind	16·4	7·3	83·8
Bengal	91·5	3·4	646·4
Assam	23·7	2·0	156·7

TABLE 39.—*Experimental, district and demonstration farms.*

Province or State.	Experi- mental Farms.	District and Demonstration Farms.	Cattle- breeding Farms.
Madras .. ..	..	..	2
Bombay	5	10	5
Sind	1	6	..
Bengal	3	22	1
United Provinces	4	18	4
Punjab	8	14	1
Bihar and Orissa	5	18	2
Central Provinces	3	2	9
Assam	3	..	4
North-West Frontier Province ..	2	3	..
Indian States	22	16	11
Total	56	109	39

TABLE 40.—Acreage of farms and number of live-stock at provincial agricultural and veterinary colleges.

	Provincial Agricultural Colleges.						Provincial Veterinary Colleges.					
	Allaha- bad.	Cawn- pore.	Coimba- tore.	Lyall- pur.	Nag- pur.	Poona.	Bombay.	Lahore.	Madras.	Patna.	Calcutta.	
Total area of farm (acres)	500	39	270	*30	275	355	None	None	None	650	None	
Total head of bovines	239	74	131	74	104	204	None	None	None	634	20	
Whether oxen are pure-bred or cross-bred.	Both	Pure- bred.	Cross- bred.	Pure- bred.	Cross- bred.	Pure- bred	..	..	..	Pure- bred.	Cross- bred.
Whether buffaloes are kept	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	
Total milk produced (lb. per day).	875†	324	325	400†	400	1,000	None	None	None	1,177	16	

* Refers only to the Dairy Farm.

† Additional milk is purchased for use in the College Dairy.

TABLE 41.—*The number of agricultural and veterinary officers in British provinces in 1936-37.*

Provinces.	Agriculture.		Veterinary.	
	Gazetted officers.	Non-gazetted officers.	Gazetted officers.	Non-gazetted officers.
Central Provinces	25	166	7	163
Bombay	38	208	9	143
Madras	69	464	23	274
Punjab	69	236	36	406
United Provinces	44	274	4	226
Bengal	26	188	13	174
Bihar	18	113	11	139
Orissa	14	14	2	28
Assam	9	54	2	60
North-West Frontier Province	5	18	2	33
Total	307	1,735	109	1,646

TABLE 42.—Expenditure on live-stock improvement and veterinary services.

	Agricultural Department.		Proportion allotted for live-stock improvement.	Veterinary Department Total budget.	Total for veterinary department and live-stock improvement.	Total budget for both departments.	Proportion utilised for animal husbandry work.*
	Total budget.	Allotted for live-stock improvement.					
Madras	Rs. 18,47,000	Rs. 1,15,800	6.2%	Rs. 9,63,000	Rs. 10,78,800	Rs. 28,10,000	38.3%
Bombay	12,29,000	91,000	7.4%	3,78,000	4,69,000	16,07,000	29.2%
Bengal	9,95,000	54,367	5.4%	4,82,000	5,36,367	14,77,000	36.3%
Punjab	25,96,500	53,836	2.1%	12,91,000†	13,44,836	38,87,500	34.6%
United Provinces	23,62,200	1,20,738	5.1%	4,36,000	5,56,738	27,98,300	19.9%
Central Provinces	9,00,000	95,020	10.5%	3,86,000	4,81,020	12,86,000	37.3%
Bihar	6,92,617	43,218	6.2%	5,21,574†	5,64,792	12,14,191	46.4%
Assam	4,86,881	1,15,386	23.7%	1,41,203	2,56,589	6,28,084	40.8%
North-west Frontier Province	2,15,000	..	..	1,28,700†	1,28,700	3,43,700	37.2%
Total	1,13,24,298	6,89,365	6.1%	47,27,477	54,16,842	1,60,51,775	33.7%

* *i.e.*, expenditure on veterinary departments *plus* expenditure on live-stock improvement allotted by agricultural departments.

† The amounts allotted for live-stock improvement by these veterinary departments are as follows :—
Punjab, Rs. 2,32,000 ; Bihar, Rs. 53,151 ; North-West Frontier Province, Rs. 20,200.

TABLE 43.—*Number of cattle per veterinary assistant and expenditure per head of cattle in British provinces.*

Provinces.	Number of cattle per veterinary assistant.	Expenditure on veterinary services and live-stock improvement per head of cattle (pies).
North-West Frontier Province	29,500	23·8
Punjab	36,000	16·3
Bombay	65,500	9·1
Central Provinces	81,500	6·7
Madras	82,500	8·4
Assam	96,500	8·2
Bengal	135,000	4·1
United Provinces	141,000	3·3
Bihar	142,000	5·1

TABLE 44.—*Amounts spent annually on the gowshalas and pinjrapoles at seven typical centres.*

Town.	Total population.	Amount annually spent on pinjrapoles.	Per head annual donation.
		Rs.	Rs. a. p.
Karachi	263,565	1,48,337	0 9 0
Cawnpore	243,755	95,319	0 6 3
Bombay	1,161,383	3,09,594	0 4 3
Delhi	447,442	1,11,919	0 4 0
Muttra	60,590	4,200	0 1 1
Agra	229,764	14,968	0 1 0
Allahabad	183,914	3,000	0 0 3

TABLE 45.—Details of the milk supplies of certain cities.

	Bombay.	Madras.	Lahore.	Hyderabad.	Lucknow.	Bangalore.
Population	1,161,383	692,336	460,075	304,799	251,097	134,113
<i>Number of cattle in—</i>						
cattle stables	15,679	11,863	7,531	5,958	2,238	1,047
private milch cattle keepers' premises	2,570	1,485	3,098	1,351	584	281
<i>Percentage of milk produced —</i>						
(a) within the municipality	66.7	82.0	34.0	80.6	77.3	38.2
(b) within 5 miles of the municipality	33.3	7.3	28.0	14.1	8.7	42.2
(c) more than 5 miles outside the municipality		10.7	38.0	5.3	14.0	19.6
Number of milk shops	971	56	593	255	289	24
Number of milk vendors	1,483	1,442	275	54	152	225

TABLE 46.—*Relative demand for milk each month.*

Month.						Hill Station A.	Hill Station B.
January	..	..	..	..	..	100	127
February	..	..	..	..	..	130	100
March	..	..	..	..	..	260	146
April	..	..	..	..	..	492	181
May	..	..	..	..	..	673	378
June	..	..	..	..	..	650	446
July	..	..	..	..	..	547	490
August	544	500
September	597	527
October	647	357
November	318	179
December	163	160

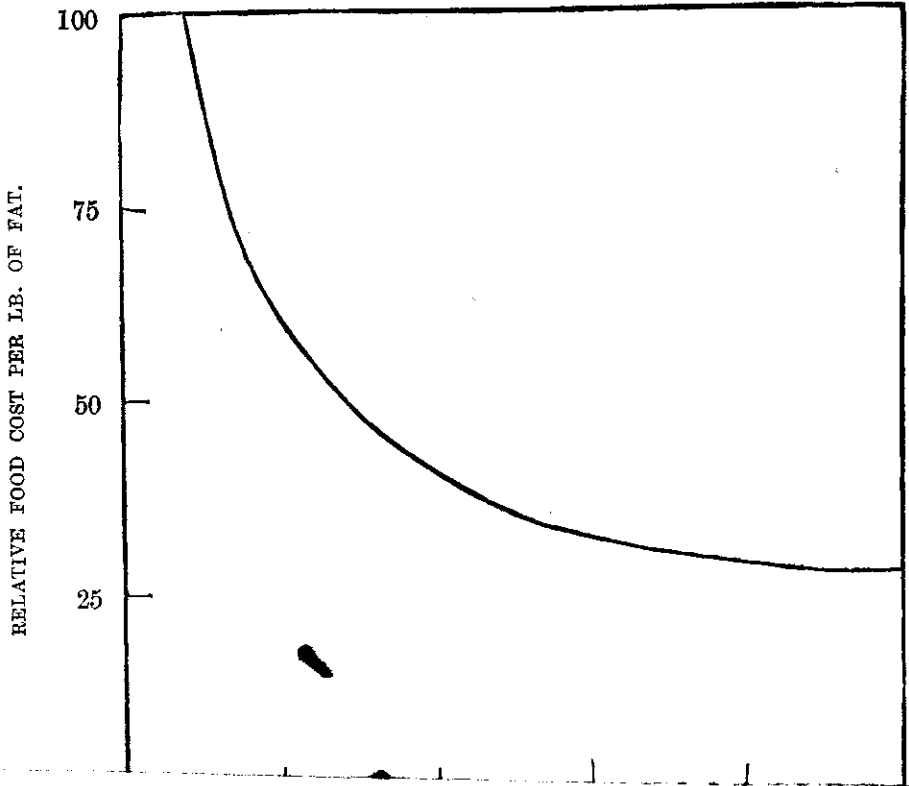


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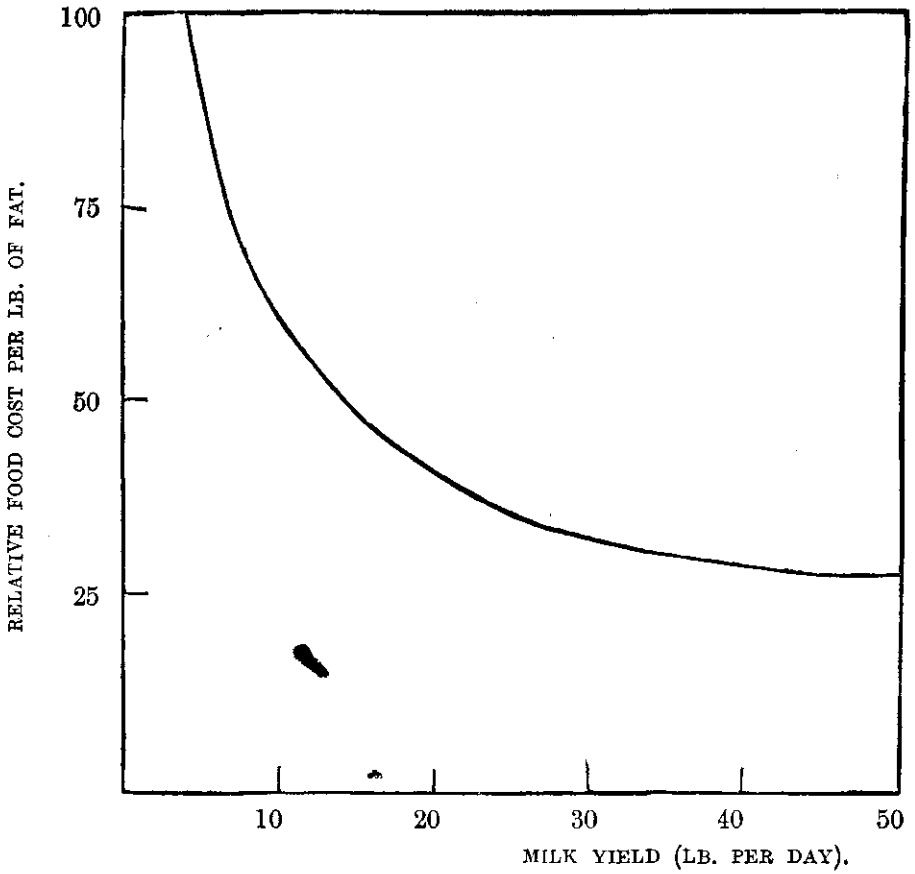
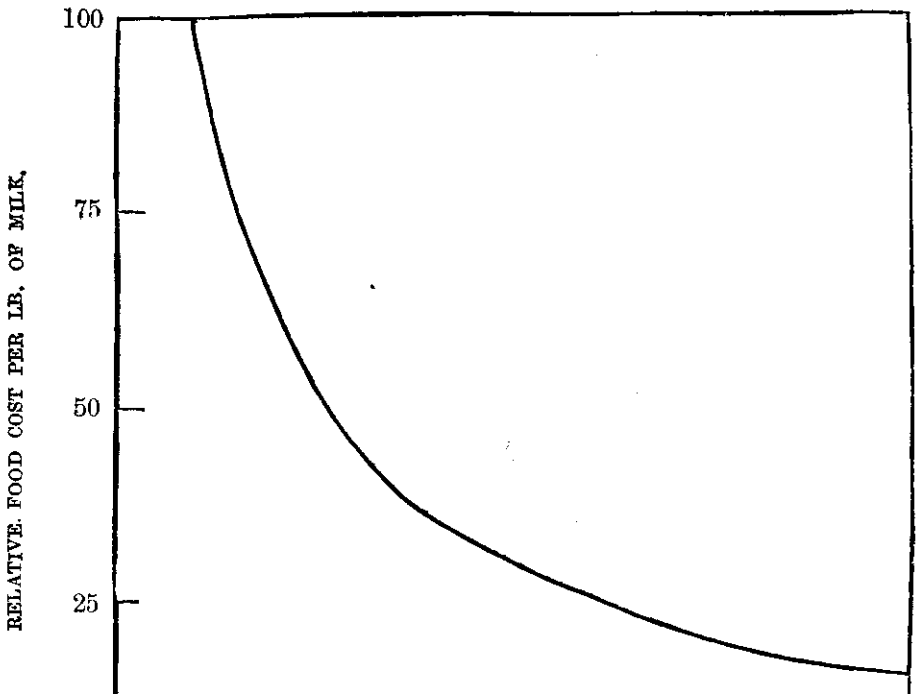


FIGURE I. RELATIVE FOOD COSTS PER LB. OF FAT
AT DIFFERENT LEVELS OF MILK YIELD (INDIAN DATA).



Report on the work of the Imperial Council of Agricultural Research in applying science to Crop Production in India

BY

SIR JOHN RUSSELL, D. Sc., F. R. S.



PUBLISHED BY THE MANAGER OF PUBLICATIONS, DELHI.
PRINTED BY THE MANAGER, GOVERNMENT OF INDIA PRESS, SIMLA
1937

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To

**The Honourable The Chairman of the Imperial Council
of Agricultural Research,
New Delhi.**

Sir,

Herewith I beg to transmit my Report on the work of the Imperial Council of Agricultural Research in promoting investigations on the science and practice of crop production in India.

The Report is in two parts.

In the First Part I have brought together the general results obtained, and discussed them in relation to the difficult problems associated with the improvement of agriculture and the raising of the standard of life for the cultivator.

In the Second Part I have dealt with the individual schemes fostered by the Council, and set out various recommendations. This part is necessarily somewhat detailed, but I have endeavoured to keep it within manageable limits. During my visit to the Stations I discussed each man's work at length with him and made numerous recommendations on points of detail or of experimental technique which are not included in this Report. Here I have confined myself to those recommendations which the Council alone could implement, should they approve of them.

This method of presenting the Report in two parts involves a certain amount of repetition, but it will, I hope, be found quite convenient in use.

I wish to record my thanks to all those who helped me in the course of my enquiries: especially to His Excellency the Viceroy, who set out the problem with characteristic lucidity and discussed possible solutions with great penetration and insight. I owe much also to the Honourable Sir Jagdish Prasad for several important discussions which proved most helpful in clearing up some of the difficulties I had met during my work; much also to those Governors, Ministers and Commissioners who received me on my journey and gave me the benefit of their knowledge and wide experience of their Provinces. I have to thank also Mr. N. C. Mehta and the Staffs of the Secretariat, of the Agricultural Departments, Colleges and Experiment Stations, for dealing with my numerous enquiries and furnishing information which often took some time to collect. Particularly I wish to thank Sir Bryce Burt and Dr. Burns for much help ungrudgingly given on innumerable occasions and for placing unreservedly at my disposal their extensive knowledge of Indian agriculture. I am much indebted also to the "Review of the work on Crops and Soils"—the "Brief"—prepared at the Secretariat, which proved most helpful both on the journey and during the preparation of the Report. Since my return to England I have received much useful help in regard to statistical matters from Mr. E. J. Turner of the India Office.

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Finally I wish to thank my personal staff for their loyal and devoted assistance during the whole of my period in India : especially Mr. R. L. Sethi, my Secretary Adviser, who accompanied me on the long tour which lasted with only two short breaks from the beginning of November, 1936 to nearly the end of March, 1937, during which he was responsible for the travel arrangements and for reducing the programmes at each centre to manageable dimensions. His knowledge of the schemes and of the men greatly facilitated the work just as his kindly and indefatigable helpfulness lightened the journey. I record also my appreciation of the services of Mr. Kasturi Lal, my stenographer, who, under the most trying circumstances, never failed me.

I am Sir,

Yours obediently,

E. J. RUSSELL.

Terms of Reference.

1. Generally, to report as to the manner and extent to which the Research Council has discharged its primary duties of co-ordinating and promoting agricultural research in India so far as it relates to plant industry, to comment on the value of what has been accomplished and to suggest directions in which improvements may be effected.

2. To draw attention to any important *lacunae* in Council's present research programme and to any undesirable overlapping.

3. To advise on the most promising lines of future development having regard to recent advances in science.

4. To advise on the policy to be followed regarding schemes now in operation, and which of them should be renewed at the end of their term.

5. To advise which of the schemes now on the ' waiting list ' should be financed and which should give way to new schemes (Page 4 of introduction to " Brief ").

6. To comment on the present working of individual schemes (or groups of schemes) and to suggest improvements.

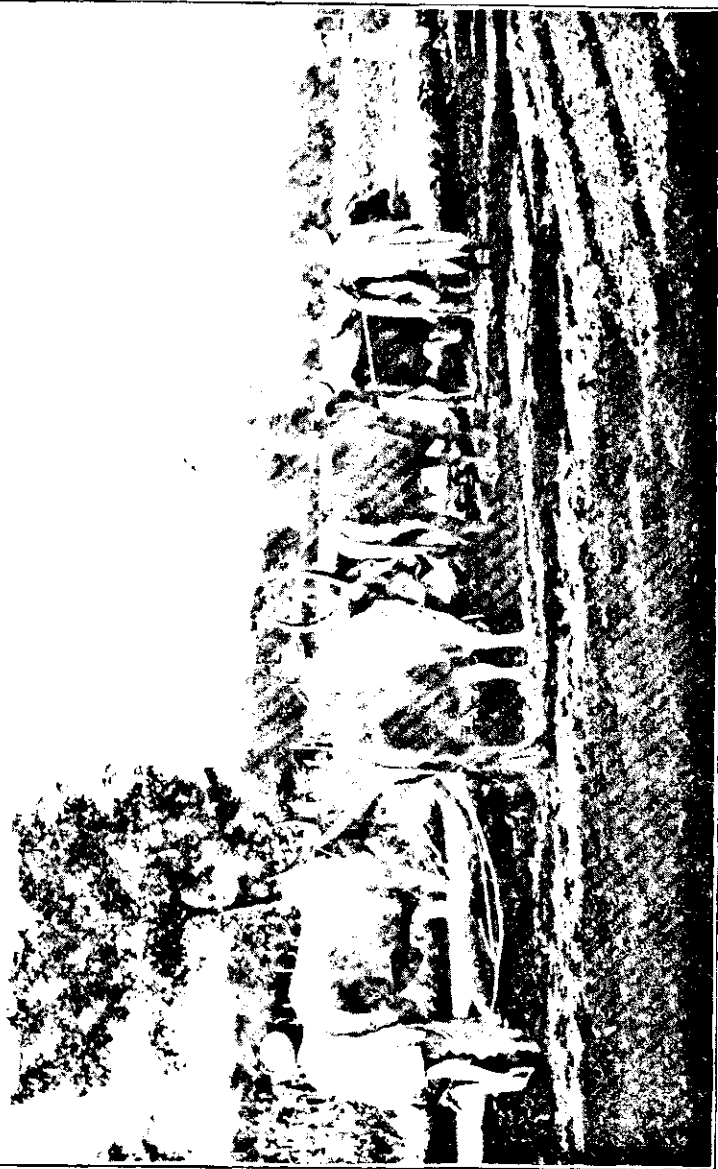
7. To report how far the dissemination of scientific and technical information, not only in regard to results of research, but also with regard to agricultural matters in general can be improved in order that the results of scientific work may be applied in ryots' practice and to advise what further steps are desirable to this end.

CONTENTS.**Report on the work of the Imperial Council of Agricultural Research
in applying science to crop production in India.****PART I.**

	Page.
<i>Introduction</i>	1
<i>Chapter 1.</i> —The stages in agricultural improvement	3
<i>Chapter 2.</i> —The crops	7
<i>Chapter 3.</i> —Factors improving the yields of crops	46
<i>Chapter 4.</i> —Special difficulties confronting Indian agriculture	60
<i>Chapter 5.</i> —The machinery for dealing with these problems	70
<i>Chapter 6.</i> —The Imperial Research Institute, New Delhi	47

PART II.**The Council's Schemes.**

Work directly carried out by the Council	87
Imperial Institute of Agricultural Research, New Delhi	90
Karnal	95
Agra	98
United Provinces	101
The Punjab	120
Sind	135
Baluchistan	144
North-West Frontier Province —	144
Simla and Dehra Dun	147
Mungpoo	149
Assam	150
Bengal	155
Bihar	166
Orissa	171
Central Provinces	173
Indore	175
Bombay Presidency	178
Hyderabad	193
Mysore	194
Madras	198
Travancore	214
Summary and Recommendations	215
<i>Appendix.</i> —List of schemes visited and reported upon	227



The old wooden plough in Poonna.

REPORT ON THE WORK OF THE IMPERIAL COUNCIL OF AGRICULTURAL RESEARCH IN APPLYING SCIENCE TO CROP PRODUCTION IN INDIA.

Introduction.

The improvement of Indian agriculture has been attempted by many Governments over a long period of years and by a variety of methods. In the first instance Western methods were introduced on the assumption that as they had succeeded in the countries of their origin they would also succeed in India. Notable examples were the bringing in of twelve American cotton planters by the East India Company in 1839 to show how cotton should be grown, and the importation of steam ploughs and a battery of implements by the Madras Government in 1864 to show how the soil should be cultivated. In general these methods failed. Next followed a period of searching for some general policy or system of organisation: little was actually accomplished, but there was much discussion which no doubt paved the way for future action. Finally it was recognised that Indian agriculture constituted a problem of its own; it could not be modelled on any other system but must be developed to accord with the natural conditions of the country and the requirements of its people. The best hope for improvement lay in the scientific study of these conditions and in experiments to discover agricultural practices that would best suit them.

This conclusion was reached only slowly and as the result of pressure of events rather than of deliberate planning. The Famine Commission of 1880, set up to find some practicable means of avoiding famines or at least of mitigating their worst effects, was the first body seriously to study possible methods of improvement. Definite action began a few years later: in 1889 Dr. Voelcker was invited to India to advise on the steps to be taken; in 1892 Mr. James Mollison was appointed as Technical Deputy Director of Agriculture for the Bombay Presidency and began making field experiments; Dr. J. W. Leather came out as agricultural chemist to the Government of India, for the improvement of agriculture was then regarded as a matter more for chemistry than for any other science. Meanwhile, however, pressure of another kind was being exerted: sugar cane diseases were causing much loss to cultivators in Madras and in 1898 Dr. Barber was brought from the West Indies to Madras to deal with them; by a stroke of genius he adopted the idea of selecting or producing disease-resistant varieties and achieved such remarkable success that the whole current of Indian agricultural science set for many years in the direction of plant breeding or genetics. These various activities showed that definite advancement could be achieved on scientific lines and when in 1901 another Famine Commission had to be set up, it had more definite grounds than its predecessors for insisting on the necessity for the establishment of properly organised agricultural departments in the Provinces capable of applying scientific methods to the improvement of agriculture, and, as the principle had by this time been widely accepted elsewhere, it is not surprising that Lord Curzon's Government speedily took action on the Report.

The reorganisations that followed included the strengthening of the Departments on the experimental and scientific sides, the establishment of Agricultural Colleges, of the Central Research Station at Pusa, and other organisations for the purpose of providing sound information about Indian soils, crops and animals on the basis of which the Departments might find solutions of the problems confronting them. The position was made more definite by the Government of India Act of 1919 which put upon the Provincial Departments the main responsibility for agricultural development but reserved to the Central Government the right to promote research by means of Central Institutes and other agencies, and gave also to the Central Government the power to deal with animal and plant diseases.

Then came the Royal Commission on Agriculture in India of 1926 which may fairly be said to have inaugurated a new era in the life of the Indian countryside. The Commission recognised clearly that the problem of improving Indian agriculture was really the problem of improving Indian village life, and that this must be studied as a whole. Its far-reaching conclusions, set out in its Report in 1928—the most comprehensive account of Indian agriculture yet published—have not been allowed to remain in abeyance. Reports are issued periodically showing “the progress made in giving effect to the recommendations of the Royal Commission.” More important still, the chairman of the Commission has become the Viceroy with the declared intention of ameliorating the lot of the present, a policy, which as I found everywhere in my journeys, is warmly appreciated in the villages.

The conditions are thus extremely favourable for the application of science to the problems of Indian agriculture. The Provincial Departments have already achieved valuable results and have fully justified the confidence reposed in them from the outset. But science knows no boundaries; its pursuit is costly both in time and in money; and the more highly it is developed the greater becomes the need for co-ordination. The Royal Commission foresaw this necessity and set up an Imperial Council of Agricultural Research, whose duty it is to give the lead and to co-ordinate wherever this is necessary but not to intervene in Departmental affairs. It derives its authority from its personnel, from the fact that it makes grants for approved investigations, and from its record of successful achievement.

One of the conditions laid down was that the Council's activities should periodically be reviewed by some disinterested expert and the honour of being the first to do this has fallen to my colleague, Dr. N. C. Wright, who is dealing with Animal Husbandry, and myself.

CHAPTER 1.

The Stages in Agricultural Improvement.

The purpose of agriculture is to obtain food and raw products by the cultivation of land, and its distinctive feature is that the process can go on indefinitely without deterioration, in contra-distinction to the exploitation of mineral resources which is possible only once. The agricultural scientific services are set up with the double purpose of educating the cultivator so that he may better understand the natural forces with which he is dealing, and of increasing his means of attacking the serious problems with which he is confronted.

The system of agriculture followed in large parts of India is very ancient, and was formerly very wide spread : it is fundamentally the same as that followed for centuries in England—indeed almost until our own time. It is based on the production of grain for human food, fibre for clothing and oil for burning, but it makes little provision for animal food except the straw or stalks of the grain crop and such wild vegetation as may be available for grazing. In the east, as in olden time in the west, the source of power is the bullock, which, therefore has to be given the first choice when fodder is scarce ; the supply of milk and of meat is consequently limited. The system has two great advantages : permanence, for apart from actual removal of the soil by flood or other agency there is no reason why the system should ever fail, and economy. Some eleven persons are sustained per ten acres of land while on the modern western standards and systems more than double this area is needed. But against this are the grave disadvantages that the yields are low, consequently the villages remain poor ; and the standard of living is low ; the diet provided is almost entirely grain, it lacks variety and is poor in animal products.

The change from the ancient to the modern system took some 70 years to accomplish in the west.

There is no occasion to despair of its accomplishment in India.

The Indian ryot compares favourably with any of the peasant populations I have met in different parts of the world. I visited many Indian villages and spoke with numbers of the inhabitants both in their cottages and on their holdings. It is no mere form of words, but a fact, that the wealth of India lies in the villages. Repeatedly in my journeys I came across men and women doing good, useful work in the towns or the Colleges, and on enquiring their origin found that they had come from villages or were only one generation away. " In the keeping of village ", as Tagore reminds us, " lies the cradle of the race ".

The improvement of village life is probably the greatest need in India to-day. In this first part of the Report I deal with the ways in which science has helped and can still further help in this work, with special reference to the activities of the Imperial Council for Agricultural Research. Later on I shall refer to some of the difficulties in the way.

There are three stages in the application of science to the problems of village life. In the first instance the science must be well founded: the facts and principles must be clearly proved and their consequences well thought out. This work is never-ending: each generation seeks its own proofs and soon discovers that the supposed facts and principles of its predecessors are only partly true. Further work is done, more discoveries are made and new principles enunciated, only to be displaced in their turn. Scientific investigation consists in making successive approximations to a Truth that can never be attained by human beings.

But there is always a great deal in Science that is sufficiently nearly established to be useful to men and women in their ordinary daily labours, and much work is done in trying to find practicable means of applying the results of science to the problems of village life. This requires a different type of mind from that of the discoverer, and only rarely is the purely scientific investigator capable of doing it effectively: frequently he has no desire whatsoever to do it. The story of the professor, who at the end of a long intellectual career thanked Heaven he had never done anything useful may be apocryphal, but it embodies a great truth. There is no advantage in attempting to fuse scientific discovery with scientific exploitation: separate staffs and separate organisations are needed.

When the application has been worked out the cultivator still has to be persuaded to adopt it. This often takes a long time and the cultivator is abused as slow and conservative because he does not change his methods more rapidly. But it is frequently impossible for him to do this. His unit of time is a year; "Safety First" must always be his guiding principle, and methods known to give subsistence to himself and his family cannot possibly be discarded until the superiority and practicability of the new ones are established beyond question. Even when he is convinced of their advantage he may still lack the means for adopting them. Further, he thinks in terms of his entire system of cultivation and an isolated process, though good in itself, may not fit well in with his general management. This extension work, therefore, requires something more than education and propaganda for the new methods, it involves much adjustment of the new methods to the actual conditions and systems on the cultivators' land.

The first stage—the gaining of knowledge.

This is so distinct from the other two that there is no advantage in trying to combine them. It is best done by men for whom the search is itself the end and the reward, and who are surrounded by young helpers animated by the same spirit. A few can have their own Institutes, but in the main the Universities are the places for the work. The Council has recognised this and has made grants for investigations of purely scientific interest but of some agricultural bearing. This limitation is in my view unnecessary: the scope of the grant should be widened to include all subjects fundamental to the science or practice of agriculture, provided always that the Council is satisfied as to the quality of the research work done in the laboratory concerned and that the subject proposed for

a grant is the major study of the workers there. The ability to make scientific discoveries is just as personal a matter as the ability to paint a great picture or to compose a great poem : it is quite as rare a gift, and while it may be fostered it cannot be created. The best help that could be given to the experiment stations would be to ensure that some of the staff had had a period of serious training in a laboratory where really good scientific work was being done, no matter on what subject. The vitally important thing is the training, and for this it is the man and not the subject that counts.

Science is advancing all over the world, and it is certain that the knowledge required for agricultural improvement will be obtained somewhere and will be announced to all who are interested : the great need in India is the better training of men. The advantage of removing the present limitation would be to bring into the scheme some of the best of the Indian laboratories, which at present take no part, such as those of Professor Sir Venkata Raman, Meghanad N. Saha, Birbal Sahni and others where the scientific work is of a high standard such as would bear comparison with any of the laboratories of the West. A student taking part in some good work in one of these laboratories would imbibe the true research spirit and incidentally would learn to avoid the common but very serious faults of diffuseness of programme, uncritical acceptance of methods and conclusions, and fragmentation of publications.

I recommend, therefore, that the Council should allocate a definite sum annually for grants to the Universities to be used for the appointment of research assistants to men actively engaged in scientific research, and that there be no limitation to subjects of agricultural bearing as at present. Any of the assistants who proved successful could if they wished be absorbed in the service, but even if they were not the Council would still have the satisfaction of knowing that it had contributed to the development of research schools in India.

The second stage—the Agricultural Experiment Stations.

The purpose of the experiment station is to apply the methods and results of science to the present day problems of the cultivator. Responsibility to the present generation must be recognised : refuge should not be taken in the pious hope that practical results may somehow and some day emerge from the work. This is widely recognised in the Stations I visited and the programmes were in general on useful lines though they were often too ambitious. Three weaknesses are fairly common. The work is frequently too diffuse—a fault not confined to experiment stations : when this happens the results lack definiteness. In many cases the work is confined too much to the laboratory and the pot culture house : the field and the growing crop should be the centre. Almost always it is restricted to the experiment station : test experiments should be carried out on other soils and at other centres not too far removed, so as to ensure that all factors coming into play are recognised.

In view of the fact that Indian experiment stations have been functioning for so many years it seems at first surprising that so little of the work done has found its way into the general body of

agricultural science as expounded in the standard treatises. It is comparatively rare to find references to Indian investigations in books published outside India. Probably the chief reason is the widespread Indian practice of publishing the results in a large number of small communications, many of which are uncritical and unimportant having the character rather of journalism than of serious scientific literature. Research demands that a man should think long and carefully about it; hurried and scrappy publication prevents him doing this. It would undoubtedly enhance the dignity and reputation of Indian science if the leaders would combine to stop this fragmentation, and encourage only the publication of serious critical papers where the work has been properly planned and the results fully considered. Good memoirs compel attention and gain recognition wherever and by whomsoever they are published.

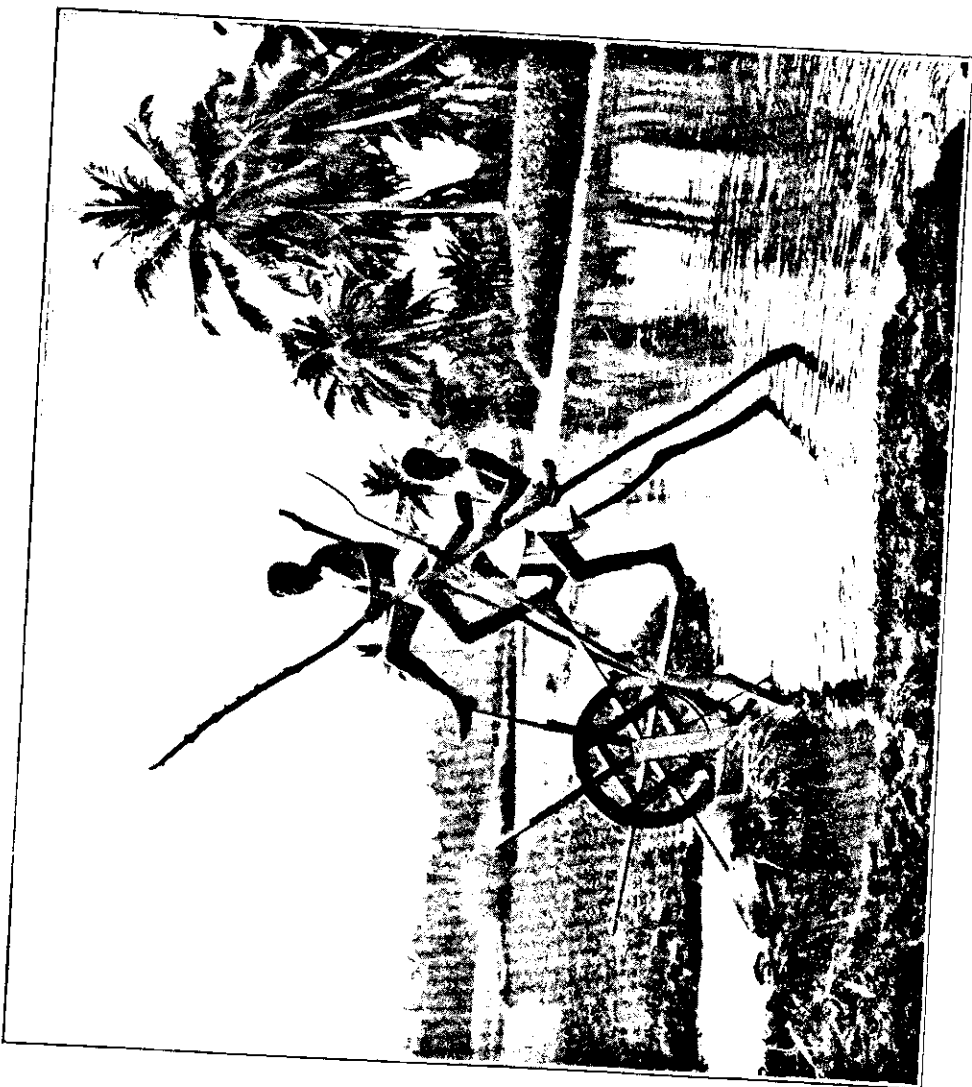
There is a considerable amount of good work in this vast mass of publications and it would be unfortunate if it all passed into oblivion. The best way of saving it would be the preparation of critical monographs, each by a specialist having thorough knowledge of his subject and able to assess the value of scientific evidence, summarising the results obtained, pointing out clearly where they differ from those recognised in the regular treatises and in what respects they represent advances in knowledge. These monographs would be of great value to teachers and to experimenters in India, and if well prepared they would be taken seriously by all agricultural research institutes; they would not only show what has been achieved in India but would also cause other stations to examine any discrepancies between the Indian results and their own.

The third stage—extension of the results to the cultivator.

The great need at the present time, however, is the wider and fuller use of existing science rather than the development of new science. Repeatedly I was told at the Experiment Stations that their yields were approximately 50 or even 100 per cent. greater than those obtained by the surrounding cultivators. There remains a great gap to be bridged between what can on present knowledge be accomplished, and what is actually being done by the cultivators. An enquiry should be made into methods of propaganda and some of the more efficient of them should be more widely used.

The present method consists largely of arranging demonstrations on cultivators' plots. A new variety is sown alongside of the local variety so that the villagers may see how the new and the old compare; or part of the land is cultivated with a new plough and part with old one. For an individual comparison a single plot suffices provided it is well enough chosen and no accidents happen. But for a group of improvements such as distinguish the experiment stations from the ryot's holding, the single plot is inadequate, and an entire small holding would be better.

The two methods should be regarded as mutually supplementary: the single plot has the merits that it is easy and inexpensive in operation, while the holding gives much fuller information but is



Water lift : human labour.
(Travancore.)

CHAPTER 2.

The crops—(a) The Cash Crops.

The common crops of India fall into two groups : those grown chiefly for sale, which we may call the cash crops, including cotton and other fibres, sugar cane, some of the wheat and oil seeds ; and crops grown for food, especially rice, juar, etc. The two groups need entirely distinct treatment. For the cash crops quality is an important factor, but it is impossible to define fully : the simplest and surest way is to obtain valuations and comments from expert buyers. For food crops, on the other hand, nutritive value is more important, and this should be assessed in association with medical experts.

The cash crops.

One of the most remarkable features in modern Indian agriculture is the increase in area under cash crops compared with that under food crops. The areas under cotton, sugar cane and wheat, have risen, corresponding with the increased area under irrigation, and the increase has kept pace with the increase in population. On the other hand the acreage under food crops show much less rise, and, if the figures can be accepted, the acreage per head of population has actually fallen. India possesses two good examples of research stations devoted to cash crops in each of which this important question of quality is in my opinion properly attacked : the tea research station of the Indian Tea Association at Tocklai, and the Cotton research station at Matunga, near Bombay. The Tocklai Station is the more complete in that it includes in the one organisation both producers and buyers, and it has devised special means of keeping close touch with both. The experimental samples of tea are submitted to expert buyers in Calcutta and in London for valuation and report : while at the other end of the chain considerable efforts are made to discover and to study the problems of the growers. Thus the staff have authoritative information as to the effect of the various practices on quality, and they can ensure that all of their results are known to, and can be used by, the whole body of the growers. The station is described on page 150.

The Cotton laboratory at Matunga works closely with the Bombay mill owners and experts, and is concerned chiefly with reducing the mill owner's rather undefined requirements to terms and quantities that can be handled by plant breeders. It is closely linked through the Indian Central Cotton Committee with all the Departmental Cotton breeding stations ; the Director has a voice in determining their programmes—in so far as they are financed by the Committee—and they have a voice in his. The cotton experimental field station at Indore is rather far away, a disadvantage, but one that is entirely unavoidable, because the conditions at Indore are suitable for field work while those at Matunga are not ; and on the other hand, Matunga is near to Bombay where the staff can

keep close touch with the mill owners. As cotton does not come within my purview I am not describing this Station, but its general organisation seemed to me to be very good.

The Council have endeavoured to make similar arrangements for sugar cane. The breeding is done at Coimbatore and the selections to suit the cultivator's requirements are made at various stations in the provinces : but a Sugar Technological Research Institute has been set up in the Harcourt-Butler Technological laboratories at Cawnpore (p. 108) where questions of quality, as the factory understands the term, can be studied. A Sugar Committee is to be set up, on somewhat similar lines to the Cotton Committee, which can take cognisance of all problems, economic, scientific and technical, associated with the growing of sugar cane and the production and marketing of the sugar. As soon as this arrangement has had time to settle down to good working order it should prove satisfactory.

The arrangements in regard to barley grown for export are also sound. The samples are produced at various stations in Northern India, and then submitted to the Institute of Brewing, London, where they are examined by experts having full knowledge of the requirements of the malting, brewing and distilling industries, and are reported upon in detail.

On the other hand, the arrangements for wheat and for rice do not appear to me to be so satisfactory. Investigations into quality of rice are being made at several centres, but there is no definition of what is meant by quality : there is no reference to expert buyers for market valuations or to medical authorities for grading according to nutritional standards. If a chemist is given a series of rices placed in a definite order based on some specific properties he may be able to find relations between composition and grading though it is always difficult to distinguish the true casual relations from merely fortuitous agreements. But if he has no guidance it is very difficult for him to get much out of his examinations. For a complex product like a seed the chemist can institute comparisons but he cannot so easily give absolute descriptions. For both these crops it is important to decide whether "quality" is to mean nutritive value or desirability in the market ; if the latter, in which market ; and to arrange the work accordingly. If market value is intended then some arrangements should be made with the buyers—an Indian group for the Indian market and a London group for the English market—to continue and extend the help already given on occasion to Sind and Punjab.

Sugar.

The Council can justly claim credit for great success in its activities in connection with the production and utilisation of the sugar cane crop. Since it began its work the area under cane has increased considerably and the old native canes have been largely supplanted by new varieties. The data are set out in Table 1.

TABLE 1.
Sugarcane Crop.
Acreage and production during 1935-36⁽¹⁾.

Provinces and States.	Area (in acres).		Yield (in tons) of Raw sugar (Gur).	
	Current year. 1935-36.	Average of preceding five years.	Current year 1935-36.	Average of preceding five years.
United Provinces (including Rampur State).	2,249,000	1,597,000	3,336,000	2,063,000
Punjab	473,000	446,000	358,000	336,000
Bihar and Orissa	465,000	313,000	668,000	371,000
Bengal	325,000	224,000	560,000	330,000
Madras	131,000	114,000	360,000	322,000
Bombay (including Sind and Indian States).	121,000	99,000	313,000	256,000
North-West Frontier Province ..	58,000	49,000	63,000	55,000
Assam	35,000	32,000	35,000	33,000
Central Provinces and Berar ..	30,000	24,000	49,000	39,000
Delhi	3,000	4,000	3,000	2,000
Mysore	50,000	38,000	53,000	36,000
Hyderabad	59,000	38,000	99,000	60,000
Baroda	3,000	2,000	3,000	3,000
Bhopal (Central India)	5,000	(a)	5,000	(a)
	4,007,000 (b)	2,980,000	5,905,000	3,906,000 (b)

(a) Not available.

(b) Excluding Bhopal.

The increased acreage is mainly in the old sugar growing districts, there being but little opening up of new regions, and the total area still remains relatively small, only 4 million acres in British India out of 227 million acres cultivated—nevertheless its importance is out of all proportion to the area it occupies. So far as the cultivator is concerned sugar cane has a valuable educational

(1) From Department of Commercial Intelligence and Statistics in Indian Trade Journal Supplement, May 21st, 1936.

effect : he learns the advantages of modern varieties of crops. of fertilizers, of proper cultivation ; the need to watch for plant diseases and to seek advice when he is in difficulties. The Agricultural Officer has more chances of coming in touch with a sugar cane grower than with an ordinary small cultivator. From the national point of view India is a heavy consumer of sugar⁽¹⁾, standing second among the nations of the world, and being surpassed only by the United States (Table 2).

TABLE 2.

Consumption of sugar : in 1,000 metric tons : raw sugar value.

1934-35.				
United States	..	..	..	5,870
British India	..	..	..	3,350
United Kingdom	..	..	..	2,283
Total—World				25,192

(Tables 1, 2 and 3 are from Indian Trade Journal : Supplement, May 21st, 1936. Gur is converted into sugar according to the ratio 100:60. Where, however, the gur is eaten as such, which is the usual course in India, the conversion factor is more like 80 than 60 so that the Indian consumption given above is actually too low.)

An assumed and abundant supply of sugar is essential to India's happiness. Most of it—some 80 per cent.—is eaten as gur which is all produced in India. Much of the white sugar used to be imported : in 1929-30 the import was 939,600 tons ; but the Indian production has risen so high that imports have fallen to 23,000 tons only in 1936-37 (Table 3).

TABLE 3.

Production in tons.

Production in tons.	1934-35.	1935-36.	1936-37.
	Tons.	Tons.	Tons Estimated.
Sugar (from Cane)	578,115	912,100	1,031,100
Sugar (from Gur)	40,000	54,600	40,000
Khandsari sugar	150,000	125,000	125,000
Total sugar produced	768,115	1,091,700	1,196,100
Total sugar imported	222,900	201,200	23,000
Net production of Gur (estimated)	3,692,000	4,105,000	4,372,000

(¹) Including gur.

From its inception the Council gave a prominent place in its programme to sugar and it was thus able to provide the technical information necessary for implementing the Government's decision to foster the production of white sugar in India.

The programme was in three parts :

- (1) The selection of canes better suited to the important sugar growing districts than the existing local varieties, and the improvement of their cultivation.
- (2) The improvement of the local methods of making gur.
- (3) The development of an advisory and research service for the sugar factories.

The selection and breeding work has been very successfully accomplished. The existing plant breeding station at Coimbatore was strengthened, and the investigations on the breeding of sugar cane so well started by Dr. Barber have been ably developed by Rao Bahadur Venkataraman, who has invented many devices for overcoming the numerous experimental difficulties. Provision was made for considerable experimental work to be done in all of the Provinces and several of the Indian States. Experimental farms were set up at Shahjahanpur by G. Clarke and at Muzaffarnagar to serve the United Provinces where about half the sugar cane of India is grown : the Station at Karnal is so near the borders as to serve a considerable area also ; while provision was made for experiments at Risalewalla, near Lyallpur and at Jullundur in the Punjab, which comes second in importance with 0.46 million acres ; at Museri in North Bihar, Patna in South Bihar, which together have nearly as large an area (0.44 million acres) ; at Dacca in Bengal (0.28 million acres) and Gudiyattam in Madras. The experimental scheme, however, was not related to the area under crop in the province, for some of the most interesting work is done at Padegaon in Bombay Presidency, which has only a small area of sugar cane (79,000 acres) and at Hebbal Farm, Bangalore, Mysore State, where area of cane is very small.

Beside the plant breeding on the classical lines proceeding at Coimbatore, a special method involving mutilation or destruction of some of the chromosomes by X-rays is being tried by Dr. Badami at Bangalore, and whether this produces better sorts or not it promises to give new material of possible value for the breeder. His experiments should certainly be continued.

Although the breeding of cane is usually regarded as necessarily restricted to the South it could if necessary be done to some extent in parts of the North : viable seed has been produced at Museri, near Pusa (Bihar).

This breeding and selection of cane is necessarily a slow business : 7 years elapse between the production of the new seed and the time when the new variety is fully tested and made available in sufficient quantity for distribution to the recognised farms from which it can be spread far and wide.

At present the selection is largely mechanical and it is possible that valuable new sorts may be overlooked and lost. The risk is minimised by making the test independently at a number of stations, but

it cannot be avoided till the Central Institute is able to find a really first class geneticist who could substitute proper scientific tests for the present mechanical ones. Meanwhile the work is being so well done that I have no suggestion to offer for its improvement. The new canes are so successful in practice that they are rapidly ousting the old ones⁽¹⁾. The improved varieties occupy a large proportion—no less than 74 per cent.—of the area under sugar cane : this being larger than for any other crop : out of the 4.14 million acres of sugar cane grown in British India in 1936-37, 3.07 million are stated to be under improved varieties.

The experiments on cultivation, watering and manuring are nearing the completion of the first series. At an early period the results should all be brought together, along with the analyses of the soils, and examined by a small group of experts, including a statistician, a soil specialist, a physiologist, and an agriculturist, to see what conclusions can legitimately be drawn and how far these agree with, or why they differ from, conclusions deducible from other good experiments made in the province. A new scheme of experiments should then be proposed for the second series. These should include practicable combinations of variety, irrigation, manurial and cultivation treatments, designed to give useful and trustworthy information without making the agricultural work and the recording too difficult. The statistician Mr. Vaidyanathan, is now at Rothamsted studying this type of design and full details will be discussed with him.

At an early stage a much simplified form of experiment should be tried on cultivators' land. Conclusions drawn from experiments at a research station are greatly strengthened if they are confirmed on other farms also ; and if they are not this shows the existence of some other factor playing an important part and needing investigation.

Considerable loss is caused by insect pests ; pyrilla and borers are mentioned specially in some of the recent reports. Investigations are proceeding but the field work needs further developing ; at each experimental centre close watch should be kept of the insects on the canes. This should not be confined to the bad attacks : it is at least as important to observe the early stages and to record the attacks that began and then died down. Knowledge of the conditions under which attacks became more intense and of those under which they died down, would form a solid foundation on which preventive or remedial measures could be devised. In view of the seriousness of the losses it is desirable to obtain the services of a visiting expert to discuss methods of control (page 219).

Utilisation of Molasses.

Closely associated with the sugar cane problems is the utilisation of molasses, the amount of which has increased greatly during recent years. The Director of the Imperial Institute of Sugar Technology, Cawnpore, has favoured me with figures showing the production and imports of molasses into India (Table 4).

(1) Indian Trade Journal Supplement, May 21st, 1936.

TABLE 4.
Production and Imports of Molasses into India.

	Production.			Available for Consumption.		
	Vacuum Pan Factories.	Khandsaris	Total.	Imports.	Total.	Excluding Khandsaris.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
5 years preceding war.	30,000	50,000	80,000	93,354	173,354	123,354
1930-31 ..	68,645	200,000	268,645	102,024	370,669	170,669
1931-32 ..	115,808	250,000	365,808	40,191	405,999	155,999
1932-33 ..	186,658	275,000	461,658	31,991	493,649	218,649
1933-34 ..	230,154	200,000	430,154	2,401	432,555	232,555
1934-35 ..	255,817	150,000	405,817	415	406,232	256,232
1935-36 ..	369,028	125,000	494,028	..	494,028	369,028

A substantial part of the Khandsari molasses is converted into low grade gur by reboiling with sugar cane juice and something like 175,000 tons of the factory molasses is either converted into alcohol, used for tobacco curing, or directly consumed. But there remains the problem of finding some way of utilising the remaining 200,000 tons.

Various possibilities are discussed on page 109, they fall into three groups : conversion into food (including yeast) for human beings or for animals ; the making of fermentation products such as industrial alcohol⁽¹⁾, acetic acid ; and industrial utilisation as fuel, road surfacing material, fertilizer, etc. Of these I regard the first and second as the most important and the third as least important : it seems unfortunate to divert so much potential food to other purposes. The problems will become less urgent when the Indian sugar factories have attained the same high level of sugar recovery as the Java factories.

(1) The quantities of low proof alcohol produced in India during 1936-37 are estimated to be :—

	Million gallons.					
Potable	6.8
Rectified	0.4
Denatured	2.3
Beer and stout	1.2
						10.7
			Total	..		

For purposes of comparison it is interesting to note that the quantity of petrol produced in India and Burmah is 91 million gallons, most of which is consumed in India.

The Making of Gur.

Progress has also been made with the improvement of manufacture of gur in the villages though this task presents greater difficulties than the introduction of new varieties. The plant is usually hired out by the *banya* to the cultivators, or if the crop is new to the district the enterprising individual who introduced it may set up to make the gur. Many of the village mills are very inefficient, leaving behind in the bagasse a considerable amount of sugar—often as much as 20 per cent. of the total quantity⁽¹⁾. The evaporation of the juice in an open pan is inefficient, but as the trash and bagasse are both available as fuel the loss is not particularly important. The skimming of the concentrated juice varies greatly in effectiveness, resulting in a wide range of quality of the gur, and there is little attempt at clarification, except in a few regions where *hibiscus* is used for this purpose. Improvement in the mills would be perhaps the easiest to effect, and would result in considerable economy. Special attention is being given to this. Still greater improvement, if it could be brought about, would be to set up village factories with efficient mills for extracting the juice, vacuum pans for evaporation, and arrangements for clarification by filtering through charcoal: in this way higher yields and better qualities would be obtained. The *banyas* are usually good business men with some capital, and it is possible that, if suitable plants were available, they would purchase them. The problem appears to be one for a good firm of engineers. but in the meantime experiments aided by grants from the Council are being made at the Sugar Research Institute, in the Punjab, Bihar and Orissa, and in Bengal, with the purpose of trying to improve the making of gur.

The Sugar Factories.

The Council from the beginning recognised the necessity for a good research and advisory service to assist the factories in the production of white sugar and they set up an Imperial Sugar Research Institute at Cawnpore, housing it in the Harcourt Butler Technological Institute. Here a semi-commercial factory unit was established to furnish the staff with information and with opportunities to design or to test technical processes; the expert in charge acts also as adviser to the factories. This section is evidently succeeding. The need for the work is shown by the wide variation in recovery of sugar at the different factories—from 4.4 to 11 per cent. of the cane, the general average being 9.5 per cent.⁽²⁾.

The proposed Sugar Committee could appropriately take over the Sugar Research Institute.

(1) The difference in efficiency between the village process and a good factory is shown by the fact that from a given weight of cane the factory obtains as much sugar (99½ per cent. purity) as the villager obtains gur (80 per cent. purity). In both cases the amount of product obtained is about 10 per cent. the weight of the cane (page 102). The figures are:—

	Per cent.
Gur	10
Factory Sugar	9.5
Khandsari Sugar	5.5

(2) This compares with 5.5 per cent. recovery where Khandsari sugar is made.

TABLE 5.

Areas of land under different crops in British India.
Thousand acres—British India.

	1915-16— 1919-20.	1920-21— 1924-25.	1925-26— 1929-30.	1930-31— 1934-35.
Net area sown	220,691	221,971	226,410	229,051
Irrigated area	47,391	46,969	47,889	49,870
Area under—				
Rice	79,331	78,981	79,167	80,367
Wheat	23,604	23,264	24,477	25,677
Jowar	21,817	22,669	21,352	21,826
Bajra	13,611	13,494	13,275	13,577
Gram	13,314	14,457	13,609	14,756
Sugar	2,797	2,757	2,830	3,233
All food crops including sugar (b) ..	210,614	209,494	208,658	214,746
Cotton	14,087	14,433	16,265	14,159
TOTAL—non-food crops ..	42,587	43,775	49,362	47,551

Summary.

	Thousand acres.
Increase in net area sown	8,360
Increase in food crops	4,132
Increase in non-food crops	4,960

TABLE 6.

Areas per head of population. British India.

	1903-04— 1907-08.	1908-09— 1912-13.	1913-14— 1917-18.	1918-19— 1922-23.	1923-24— 1927-28.	1928-29— 1932-33.
Net area sown, acres per head.	0.883	0.906	0.918	0.879	0.868	0.841
Acres under food crops per head.	0.829	0.862	0.873	0.833	0.803	0.786
Acres under food crops omitting sugar, per head.	0.818	0.852	0.862	0.822	0.792	0.774
Acres under non-food crops per head.	0.053	0.043	0.045	0.045	0.065	0.057
Population: Millions ..	237.6	243.8	245.3	246.9	259.2	271.5

(b) THE FOOD CROPS.

The quantity of food produced in India.

In no country is it easy to estimate the amount of food produced and in India the difficulties are particularly great. The areas under crops are fairly accurately known in most of the British Provinces but unfortunately considerable uncertainty exists as regards the Indian States and the permanently settled districts of the north east, Bengal, Bihar, Orissa and Assam which amount to about 20 per cent. of British India. There is now the possibility of an accurate survey of the areas under crop in Bengal.

The quantities of food produced, however, are not nearly so well known as the acreages. The published figures are obtained by the use of an old equation : Production area \times standard outturn \times seasonal condition factor. The standard outturn is not the average yield over a number of years, but the model value over a long period and so is unaffected by high or low yields of particular years. Unfortunately the standard outturn has not been redetermined for a long while, and it is very desirable that this should be done again : it involves a number of sample weighings. The seasonal condition factor can never be much more than a guess, though if it is unbiased and done year after year by the same officer, and particularly if he has the opportunity of periodically checking his estimates, the results may not be unsatisfactory.

Professors Bowley and Robertson in their Report (page 39) point out that methods based on direct estimates would really be better.

It seems desirable to make a sample survey to test as far as possible the accuracy of the present methods and the possibility of improving them. Professor Mahalanobis has suggested a scheme for doing this which deserves serious attention.

The official figures as they stand show that the acreage under food crops, unlike that under cash crops, has not kept pace with the growth of population ; on the contrary there is an actual fall in the acreage per head. (Table 6). During the period 1908-09 to 1917-18 0.89 acres per head of population were devoted to food crops while during the period 1928-29 to 1932-33 the acreage had sunk to 0.79 per head. The population had increased by 28.7 millions but the area under food crops went up only by 2.6 millions acres, only 0.09 acres per head. The non-food crops, on the other hand, have kept pace with the population, the acreage per head being 0.044 in the earlier and 0.057 in the later of the two periods.

The statistics are not good enough to show how much the total production of food has varied and whether it has kept up with the population. Unless we assume (as some assert) that the villager has less food than formerly, we can only suppose that the yields have increased, and reports from the staffs of the Agricultural Departments confirm this view.

Almost the whole of the food crops are grain. They are consumed in the country and there is no important export so that " quality " in the sense in which it exists for the cash crops does not come into account here. But as they form the dietary of the people their nutritive value is of the greatest importance.

The recorded figures for production of all food grains are given in Table 7(1). These figures in so far as they are valid represent the amounts of all grains including oilseeds produced in the various provinces: they can be described as the amounts potentially available for consumption, and while not necessarily the same as the figures for actual human consumption, they may not in fact be far out. Some grain is exported from each province, and some is imported. If it is assumed that, on balance, the total may not be much affected; and if, further, the figures accurately represented the actual production, they would need to be decreased by the amounts of husk (if any), the quantities lost on storage, and in transport and saved for next year's seed: no estimate of these can be made but the total is not likely to be less than 25—40 per cent. It is, however, safe to assume that the figures under-estimate the production. Cultivators all over the world under-estimate their crops in presence of an official, and the Indian ryot is not likely to be an exception. When a direct check was made on the production of cotton the estimates were found to have been 25 per cent. too low. For the food crops the difference may be of the same or even greater order (2). This under-estimate offsets the deduction necessary on account of seed and wastage, and if we assume they balance we obtain the average quantities of grain available per head per day set out in Table 7.

TABLE 7.

Production in oz. of all grains, including pulses and oil seeds per head per day. Cotton seed is not included.

Province.	Total grain million tons.	Population millions.	Total grain oz. per head per day.	Nitrogen grams per head per day.
Assam	1.6	8.6	18	7
Bengal	9.3	48.9	19	7
Bihar and Orissa ..	9.0	36.7	24	11
Bombay	6.1	20.6	29	16
Central Provinces ..	4.8	15.5	30	15
Madras*	10.4	46.7	22	11
Punjab	5.0	23.6	21	12
United Provinces ..	10.6	46.7	22	13

*Includes groundnuts which forms 20 per cent. of the whole.

(1) The quantities were supplied to me by the staff of the Imperial Council of Agricultural Research and by Sir Bryce Burt, and the data for composition are quoted from Dr. Aykroyd's publications.

(2) An interesting passage occurs in the Punjab Season and Crop Report of 1922-23: "The principal exporting firms get fairly good results by assuming that the wheat outturn is 33 per cent. greater than the official estimate". The Punjab Marketing Report, 1935-36, refers to this statement and sees no reason for supposing that conditions are different now. (Quoted from Report on the Marketing of Wheat in India, 1937.)

For what they are worth these figures suggest for most Provinces a production per head per day of about 20-22 oz. of all grains including pulses and oil seeds whether used for food or not : this would give a daily calorie value of about 2,000 or 2,500 according to the proportions of oil seeds taken ; and a nitrogen supply of about 12 grams daily. Bombay and the Central Provinces, however, come out higher, and Assam and Bengal lower, especially in nitrogen. The figures include no vegetables or milk products.

Unfortunately the figures are only very rough. In view of the supreme importance of this question of food production it is very desirable that better data should be available and I recommend that periodical estimates should be drawn up showing the amount of food produced.

Another means of approaching the subject is afforded by the numerous surveys of village dietaries that have been made.

The Punjab Board of Economic Enquiry in 1934 and 1935⁽¹⁾ made surveys of certain villages and the total quantity of grain eaten per head per day varies round about 15-20 oz., but for men only was 20 to 28 according to occupation. Lucas⁽²⁾ put it 10.24 chhataks (about 20.5 ozs.) per head per day. Mrs. Wiser⁽³⁾ found about 16 oz. per head was normally consumed in her village. In south-east Madras Dr. Aykroyd and his staff at Coonoor have made a survey in considerable physiological detail and calculated the results on the basis not of heads of population but of "consumption units", i.e., the equivalent number of adult men, using the scale adopted by the League of Nations Health Organisation in 1932. though Dr. Aykroyd points out that there is no evidence to show whether their scale is valid for India.*

Taking the "cross section" of a village in south-east Madras he arrived at the following dietary per "consumption unit" per day⁽⁴⁾ :-

Protein.	Fat.	Carbohyd- rates.	Calories.	Percentage of total calories derived from cereals.	Calcium.	Phos- phorus.	Iron.
g.	g.	g.			g.	g.	mgm.
62.7*	26.9	488.9	2,400	87	0.31	1.51	32.8

*Containing nitrogen 10 grams (conversion factor 6.25).

(1) Punjab Board of Economic Enquiry, Pub. 6 (C. B. Barry), Pub. 40, 1934 (S. K. Singh), Pub. 44, 1935.

(2) Economic life of the Punjab village. The figure of 15 ozs. quoted above is from C. B. Barry. Rates of Food Consumption by Non-Zemindars, Publication 6, Board of Economic Enquiry.

(3) The foods of a Hindu village of North India, Charlotte Viall Wiser, Bull. 2, Bureau Statistics and Economic Research, U. P., Allahabad, 1936.

(4) Diet surveys in South Indian villages, W. R. Aykroyd and B. G. Krishnan, Indian J. Medical Research, 1937, Vol. 24, pp. 667-688.

In order to compare these figures with those in Table 7, it is necessary to raise the latter by approximately one third : the figures are not good enough to justify a more elaborate coefficient.

It is highly important that these dietary surveys should be extended so that the actual facts may be known more definitely. The surveys should be really "sample surveys" and not "spot surveys", i.e., there should be some definite method of selecting the villages to be studied. Professor Mahalanobis is studying this problem. Two independent sets of data can be collected :

- (1) statements showing the actual dietaries, which can then be compared with the physiological requirements as set out by the medical authorities ;
- (2) records of the prevalence of various diseases caused by deficiencies of essential nutrients.

It is unfortunate that the data for food production in India are somewhat uncertain, but in the meantime if we take the figures in Table 7 as a rough approximation of the average quantities available the question arises : are they sufficient ? Dr. Aykroyd is not yet prepared to lay down Indian standards but he inclines for the present to 2,600 calories as the average daily requirement of a man, a value which falls between the 2,200 suggested by Nicholls for an agricultural labourer belonging to the smaller races of the Tropics, and the 3,000 calories deemed necessary in Europe and America for the average man at average work. It seems a reasonable figure when allowance is made for differences in climate and in "average work". Whether it is really adequate is of course a question for the medical authorities to decide, but the agriculturist, at any rate, must accept it till they rule otherwise. Dr. Aykroyd⁽¹⁾ further suggests, as an average man's daily requirement in India, 65 grams of protein (i.e., 10.4 grams nitrogen) probably 45—60 grams of fat, 20 mgms. iron, some 0.6 grams calcium and 1 gram of phosphorus ; but there are no Indian data as to these elements. He emphasises the importance of biological value of the proteins and points out that animal proteins are biologically more efficient than vegetable proteins ; he suggests that they should form at least one-fifth of the total protein. Milk, even skim milk, is the best for growing children, but eggs, fish, liver and meat are all good sources.

It is possible that the average supplies available approximately satisfy both the nitrogen and the calorie requirements when allowance is made for the fats and gur taken. A more serious defect is the lack of vitamins, especially of A and B and this is confirmed by the prevalence of the "deficiency diseases" associated therewith. e.g., keratomalacia caused by deficiency of Vitamin A ; stomatitis due to vitamin B deficiency ; low hæmoglobin content due to iron deficiency. Calcium deficiency is also common. These missing elements can only be supplied by widening the diet and making it include more milk, vegetables, and fruit. Plantains are among the commonest fruits eaten, but they have low nutritive value. Tomatoes, oranges and other juicy fruits are much better. Oil obtained from the fruit of the Red palm (*Elaeis guineensis*), a West African tree.

(1) Health Bulletin No. 23, 1937.

that could apparently be grown in India, proved to be a valuable source of Vitamin A, and was therapeutically as effective as cod liver oil besides being much cheaper. It is clearly desirable to experiment with the growth of this tree in India so that the oil may be available in quantity. Dr. Aykroyd has drawn up an instructive table showing two dietaries : a common ill-balanced one, and a well-balanced diet which should be substituted for it⁽¹⁾. The data per consumption unit in ounces per day are :—

	—				Ill-balanced diet.	Well-balanced diet.
Cereals .. .. .	..	..	..	..	20	15
Pulse .. .. .	..	..	..	..	1	3
Vegetables—						
Green-leafy .. .. .	..	..	..	..	2	4
Non-leafy .. .. .	..	..	..	..	2	6
Fats and oils .. .. .	..	..	..	..	0.5	2
Fruits .. .. .	..	..	..	..	..	2
Milk .. .. .	..	..	..	..	2	8

The well-balanced diet does not require more but less cereals than at present, but it includes more of everything else, especially of vegetables fruit and milk, and one great need for the food supply is to increase the production of these three. It is essential, therefore, to increase the yield of the staple crops so as to liberate land for the cultivation of these supplementary foods. No improvement in 'quality' of the cereals or pulses will convert the ill-balanced into a well-balanced diet. I am strongly of opinion that in dealing with food crops intended for home consumption the agriculturist should aim at securing the largest and healthiest crops possible, but that he need not concern himself with trying to change their composition. The amount of alteration possible is too small to justify the expenditure of time and resources that can better be spent in other ways.

The first need in my view is to make a nutrition survey in each Province so as to discover what are the chief deficiencies in dietary : the medical authorities should then meet the agricultural experts to decide what crops, including fruits and vegetables, should be grown to supply the missing elements. The approximate quantities needed should be indicated, and the agricultural staffs acting along with the rural development authorities would then encourage by all means in their power the growth of these crops.

The nutritional survey should not in the first instance be over-elaborate : in most Provinces there is already a fair amount of material, probably sufficient as a first approximation, to allow the agricultural problems to be put in hand. More detailed studies could continue as part of the Public Health work of the Province in relation to nutrition of children, deficiency diseases, etc.

(1) W. R. Aykroyd and B. G. Krishnan, *Indian Journ. Med. Res.*, 1936, Vol. 23, p. 731.

The "well-balanced diet" set out above costs about Rs. 5 per month for a growing adult and very little less for growing children : it is therefore out of the question in many households, but others, cheaper though not so good, have been suggested⁽¹⁾. The figures do not suggest marked protein deficiency but Dr. Aykroyd points out that it is greater than it appears because of the lower efficiency of the vegetable proteins as compared with those of animal origin. From time to time it is suggested that soya bean would be a valuable addition to the Indian dietary, but there is no evidence that it has any special value and until any is forthcoming there is no point in trying to develop its cultivation.

These nutritional deficiencies have been studied most fully in Madras but they probably hold also for most of India including the Bombay Presidency, Bengal, Bihar and Orissa. In the Punjab and the United Provinces, where more wheat and milk are consumed, the problems are probably different.

Dr. Aykroyd has pointed out that the deficiencies of the diet could most easily be remedied by the inclusion of animal products : milk, eggs, fish and meat. It is difficult to exaggerate the importance of increasing the milk supply : Dr. Wright is dealing with this. From the agricultural point of view the production of meat is the most costly of these foods, but supplies of fish could probably be increased. The Council already subsidises schemes of fish research at Calcutta and Madras and there is a strong case for further development.

Much more work should be done on the cultivation of the green leaf vegetables and demonstration fruit and vegetable gardens should be set up adjacent to the village where they can receive manure and water.

The new nutrition officer at Delhi.

Recently a nutrition officer has been appointed to act as liaison officer between the work of the nutrition laboratory at Coonoor and the Agricultural Research Stations at Delhi and in the provinces. This is an admirable development which cannot be too heartily commended. Where there is so much to do it is important that he should begin straight away with the essential problems, leaving the minor ones to later occasions.

His first duty should be to collect the evidence obtained by the medical authorities and other public health workers as to the state of the nutrition of the villagers and townspeople, and discuss with the agricultural experts the best ways of remedying the observed defects.

It has been suggested that he should study the nutritive values of the new varieties of cereals and the relation of deficiencies to soil conditions. I do not agree with this view. There are of course differences in composition and in nutritive value of different varieties of cereals and of cereals grown under varying soil conditions. These may be of considerable importance in technical processes such as

(1) W. R. Aykroyd and B. G. Krishnan, *Indian Journ. Med. Res.*, 1937, Vol. 24, p. 707.

brewing, baking, etc., but they are probably of far less importance in human nutrition. I am very strongly of opinion that the best varieties for home supply of food are those that give the largest yields per acre. The really vital matter is the food value per acre, not per ton, of produce.

It is particularly important that the work on human nutrition should not become diffuse : everything else should be subordinated to the two vital problems : what are the deficiencies in the village dietary and how best they can be overcome ?

With the greater part of the Report of the Nutritional Advisory Committee⁽¹⁾ I am in entire agreement.

Rice.

Rice is by far the most important crop in British India, occupying 67 million acres out of the 186 million devoted to food crops : it is the chief crop in Bengal, Bihar and Orissa, the Central Provinces and Madras, and it is surpassed only by wheat in the Punjab, the United Provinces and the North-West Frontier Province, and by jowar and to a less extent by bajra in Bombay. It is also one of the most interesting of Indian grain crops, for being indigenous to India it occurs in a large number of varieties which differ greatly among themselves. Among its most remarkable forms are the long stemmed paddies which grow in deep water so rapidly that they keep pace with the rising flood during the monsoon period.

Some very good work has been done in India on the classification and breeding of rice : the foundations were laid from 1913 onwards by G. P. Hector in Bengal and by F. R. Parnell in Madras, Hector showed that self-pollination was the rule but cross-pollination also occurred through the agency of the wind : he studied colour inheritance and worked out methods for artificially crossing rice. Parnell worked on somewhat similar lines, and incidentally studied the errors of experiment in field trials. These investigations have been developed, and the Council has organised a co-ordinated scheme of rice research in the Provinces, but especially at Coimbatore (Madras) under Mr. K. Ramiah ; at Nagina in the United Provinces ; Chinsura, Bankura and Dacca in Bengal ; Habiganj in Assam ; Sabour in Bihar ; Raipur in the Central Provinces ; Karnal in the Punjab, and on farms elsewhere.

At these stations new strains or varieties are selected to suit the widely varying conditions of the provinces. The labour involved is arduous and is perhaps the most disagreeable that falls to the lot of any agricultural experimenter ; it necessitates paddling about in gum boots in water or deep mud in the hottest part of the year with no shelter ; leeches and snakes are frequent pests while the stations are commonly in mosquito infested regions. But in spite of the difficulties the selection work is well done, large numbers of varieties and pure lines are examined, and vast masses of data are collected about their botanical and agricultural properties. The experiments on cultivation are also good and calculated to give the kind of information the cultivator needs.

(1) June 1936.

The work on manuring, however, is not always up to the same standard. At some centres it is satisfactory, and properly designed experiments show how different varieties react to differences in manuring. But at other centres the experiments are less well designed and the results are less definite. Few of the experiments give really useful information about the effect of fertilizers on the growth of rice. Yet there is great need for experiments, for by common consent an increase in yield is very desirable. The rice crop is peculiar among grain crops in its requirements and conditions of good growth. A uniform but simple scheme carried out at the various stations would give valuable information ; it should include nitrogenous and phosphatic fertilizers alone and in combination with and without green manure. I suggest that the statistician should collect the results of the first five-year period and set them out in a form in which they can be fully discussed by the proper sub-committee with a view to the adoption of a more definite scheme.

There is need also for more work on the water requirements of the different varieties of paddy in different environmental conditions. The possibility of making complex experiments including the effect of different watering and manuring on two or three varieties, similar in general type to that suggested for sugar, should be considered. The diseases problems are important, and I recommend that a critical summary of the position be prepared so as to guide the Council in the allocation of its funds between the various groups of rice problems.

In addition various problems connected with the physiology of the rice plant, and the sources from which it derives its nitrogen have been investigated. This work is described on page 178 ; while it may not lead to practical results it is a good subject for college investigation, and serves a useful purpose in the training of students. It should be kept to the University section of the Council's activities as suggested on page 5.

At several centres work has been undertaken on " quality " in rice. As already pointed out the term is ambiguous and has at least two meanings ; market quality, which is really commercial desirability ; and nutritive quality, which relates to value as a human food. The export of rice from India proper is so small that considerations of market quality hardly count so far as the export market is concerned, though there is an important home market for high quality table rice which the Marketing Branch is investigating : and if it succeeds in defining the grades by some system of marks the chemist may be able to discover some connection between composition and grading. By far the most important properties, however, are those associated with nutritive value.

I recommend, therefore, that the chemical investigations on " quality " of rice be examined by the nutrition experts, and either brought within their ambit or discontinued.

Some definite action seems desirable in relation to the use of milled and polished rice which is so strongly deprecated by the nutrition experts.

The rice crop is peculiar in that there are very few possible alternatives : on the lighter rice soils ground nut, sunn hemp, arhar,

juar, bajra and maize might to some extent be grown, but on the heavy soils there are usually no other possibilities but rice.

The acreage under rice is apparently declining. If this means that other grains are taking its place as food so that the dietary is becoming more varied, the change is probably to the good. I was on several occasions informed, however, that the yields are declining. No good figures seem to be available but if further enquiry indicated any basis for the belief it would be desirable for the Council to arrange for sample surveys to be taken in a region where the decline is said to be going on in order to obtain definite information on the matter⁽¹⁾.

Wheat.

The total area under wheat in India during the past five years averaged 32.1 million acres, of which 25.6 million acres are in British India. It is concentrated almost entirely in the North and towards the west. No fewer than 16.7 million acres are in the Punjab and the United Provinces (9.0 millions in the former and 7.7 millions in the latter, about half in each case being irrigated, rather more in the Punjab and rather less in the United Provinces), the rest is in Central Provinces (3.6 million), Bombay and Sind (2.8 million) Bihar and Orissa (1.2 million) and the North West Frontier Province (nearly 1 million acres). Several of the Indian States, however, have important areas under wheat: the Central India States, Gwalior, Hyderabad and the Punjab Agency States, and Rajputana States have nearly 6 million acres between them, the first four groups each exceeding one million acres. The total area in British India has increased during the last 20 years from 23.6 million to 25.7 million, the increase being both on the irrigated and on the unirrigated land.

The average yields reported for the period 1925-26 to 1934-35 are given in Table 9.

Table 9.—Average yield of wheat and seed rate (2).

(1 lb. per acre).

		Seed Yield.				Seed Yield.	
		rate.				rate.	
Punjab	50 738	Sind	..	..	100 593
United Provinces	103* 786	Hyderabad	..	..	66 231
Central Provinces	86 444	Gwalior	..	..	85 458
Bihar and Orissa	100 882	Central India	..	..	85 382
Bombay	82 447				

*1½ maunds per acre.

(1) In the examination of the 38 years' records of a Bengal rice farm, there was no evidence of deterioration of yield.

(Haskim Amir Ali, Vishva Bharati Rural Studies, 1934, No. 1.)

(2) Quoted from Report on Marketing of Wheat in India, 1937, pp. 11, 320.

The great difference between the seed rates of the Punjab and the United Provinces requires investigation.

The return varies from less than 4-fold in Hyderabad to more than 14-fold in the Punjab : in the other regions it varies from 5 to 8-fold. The yields on irrigated land are naturally higher than on unirrigated ; thus in the Punjab, the only Province recording the yields separately, the figures are :—

Average yield on both types of land in the Punjab⁽¹⁾.
5 years 1927/28 to 1931/32.

	Average.	Minimum District figures.	Maximum District Figures.
Irrigated	967	510	1,250
Unirrigated	572	400	720
Average for Province	791	..	..

The total production for British India is reported to be about 7.5 million tons and for the whole of India 9.3 tons.

TABLE 10.

Million tons : average for 1925-26 to 1934-35.

British India.				Indian States. ⁽²⁾			
Punjab	2.9	Central India States ..	.3	United Provinces	2.6	Gwalior .. .. .	.3
Central Provinces .. .. .	.7	Hyderabad .. .. .	.1	Bombay .. .. .	.3	Punjab States .. .. .	.4
Sind .. .. .	.2	Others .. .. .	.7	Others .. .. .	.8		
Others .. .. .	.8						
Total British Provinces	7.5	Total Indian States	1.8				
	All India 9.3.						

(From Report on the Marketing of Wheat in India, 1937, pp. 13 and 14.)

Of the total wheat area in British India nearly one half is irrigated (11.2 million acres) : the rice crop alone has a greater irrigated area (18.4 million acres). It is a rabi crop and from the irrigation point of view one of the best of all crops because it requires so little water : while rice may require 7 to 8 ft. (including rain) cotton may require only about 2½ ft. and wheat only about 1½ ft. ⁽³⁾.

(1) Published by the Director of Land Records.

(2) The figures for the Indian States are not complete and also they are far less accurate than those for British India. The total area of the Indian States is about 461 million acres, with a population according to the 1931 census of 81 million, but the Statistics for 1934-35, for example, relate only to 70 States with an area of 258.8 million acres and a population of 55 million, i.e., 56 per cent. of the total area and 68 per cent. of the total population only. Even for purposes of comparison the statistics are incomplete, as the number of reporting States has increased from time to time.

(3) For examples of amounts of water supplied see "Statistics of Irrigation Water Distribution and Working of Distributaries of the Canals in the Punjab for the year 1932-33". (Government of the Punjab, Public Works Department, Irrigation Branch, Lahore, 1934.)

The possibility of combining wheat and cotton into one system is therefore very alluring : wheat being the rabi and cotton the kharif crop. Unfortunately the difficulties are very great and have not everywhere been overcome : they are more fully discussed on page 137.

Formerly there was a large export trade in wheat : for some years past it has been very small. The area of wheat grown, however, shows no corresponding diminution, suggesting that much more wheat is eaten in India than formerly :—

	1910-11 1914-15.	1915-16 1919-20.	1920-21 1924-25.	1925-26 1929-30.	1930-31 1934-35.
Area under wheat thousand acres—					
British India ..	24,284	23,604	23,264	24,477	25,682
Indian States (1) ..	4,087	4,440	5,387	5,921	6,459
All India	28,371	28,044	28,651	30,398	32,141
Exports, thousand tons ..	1,239	668	453	163	46

The latest figure available for area is 33.6 million acres. Further increases in wheat area seem probable as the irrigated areas increase.

When the Lloyd Barrage scheme was set up in Sind it was intended that the area under wheat should finally attain 2 million acres. The present acreage is about 1 million : it remains to be seen how far the initial plan can be realised, but further expansion is almost certain to come in one or other of the Provinces especially in the Punjab now that the Sutlej valley scheme is sanctioned. The possibility of over-production was discussed by the Crop Planning Sub-Committee of the Advisory Board of the Imperial Council of Agricultural Research in June 1934 but no clear evidence was forthcoming. It was decided not to stimulate further production, but also not to discourage it. A steady demand for wheat will inevitably call forth the supply.

Experimental work on wheat in India.

The foundation for the experimental work on wheat was laid by Mr. W. H. Moreland, for many years Director of Land Records and Agriculture in the United Provinces who collected various wheats and sowed them so that they might be studied. J. Hayman, the first Deputy Director of Agriculture, carried out the work, and Mr. B. C. Burt (now Sir Bryce Burt) grew the collection on the Cawnpore experimental farm—the first experimental farm to be set up in India (2) and showed them to Mr. Howard (now Sir Albert Howard) and Dr. Martin Leake who at once recognised

(1) See Note 2 on page 25.

(2) It was started by Mr. (later Sir) Edward Buck about 1880.

the importance and value of some of the varieties and used them in their later work. The actual founders of the modern Indian wheats are unquestionably the Howards, who had the artist's eye for picking out the varieties likely to do well and those that would not; in consequence the selections and crosses finally made have proved remarkably successful. Their work began in 1905 and Pusa 4 and Pusa 12 soon proved valuable in the United Provinces and the North West Frontier Province.

Mr. David Milne carried out systematic selection of the Punjab wheats at Lyallpur from 1907 onwards, and multiplied the best strains for distribution. In consequence of all this work a considerable area is now sown with the improved Pusa and Punjab wheats; over all India an area of about 7 million acres, or 20 per cent. of the total was in 1934-35 sown with improved wheats⁽¹⁾. Of these Punjab 8-A, bred at Lyallpur, is said to be one of the most popular, accounting for about 2½ million acres—nearly one half of all the area under improved wheats. The Central Provinces and Central India, however, have not benefited so greatly from the improvements as they grow a good deal of durum wheat, which have not yet been so fully studied as the others.

From the papers and the close touch with the English millers, it seems clear that the Howards had always in view the requirement of the English market and they enlisted the assistance of Mr. (later Sir) Albert Humphries, a well-known miller, in assessing the quality of the wheats they bred. The English value for "strength" was adopted. This purpose was justified by the considerable export of wheat to England in those days. Several factors contributed to the ready saleability of Indian wheat on the English market. It was certainly dirty, but it was cheap and it contained less moisture than some of its competitors so that its real price was even lower than its market price. In pre-war days it made a useful combination with the Russian wheat, because while Russian wheats yielded rather soft and runny doughs, Indian wheats gave "short" and clay-like doughs, and the two together gave satisfactory results. Modern Russian wheats no longer show this defect. English millers still, however, find use for Indian wheats when the price is sufficiently low, and in point of fact they are now using the not dissimilar Persian and Iraq wheats.

The modern improved Indian wheat is very different from the ordinary Karachi wheat and compares favourably with good Australian, Canadian and South American samples; if ever it became the predominant wheat exported from India it would readily compete with them in England provided it were clean and properly graded. This would mean the setting up of proper cleaning machinery and elevators at the Indian ports as well as adequate arrangements for grading and control of shipments—altogether a big business.

The important question of policy arises: should the Agricultural Departments in India aim at securing a place in the English market or should they develop the home demand? If the aim is the English market then vigorous steps should be taken to export

(2) 34.5 million acres of wheat were sown in that year.

only graded improved wheats, which should therefore be produced on such a scale that they can displace the old varieties on the English market. If, on the other hand, it is proposed to develop the home market then English standards of "strength" should no longer dominate the investigations but close study should be made of Indian requirements, which are almost certainly different. By far the greatest part of the wheat used in India is ground in hand mills or small power mills and made into chapatis: there is not much demand for the white flour produced by roller mills which is the most popular kind of flour in England⁽¹⁾. Instead of studying the milling and baking qualities of Indian wheats only from the standpoint of the roller mill it would be far better to study their behaviour in the *chakki* and for making chapatis.

On the question of policy I express no opinion. Two important factors must be taken into account. In favour of the export market is the consideration that a large export trade in normal years affords the best guarantee against famine in years of low yield. In favour of developing the home consumption is the fact that Western nations having a choice of cereals always choose wheat, maintaining that it is the most suitable to the normal man's life. Physiologists may point out that other grains are richer in various constituents: that bajra contains more fat and has a higher calorie value: that ragi contains more calcium: nevertheless people who have the choice take wheat. Against this it has been argued that wheat being a rabi crop is less suitable as a food than the kharif crops, bajra, cholam, ragi, maize, etc., because it takes water that might be given to more lucrative cash crops; further, that these kharif crops give higher yields than wheat; in the Punjab, for instance, 20 to 25 maunds per acre against only about 12 of wheat. In spite of all this, however, if one may judge from what is happening elsewhere it seems probable that the consumption of wheat in India will still further increase and investigations as to quality should therefore be directed mainly to Indian requirements.

The Council should form some estimate as to the extent to which an export trade is desirable so as to guide the Departments in regard to the sowings. The export trade and the Indian roller mills will require improved strong wheats and enough should at least be sown to provide these: the home trade may prefer some other variety in which case the necessary multiplication of seed would need to be done.

Meanwhile a new factor has come into prominence: the necessity in resistance to rust, which by common consent is the most serious disease of wheat in India. One of the Pusa wheats—No. 114—is fairly rust resistant and so is spreading in Sind: a watch for other varieties is being kept by all wheat breeders. Professor K. C. Mehta, of Agra, is studying this question of rust resistance and in conjunction with Dr. Pal of the Imperial Research Institute,

(1) In 1936-37 about half a million tons of wheat were taken by the roller mills, leaving about 9 million tons for the hand or small power mills.

Delhi, is breeding rust resistant varieties from which it is hoped to select some possessing high yield and vigour.

The work is described on pages 98 and 148, where also Professor Mehta's recommendations are given. These should be seriously considered with a view to giving practical effect to the underlying relationships which he has worked out.

Barley.

Barley occupies only about 6½ million acres in British India, two-thirds of the acreage (4.17 million) being grown in the United Provinces, and the rest in Bihar and Orissa (1.2 million acres) and the Punjab (0.61 million acres). But since good malting samples command a price far above that ruling for ordinary cereals it may have special value as a potential cash crop.

For many years now Indian barleys have been exported to England and some have been taken by maltsters, though never at a high price. Numerous attempts have been made to produce improved varieties that would obtain a better price and a more secure position in the market.

Two types of barley are used by English brewers : two-rowed and six-rowed : they serve somewhat different purposes in the brewing processes and they are not altogether interchangeable. There is no evidence that India could produce the two-rowed barleys, but some of the recent six-rowed varieties compare favourably with the Californian barleys at present used.

If Californian barley were indefinitely obtainable in its present quantity the Indian barleys would have difficulty in supplanting them. Two new factors have, however, recently come into the situation. It seems probable that the supplies from California will fall off. The United States are no longer "dry" : the manufacture of beer has recommenced, and necessitates the use of much of the Californian barley that used to be exported. Further, the preference given at the Ottawa Conference confers a price advantage on Indian barley as against Californian. For these two reasons, therefore, the improved varieties may be expected to sell in England as soon as they are obtainable in commercial quantities, provided always, and this is extremely important, that they can be shipped clean and free from the Khapra beetles that have in recent years so much damaged the reputation of Indian barley abroad. This would probably mean the setting up of some large scale cleaning plant at the port, and shipment under the Certificate of a Government inspector.

The millets : Juar, Bajra and Ragi.

These three crops occupy nearly 40 million acres in British India and about 63 million acres in the whole of India : Juar

(*Andropogon sorghum*) is the most important, Bajra (*Pennisetum typhoideum*) comes next, and Ragi (*Eleusine corana*) third :—

Million acres 1934-35.

	British India.	Indian States.	All India.
Juar	21.8	14.5	36.3
Bajra	13.1	7.1	20.2
Ragi	3.7	2.8	6.5
Total	38.6	24.4	63.0

The acreages are far below those for rice but they exceed those for wheat or any other crop. The special feature of the millets is that they are kharif crops sown just about the time when the monsoon breaks : and they may receive little or no water beyond what the rain brings, though if water is available it is of course given when necessary. They are, however, associated with dry rather than with wet conditions : they are the chief crops in the non-irrigated and dry farmed areas ; usually they are more or less complementary to rice, *i.e.*, in districts where there is a large area of rice the area under the millets is small and *vice versa*. Hyderabad State has the largest juar area (8.8 million acres) ; Bombay has a little less (8.4 million acres) but it has the largest acreage of bajra (4.8 million acres). Madras and the Central Provinces have respectively 5.1 and 4.3 million acres of juar : the Punjab, Madras, Hyderabad State and the United Provinces have also considerable areas of bajra, while Mysore has the largest area under ragi (2.3 million acres) followed by Madras (2.15 million acres).

The millets serve a dual purpose : the grain is used for human food though there is a certain social distinction involved ; the millets being associated with the lower rather than with the upper grades of society⁽¹⁾. The stalks form, in many districts, the chief food of the cattle for some six months in the year.

A certain amount of work has been done on these crops in several of the Provinces but none of the selected varieties have spread far, and there are no successes comparable with those obtained with sugar cane, wheat, or rice, to which the older plant breeders had confined their attention. There has, however, hardly been time to find improved sorts, and certainly no time for them to spread. Moreover these crops are indigenous : they have been grown for hundreds, if not thousands, of years, and considerable selection has already gone on in the villages. There is no indication of any possibility of drastic change comparable with that made by Dr. Barber

(1) " Many of the hostel superintendents told us that they had the greatest difficulty in persuading the children to eat ragi and other kinds of millet, even when millet is the staple food of the district from which they come. Adolescent country boys and girls, who are hoping to raise themselves above the status of their parents, feel entitled to consume the cereal of the townsman and the educated classes—milled rice." W. R. Aykroyd and B. G. Krishnan, *Indian Jl. Med. Res.*, 1937, Vol. 24, p. 723.

in sugar cane when he succeeded in crossing it with the wild *Saccharum*. Finally, these crops have definite taste, and the peasant accustomed to one variety is not likely to change if the taste is different.

With the establishment of a millet section at Coimbatore and at Indore, and experimental schemes in Nagpur, Lyallpur, and in Bombay in connection with the dry farming scheme in the Punjab and the Central Provinces, one may hope for improved strains, giving higher yields or being more resistant to drought, pests and diseases, and to the troublesome parasitic plant *Striga* (page 179).

More work is, however, needed, in view of the importance which the nutrition experts attach to the millets. In particular some of the humbler varieties such as Kodon, the poor man's crop, should be more studied and either improved or replaced by something better.

The Pulses.

The Council has no schemes for studying the pulses but in view of their importance as sources of protein I suggest that a conference should be held with the nutrition experts to discover whether more work could usefully be done, and, if so, on what lines.

Vegetables.

A considerable amount of good work is being done on potatoes, one of the most useful vegetable crops ; it is described on page 147. In view of their importance more attention should be paid to other vegetables, particularly the cheaper and more easily cultivated of those commended by the medical authorities as supplying vitamins or mineral constituents deficient in the ordinary diet. The peasants in Northern India can grow very good vegetables, and at some of the shows I have seen specimens that could have been exhibited with satisfaction anywhere. A marked extension of vegetable growing, as of fruit, is very desirable.

Fruit.

Although fruits of various kinds have been grown all over India from time immemorial it is only in recent years that efforts have been made to put fruit production on an organised basis. The natural inclinations of the people to eat more fruit have been stimulated by the medical advice that fruit and vegetables are among the best sources of the vitamins and other substances missing from the ordinary Indian dietaries. Consumption appears to be greater than production, for there is a considerable import of apples from the United States and Japan, and of grapes and oranges from the United States. In consequence every Department has taken up the question of fruit growing within its province and some very useful work has been begun at Ganeshkhind and elsewhere which deserves every encouragement.

The range of fruits that can be grown in India is unusually wide. All the ordinary European varieties can be grown in the high country in the North of India ; while the tropical fruits can be grown in the plains and in Southern India⁽¹⁾.

The North West Frontier Province, Baluchistan and Kashmir all produce fruits familiar in Europe : apples, plums, apricots, peaches, grapes, etc. Other hill districts in the Punjab, the United Provinces and the Nilgiris produce strawberries and apples. The possibilities of development in the hills seem considerable. The plains produce mangoes, leitchis, papayas and oranges, while Bengal and the Peninsula produce bananas and in the wetter regions, pine-apples. Mysore is remarkable in being able to produce two crops of apples in 12—15 months, which is I believe a unique achievement, in addition to the grapes, mangoes and bananas which do very well there.

There are two aspects to the problems of fruit and vegetable production : supplies to the towns and supplies to the villages.

The town supply involves difficult questions of quality, transport, storage and marketing ; they can be solved but usually require some special machinery. Transport is so important and liable to be so difficult that no area should be put into fruit unless it seems clear that adequate transport arrangements can be made. The production problems are fairly straightforward and a good start has

(1) Mr. H. C. Javaraya has furnished me with the following list of common fruits in the various provinces :—

Baluchistan	..	..	grape, peach, apricot, plum, melon.
N.-W. Frontier	..	..	the above and also quince, apricot, pear, orange, sweet lime.
Kashmir	..	..	apple, pear, cherry, plum, apricot.
Punjab	..	..	orange.
Kulu Valley	..	..	apple.
United Provinces : Nainital			apple, strawberry.
elsewhere and on plains			mango, loquat, leitchis, melon, pineapple.
Assam	..	..	pineapple, orange.
Bengal	..	..	pineapple, banana, mango, orange, melon.
Bihar and Orissa	..	..	mango, leitchis.
Central Provinces	..	..	orange, banana.
Hyderabad-Deccan	..	..	grape, orange.
Bombay	..	..	mango, orange, banana, strawberry, fig, grape.
Madras	..	..	mango, orange, banana, grape, pear, pine-apple.
Nilgiris	..	..	strawberry.
Mysore	..	..	apple, grape, mango, banana.
Travancore	..	..	banana, pineapple.



Fruit transport from Quetta.

been made with them. The first essential is to clear up the rather considerable confusion in regard to the varieties: the indigenous fruits—mangoes, bananas, etc.—occur in large numbers of varieties, some of which, however, have different names in different places.

Good stocks must be selected and produced in quantity for budding or grafting and having done this perhaps the most difficult task is to arrange for distribution of stocks and trees true to type: this must be done either from Government farms or from commercial nurseries which are rigidly inspected and certified.

The extension of fruit culture will almost certainly be accompanied by an extension of fruit pests. The San Jose scale has already appeared in Northern India and may do much damage unless it can be checked. The Imperial Research Institute should be empowered to keep a close watch on all potentially harmful pests and advise as to the proper precautions and remedies.

A special feature of large scale fruit growing, and one which makes it very attractive to men who like the organisation of an estate and the possibility of doing well, is that it requires for full success and development in each important fruit growing centre of certain subsidiary industries. The most important of these is the preserving of fruit and vegetables by various means and the making of fruit products, so that unmarketed fruit can be converted into some marketable form and potential waste material can be used to good purpose. Investigations on these lines are being made at Lyallpur. Other industries, smaller but also important, are the keeping of bees, which beside giving honey play an important part in the fertilizing of the blossom and the setting of the fruit; and the making of baskets or boxes as containers: this in turn necessitates the collection or cultivation of suitable shrubs or trees to furnish the necessary material.

Thus the cultivation of fruit leads to the employment of far more labour than the cultivation of other crops, and it is admirably suited for graduates of agricultural colleges who may wish to become something better than ordinary farmers.

The problem of fruit and vegetable supplies for the villages is, however, on a different footing. Here the need is for cheap hardy fruits and vegetables, which can be grown around the village and which require nothing in the way of costly management. The problems are those of action rather than of research. Finality in fruit and vegetable culture can never be attained, and there will always be need for more experiments on selection, propagation, cultivation and general management. But in the meantime a great deal more is known at the Experiment Stations than is practised in the villages, and the chief need at the present is to spread the cultivation of fruit and vegetables as widely and as speedily as possible. Adequate place should be given at the experiment stations to easily cultivated and inexpensive fruits and vegetables so as to keep them prominently before all interested in the development of the countryside. But the work must be carried into the

villages. The planting of mango trees along the roadway leading to the village ; of vegetables on any available site near the village, e.g., the slopes of the nullahs where these are cultivable, and where possible the planting of orchards, are really urgent matters. At most of the experiment stations where fruit is grown I found men sufficiently skilled in the art of fruit and vegetable production to be able to render great help to the villages. Still more important, the help of the village teacher, where there is one, should be enlisted. This extension of fruit and vegetable growing is so important that it should be pushed forward as rapidly as possible.

Reference has been made to the increased interest in fruit growing but the statistics reveal a rather remarkable trend. The fruit areas are not shown separately but are included with vegetables and root crops ; the total areas have declined since 1914-15 (Table 11) in spite of the increase in population, particularly on the eastern side : Madras, Bihar and Orissa, Bengal and also Bombay : the decline is less marked in the United Provinces and the Punjab and there has been an actual increase in the Central Provinces and the North West Frontier Province. From the reports of the Marketing Officers, it appears, however, that the areas under fruit have increased⁽¹⁾.

TABLE 11.

Area of Fruit and Vegetables (including root crops), growing in India since 1914-15 : average 5 year periods.

Five year period.	Million acres Average.
1914-15—1918-19	5.70
1919-20—1923-24	5.42
1924-25—1928-29	5.06
1929-30—1933-34	5.00
1934-35	4.82

Oilseeds.

Oilseeds occupy about 5 per cent. of the total sown area in British India (14½ million out of 259 million acres) : but the precise acreage is difficult to ascertain because they are often sown in rows among other crops. They are concentrated chiefly in Madras (28 per cent. of the total area grown), the Central Provinces (13 per cent.), Bihar and Orissa (12 per cent.) and Bombay (11 per cent.). Cottonseed is not included in these acreages : practically all that is not wanted for sowing is fed direct to cattle, a rather wasteful process.

(1) I am indebted to Mr. H. C. Javaraya for a summary of all the available data on this point.

The estimated areas and yields for all India are given in Table 12.

TABLE 12.
Acreage and production of Oil Seeds.

	Estimated Area (1). Thousands Acres.				Estimated Production. Thousand Tons.							
	Average 3 years. 1927-28—1929-30.				Average 3 years. 1927-28—1929-30.							
	British India.	Indian States.	All India.		British India.	Indian States.	All India.					
Ground Nut	4,914	927	5,842	4,675	1,917	5,592	2,291	230	2,521	1,964	626	2,481
Castor	507	885	1,392	421	1,055	1,476	61	61	122	47	75	122
Linseed	2,622 (561)	452	3,074	2,700 (622)	658	3,358	326 (86)	24	350	340 (99)	54	393
Sesamun	4,373 (830)	1,098	5,471	4,561 (876)	1,129	5,723	392 (73)	106	498	383 (79)	87	469
Cotton	15,816	10,085	25,912	14,984	9,747	24,701	653(2)	358 (2)	1,011 (2)	620(2)	328(2)	948 (2)

(1) The note on page 25 in regard to Indian States holds here also. Two other qualifications are necessary:

(a) *Castor seed*.—The figures do not include any estimate for the mixed crop, i.e., seeds sown in the same fields with other crops, in the United Provinces for which there are no reliable data at present.

(b) *Linseed, Rape, Mustard and Sesame*.—The figures include the highly conjectural estimates for the mixed crop in the United Provinces shown in brackets alongside them.

(2) *Baled*. These are figures of raw cotton. Figures of cottonseed are not available.

There has been a marked change in the fate of the oil seed crop in recent years. Prior to the war there was a large export, but this has fallen considerably and except in the case of linseed, still seems to be falling. Much of the ground nuts, and most of the rape, mustard, sesamum, safflower and niger are now used in India as food : about a quarter of the ground nuts are exported, and a large proportion of the castor and linseed (Table 13). These are sent out mostly as seed, but there is a substantial export of ground nut and linseed cake and some rape cake and castor oil—used as lubricant. The export of cake finds some explanation in the fact that in absence of a cattle fattening industry linseed cake is not much in demand in India, while some of the ground nut cake goes to Ceylon as manure. Of the cakes that remain in India, castor and neem cakes are used as manure, and the others as foods for livestock.

TABLE 13.
Oil Seeds : Total exports from ports in British India⁽¹⁾ and values in £ sterling.

	Seeds.				Oil.				Cake.			
	Average 3 years 1927-28—1929-30.		Average 3 years. 1933-34—1935-36.		Average 3 years. 1927-28—1929-30.		Average 3 years. 1933-34—1935-36.		Average 3 years. 1927-28—1929-30.		Average 3 years. 1933-34—1935-36.	
	Thousand tons.	£ thousands.	Thousand tons.	£ thousands.	Thousand gallons.	£ thousands.	Thousand gallons.	£ thousands.	Thousand tons.	£ thousands.	Thousand tons.	£ thousands.
Groundnuts ..	705	12,848	490	4,803	237	39	427	40	161	1,378	215	920
Castor ..	116	1,797	70	659	507	82	1,319	143	..	..	..	..
Linseed ..	209	3,398	261	2,445	97	19	71	9	69	636	55	265
Rape ..	62	1,015	43	374	246	54	265	25	47	392	29	120 (£)
Sesamum ..	17	353	7	81	146	32	127	15	..	..	..	..
Cotton seed ..	114	830	3	10	..	..	..	..	..	..	..	..
								All cakes	292	2,528	312	1,359

(1) These are from British India ports only: the exports from other ports are not known but must be considerable. The States of Kathiawar and Travancore have recently published statistics and the exports of groundnuts, etc., from Kathiawar for the last three financial years were as follows:—

	1934-35.	1935-36.	1936-37.
Groundnuts (Tons)
Groundnut Oil (Gallons)	..	36,639	61,279
Groundnut cake (Tons)	..	17,170	620,291
	..	42,863	26,733
	31,369

(2) Chiefly to Ceylon.

Oilseeds are of great importance in human nutrition and as crops they have many agricultural advantages : they fit well with irrigation schemes ; and the chief of them, the ground nut, has the further advantage that it is a leguminous crop and so improves the productiveness of the soil : indeed advantage is taken of this property in parts of Bombay and the Central Provinces and Berar, where groundnut precedes cotton in the rotation to an increasing extent.

It is therefore very desirable to encourage their cultivation, and a co-ordinated scheme of research has been set up with the view of improving both yield and quality of the crop. The necessary selection and breeding work has been put in hand on a properly organised plan at Delhi, Coimbatore, Lyallpur, and other centres. The brassica oilseeds are likely to give some trouble but the work is proceeding satisfactorily : it would be improved if a first class geneticist could supervise the procedure and the classification.

Search for rust resistant varieties of linseed is made and at the Harecourt Bulter Technological Institute the various oils are studied chemically and physically.

The programme of work is good and it is being satisfactorily carried out.

Mixed Cropping.

The agricultural economic aspects of mixed cropping should be studied in view of the widespread use of this practice and the probability that some crops mix better than others.

Fodder crops and grazing for livestock.

Under present conditions the amount of food produced is insufficient for the large number of animals in India and in consequence many of them are inadequately fed. So long as this continues the efforts now being made to improve the quality of the livestock by distributing better bulls cannot attain wide success. The bullock, as the source of power, usually comes off best, but the cow is not so well fed and in consequence of a low diet gives only poor yields of milk. If it were feasible the best course would be a large reduction in numbers of animals so as to bring the livestock population more into line with the supplies of food, but this cannot be done rapidly. Some gradual reduction will no doubt come about by economic pressure as the grazing grounds become more closely settled for cultivation, and as the castration of scrub bulls becomes more commonly practised. Improvements in the farm implements, and particularly in the bullock cart, would reduce the need for so many bullocks in the village. It is commonly stated that the cultivator must have large numbers of animals in order to obtain sufficient farmyard manure : this is only partially true. The quantity of manure produced depends on the amount of food eaten, and a given quantity of food produces more manure if fed to one animal than if fed to two. For the present, however, the only practicable solution is to increase the production of animal food.



Forest grazing.

Over a large part of India the only food for the animals consists of the stalks or straw of the grain crops : rice, wheat, juar or millets and such grazing as is obtainable. A few Provinces, however, grow definite fodder crops, especially the Punjab, Bombay and the United Provinces :—

	Million acres. Total area sown.	Fodder crops.	Fodder crop as per cent. of total.
Punjab	29.8	4.8	16.1
Bombay	34.1	2.6	7.6
United Provinces	43.4	1.4	3.2
Central Provinces	27.5	0.46	1.7

The others have a smaller proportion of fodder crops.

Grazing.

The grazing areas fall roughly into two groups associated respectively with forest and with cultivable wastes : the latter are much more important. Only about 10 per cent. of the cattle of the five Provinces possessing much forest have access to forest grazing : the figures are given in Table 14 (p. 40). The acreage of forest grazing available per head is only an average figure and it includes considerable areas that are almost inaccessible : the density of livestock is much greater on the areas actually used.

Where the grazing is under the control of the Forest Department, or where, as in part of Madras, it is leased in blocks for sub-letting subject to certain conditions, the pasturage remains good and there are possibilities of improvement. But where the Forest Department has no control the losses have been greater. Considerable areas of wooded pasture—marginal land between grass and forest—in the regions of low rainfall have been taken out of the Forest department control and handed over to a non-technical department or to the panchayats : here grazing has been more or less unrestricted and losses have resulted. In the Punjab foothills where unrestricted grazing has been given as a right, the vegetation is denuded and soil erosion has set in : some really appalling losses have already occurred and more can be expected.

The improvement necessitates two regulations :

- (1) restriction of the period during which grazing is permitted : all animals being excluded during the first 3 or 4 months of the monsoon so as to give the herbage a chance of developing ;
- (2) rigid restriction of the numbers of animals finally admitted ; the restriction being either by regulation or by increasing the grazing fees. There are no set rules about acreage but 2 acres per head is recognised as a suitable standard for cattle, subject of course to variation according to conditions.

TABLE 14.
Number of animals using grazing land and of those unable to do so. (1)

Province.	Forest Grazing Lands.		Nos. of Livestock in millions utilizing forest grazing.				Non-Forest Grazing.		Total Nos. of animals. Millions.	
	Total area of forest lands in square miles.	Area open to grazing in square miles.	Cows and Bullocks.	All Live-stock.	Acres available per head.	Livestock in millions.	Area available square miles.	Cows and Bullocks.	All Live-stock.	
United Provinces ..	6,000	4,000	0.88	1.3	2	42	31,000	23.2	43.3	
Madras ..	16,000	14,000	1.4	2.2	4	41.3	51,000	17.8	43.5	
Punjab ..	5,200	4,700	0.87	2.7	1.1	23	42,000	9.8	25.8	
Central Provinces ..	19,400	17,000	2.5	3.1	3.5	13.1	30,000	11.6	16.2	
Bombay ..	14,000	12,400	1.5	2.4	3.25	11.5 (2)	40,000	7.4	13.9	
Total ...	60,600	52,100	7.1	11.8 (2)	2.8	130.9	194,000	69.8	142.8	

(1) Taken from a Report on the better utilization of forest areas for grazing 1937 (Sir C. G. Trevor, Chairman).

(2) Including 1,166 buffaloes and 3,381 sheep and goats.

(3) Including Sind.

Instances could be multiplied of successful results obtained in this way.

The great majority of the livestocks—90 per cent. according to the above figures—have access only to non-forest grazing and this includes a considerable amount of very variable land much in need of fuller classification and study : it mostly falls within the category of “cultivable waste land not available for cultivation” of which there are large areas in all provinces. Much of it could be utilised as grass combined with plantations for the provision of fuel and fodder : the Forest Department in the United Provinces have planted up, at but little cost, some thousands of acres in the Saharanpur and Bahraich districts and hope to obtain about 600 tons of green leaf fodder and 1,500 tons of fire wood per square mile of plantation per annum.

Sir C. G. Trevor's Committee recommended the formation in every Province of a Standing Fodder and Grazing Committee composed of officers deputed by the Forest and Revenue Departments and an Animal Husbandry officer to study these waste soils and advise as to their development. I entirely agree and would only recommend the addition of an agricultural officer having special knowledge of soils and who could suggest suitable fodder crops for any areas where they might grow.

Besides these “cultivable wastes” there are better grazing lands some of which are in private hands, and others more or less communal.

So long as the grazing lands remain open and unfenced it is difficult to effect much improvement : the animals wander freely and can eat out the best of the herbage, leaving it no opportunity to recover.

Enclosure and rotational grazing are the most effective improvements. Division of the area into fields which are grazed one by one in rotation gives the vegetation a chance to recover, and, there being more of it, the animals need not wander far in search of food, and some of the enclosed grass may be spared for conversion into hay.

The chief practical difficulty is of course the problem of fencing : cattle-proof fences of the ordinary kind being costly (1).

The time at which the animals are allowed to graze the herbage is important : indeed in England one can change the character of the herbage entirely by merely altering the incidence of the grazing : heavy autumn grazing changing the flora in a different direction to the change produced by heavy spring grazing.

Dr. Burns' investigations on the improvement of grasslands in Bombay are well-known (2).

(1) An alternative and much cheaper method might succeed : a single strand of barbed wire in circuit with small induction coil charged by an ordinary motor car battery suffices to keep the tame British cattle from straying : they greatly dislike the slight shock received when they explore the wire with their noses.

(2) Pusa Memoirs, Bot, Series, 1925, Vol. 14 and 1929, Vol. 16 ; Bombay Department of Agriculture Bulletin.

Further investigations are needed on the manuring of the land : open grazing lands in the dry parts of Australia and New Zealand have greatly benefited from phosphatic fertilizer. An experiment on these lines is being organised on the *barani* grazing area of the Hissar Farm in the Punjab. Heavily grazed enclosed land may respond to manurial treatment where the open land did not.

Closely associated with manuring is the provision of "licks" to give the animals any mineral nutrients that may be deficient in the herbage. Chemical analysis of the herbage from various hill pastures is being carried out at Lyallpur and other centres (page 133).

Enclosed land can also be improved by reseeding with mixtures of grasses and leguminous plants as has been done in the Central Provinces, and this gives an opportunity of introducing better or more drought resistant grasses. Some excellent work on this subject is being done by Dr. Pole Evans of Pretoria, who has searched the highlands of East Africa and the deserts of South-West Africa for drought resistant grasses and found a family of Woolly Finger grasses some members of which, notably *Digitaria Seriata* and *Digitaria Pentzii* are proving remarkably successful. It is desirable to experiment with these and with other drought resistant grasses. I gather from Mr. C. C. Calder of the Botanic Gardens, Calcutta, that certain Central American plants thrive very well in India, evidently finding the conditions suitable, and some of the grasses might prove useful as fodder. Introduction of exotic species, however, demands very great care and close botanical supervision.

Some of the indigenous grasses are very good : lists of the kinds best suited for hay are given in the Military Grass Farm Manual. More experiments should be made on the indigenous grasses at the Stations : a few selections are being made at Hebbal Farm, Bangalore and at the Experimental Farm, Nagpur, and this type of work should be extended ; there may be possibilities of considerable improvement.

The grazing lands around the village may in the monsoon give more vegetation than can be consumed at the time. Ensilage seems the best way of utilising this temporary excess and experiments should be undertaken to find the relative advantages of pit and of stack silage ; and of one cut of full grown herbage as against two cuts of less mature material. The effect of molasses on the making of silage should be examined.

Fodder Crops.

A wider introduction of fodder crops into Indian agriculture would probably effect great improvement in yields and in total output. More food for the animals would mean more manure and enhanced fertility of the soil. This was the prime factor in the improvement of British agriculture and the additional yields of grain more than compensated for the area taken from grain and put into fodder crops. Leguminous fodder crops in addition to increasing the quantity of farmyard manure also enrich the ground on which they grow ; they cannot usually be fed alone, however, and generally are mixed with non-leguminous crops.

In the Punjab considerable areas of fodder crops are grown without irrigation but in many parts of India this is not possible, and water must be supplied; considerable quantities of food per acre can then be obtained. Berseem (*Trifolium Alexandrinum*) is one of the best fodder crops: it is a native of Egypt but it grows well in Northern India (North-West Frontier Province, Sind, Punjab, United Provinces, Bihar) under irrigation. Some striking results have been obtained with it in Sind (page 138): it can be sown in the cotton just after the last picking. One of its great advantages is that it increases the fertility of the land on which it grows and hence it furnishes not only its own weight of food but additional yield of the succeeding crops. In Sind it has the added advantage of being Kalar resistant and useful in the reclamation of saline land. Mr. C. H. Parr of the Meerut division has experimented with berseem as a catch crop, feeding it to buffaloes for milk and obtaining also additional yield of the succeeding crops: this type of work should be extended. One difficulty in regard to berseem is the supply of seed which was reported to me to be both insufficient and bad owing to a mixture of weed seeds. Peshawar is at present the chief source, but a wider area of supply could no doubt be developed. Two local leguminous crops seem to deserve further investigation and selection: Sengi (*Mellilotus parviflora*) and Shaftal (*Trifolium resupintum*) or Persian clover.

Various exotic grasses grow well as fodder crops: Napier grass (*Pennisetum purpureum*), Guinea grass, Sudan grass (*Andropogon sorghum*), var. *Sudanensis*: under irrigation and manuring these can give several cuts a year to be fed green or made into hay or silage.

One of the Australian grasses, *Paspalum dilatatum*, has given promising results in Assam, and it would be worth while trying a successful Australian clover, subterranean clover.

The fact that fodder crops are used to supplement to grass probably explains why some of the best developed cattle in India are produced in dry areas where the growth of grass is sparse. The cattle reared on coarse rank grass in the wetter parts of India are of poor quality and of little use either for milk or for work.

In the event of a dairy industry developing there would be great scope for these fodder crops.

Fodder trees.

If any extensive planting of the "cultivable waste" were done it would be necessary to study the fodder trees more fully so as to know which to choose for the plantations. In addition to the native trees the Carob tree, cultivated in Palestine, a leguminous tree providing pods of nutritious seed, might be worth investigation.

Tobacco.

One of the most striking changes in personal habits since the war has been the increased smoking of tobacco. Large quantities are grown in India, most of it for home consumption, but an increasing amount, of increasingly good quality, is exported. Tobacco has many advantages as a cash crop and its cultivation deserves cautious encouragement.

It grows best under conditions of good natural rainfall, and there is no evidence that it would develop any high degree of quality under irrigation. The most important tobacco growing area in India is the Guntur district of Madras where some 120,000 acres of cigarette tobacco were grown in 1936, of which 42,000 acres were Virginia tobacco of the best quality—mostly Harrison's Special. Tobacco intended for the higher quality markets is flue cured, most of this is Virginian :—

Production of Flue cured tobacco.

	Million lb.			
Flue cured Virginia tobacco 29
Flue cured country tobacco 3.6
Total, Guntur district 32.6

The total production of tobacco of all grades in India in 1936 was 1643 million lb. but of this only about 110 million lb. were up to export quality, and only about 29 million lb. were in fact exported : the United Kingdom took nearly half. The total quantity exported has not varied much in the last ten years and of course the values are less than they were, but so far as the United Kingdom is concerned there has been a shift in the direction of higher quality, so that not only are its imports higher but also the values :—

	Tobacco.		Total exports.	
	To all Countries.		To United Kingdom.	
	lb.	£	lb.	£
Average 3 years.	(thousands).	(thousands).	(thousands).	(thousands).
1927-28 to 1929-30 ..	30,071	855	9,977	288
1933-34 to 1935-36 ..	28,978	670	11,460	320

Both dark tobacco and cigarette tobacco are exported from India to England, the latter in increasing quantities :—

Imports into the U. K.	Million lb.		
	1934.	1935.	1936.
Indian dark tobaccos	5	6.4	6.2
Flue cured Virginia	4.8	5.2	7.5
Total	9.8	11.6	13.7

The production of good quality tobacco requires a good deal of skill at all stages. The crop has to be well grown, adequately manured, carefully harvested, dried and cured in flue barns. A cultivator who can produce tobacco well is equal to any type of crop production. It is unfortunate that the regions of good tobacco production are so restricted, for a leaven of successful tobacco growers would go far to raise the level of agricultural education in the country. I was informed by representatives of the fertilizer industry that the Guntur tobacco growers have a better appreciation of the proper use of fertilizers than almost any other Indian cultivators. The Council has organised a comprehensive scheme of research on the subject the results of which cannot fail to be of value.

These investigations should be done in consultation with the buyers' experts. The principal purchasers are said to be the Indian Tobacco Leaf Development Company, a subsidiary of Imperial Tobacco Co., who are in a position to give information about the buyers' requirements.

CHAPTER 3.

Factors improving the yields of crops.

Seven great factors capable of improving the yield of crops in India are :—

- (1) Better varieties of crops.
- (2) Better control of pests and diseases.
- (3) Better control of water supply for crops.
- (4) Prevention of soil erosion.
- (5) Better use of manures and fertilizers.
- (6) Better implements and cultivations.
- (7) Better systems of cropping, in particular better rotations and the use of more fodder crops with the view of obtaining more farmyard manure.

(1) BETTER VARIETIES.

As already stated, the search for better varieties is being vigorously and effectively pushed forward. The work has reached a stage when persons selected for new appointments in connection with it should be expected to have had specialised genetical and cytological training in addition to a sound scientific education, but this presents no difficulty. A cytological assistant has been appointed to the Sugar Cane Station, Coimbatore, and a good case has been presented for appointing another at Lyallpur in connection with the investigations on the very difficult group of Brassica oilseeds. The results of this cytological collaboration should be closely watched and if it appears that the work is aided thereby it can be extended to other crops.

The whole of the plant breeding work in India would gain if it could be associated with a first class geneticist of sufficient scientific distinction to win the respect of the officers in charge of the various crops. They are, however, doing their work so well that no one of less than the recognised first rank would be of any use.

In spite of their merit the new varieties are not as yet in general cultivation. It is impossible to say with certainty what proportions they occupy of the areas sown, but the figures are greater for the

cash crops than for the food crops. So far as I have been able to obtain them they are as follows :—

TABLE 15.

Approximate Proportion of area sown with improved seed.

Crop.	Total acreage Million acres.	Acreage under improved seed. Million acres.	Percentage.
Sugar Cane	4.00	3.22	80.0
Jute	2.18	1.12	50.0
Wheat	33.61	6.96	20.6
Cotton	26.00	5.04	19.2
Rice	83.43	3.58	4.3
Ground Nuts	5.86	0.22	3.4
Milleta	38.69*	0.34†	} Not calculated as figures are in- complete.
Gram	16.90	0.33†	

*Including Juar, Bajra and Ragi only.

†Not separately reported by some provinces.

Probably the chief reason for the slow adoption of the improved varieties is the difficulty of obtaining adequate supplies of certified seed, which in turn may be attributed to the lack of an honest and effective seed trade to take up the new varieties, to multiply them and distribute them to the cultivators at a reasonable price.

At present this work is left to the Agricultural Departments which are already overburdened with duties. Several methods have been devised, *e.g.*, in the United Provinces by Mr. P. B. Richards, and in Sind by Mr. W. J. Jenkins : these deserve close attention.

The Council should at an early date enquire into the methods of seed distribution with a view to discovering what improvements might be adopted, and it should consider the advisability of setting up some central organisation in each Province for the multiplication and distribution of seed of approved varieties of crops, sets of sugar cane, named varieties of fruit trees, etc.

(2) CONTROL OF INSECT PESTS AND PLANT DISEASES.

Insect pests and plant diseases cause serious losses to Indian agriculture and the trouble is likely to become worse with every improvement in transport. If a pest or disease appears on a crop in any part of the world it is only a matter of time before it has travelled to all other parts where the crop is grown, and although quarantine regulations may cause delay they are rarely effective enough to keep the pest out altogether.

Conditions in sugar cane fields are particularly favourable to insect and fungus life and large numbers of pests are known to occur there : only few are serious, but they do great damage. Among the worst at the present time are the borers, which reduce not only the yield but also the percentage of saleable cane and its milling value, and the trouble seems to be increasing. An instructive survey of the cane delivered to five factories in Bihar⁽¹⁾ shows that 37 to 55 per cent. of the cane was infested in 1937 as against 20—30 per cent. in 1935. More surveys of this kind are needed so as to show which pests are increasing and which, if any, are decreasing.

The increase in area under sugar cane is almost certain to be accompanied by an increase in insect and fungus attack and an accumulation of the pests, and the problems concerned are more serious than those of cultivation and manuring, because they are less definite and more spasmodic in their incidence. In particular more information is wanted as to the extent to which ratooning, which has obvious economic advantages, is sufficiently favourable to the carrying over of pests and diseases to cause serious difficulties later on. Also it is important to ascertain the effects on subsequent pest and disease attack, of destroying the tops, leaves, and trash immediately the crop is harvested : or of making them into compost, or simply leaving them to be disposed of at some later date. The information should be collected by means of surveys, the results of which should be worked up at the Imperial Research Institute.

Diseases are, as a rule, best studied by a group of workers keeping to one crop : *e.g.*, a cotton group : a sugar cane group, etc. : the organisation of research work on a crop basis adopted by the Council is a very sound procedure. Much of the work, usually the most important part, must be carried out in the regions where the diseases occur : arrangements for co-operation must always exist between the Central body and the Provincial Departments and the Council should always be prepared to send, if possible a research officer to a station where a pest or disease is doing serious damage, both with the purpose of obtaining more information about it and of helping in its control. Co-ordinating investigations and detailed studies of collected records should be carried out by the Imperial Research Institute at Delhi.

It is very desirable to produce at an early date a handbook giving the various diseases of sugar cane and describing the methods found in India and other countries to be effective against them.

Three methods for control are in general use :—

- (1) Avoiding the trouble altogether by finding resistant varieties of crops ;
- (2) Obviating the attack of the pest by some change in soil conditions or in methods of cultivation, *e.g.*, by better drainage, by earlier or later sowing ;
- (3) Destroying the insect or fungus by chemical or biological means.

(1) Carried out by Dr. L. H. Haldane, Chief Chemist to Messrs. Begg, Sutherland and Co.

The search for resistant varieties is going on vigorously : *e.g.*, for rust resistant wheat by Professor Mehta : for varieties of linseed resistant to wilt. The method is very useful but not final because the resistance of the plant may break down and the insect—though not as a rule the fungus—may change its habits. The usual method of selection is to grow varieties side by side and observe which are least attacked. Escape from attack, however, does not necessarily imply actual resistance : it means only that some other varieties are preferred ; it does not show that the so-called resistant variety would escape attack if grown by itself. The search therefore must be continuous, and when a “ resistant variety ” comes into cultivation selection must still continue in hopes of finding a more resistant form. The final stage, immunity, is hardly likely to be reached : true immunity is very rare.

The causes of resistance and immunity are of great scientific interest and would form a very suitable theme for the main work of a large University Department but they are outside the scope of an agricultural experiment station.

The obviation of insect and fungus attack by changes in methods of cultivation or in soil conditions is in some cases very effective. A good instance of work on these lines is at the Toeklai Tea Research Station where Mr. Andrews has followed in detail the waxing and the waning of attack of certain important insects and so discovered the conditions favourable and unfavourable to their multiplication. Mr. P. B. Richards is attacking the problem of sugar cane pests in the United Provinces in a similar way : he lays special stress on the education of the cultivator to ensure that only suitable soil is chosen for the growth of the cane and that proper rotations and good agricultural methods are adopted. While entomologists cannot prevent insect attacks they can estimate the relative intensities of attack under different conditions and so guide the agriculturist in the choice of practical measures for control.

The destruction of the pest or fungus by chemical means is suitable only for fruit or vegetables, but in some instances it is the only practicable method, and spraying is being taken up by certain groups of cultivators. The making up of the spray mixture always presents some difficulty, particularly when poisonous substances are used, and the search for vegetable insecticides now being made by the Agricultural Department in Mysore and by the Forestry Department at Dehra Dun is entirely commendable. I suggest on page 196 certain modifications of the programme for the purpose of bringing the direct biological tests more into prominence, and of ascertaining whether the selected plants lose their value on cultivation. It is important to have available in India safe effective vegetable insecticides.

Biological control.

The insect pests that prey upon crops are themselves preyed upon by smaller insects and it has long been realised that these parasites might be utilised for keeping them in check. The possibility is extremely attractive : in principle one has only to find the parasite, breed it in sufficient numbers and let it loose in the

field, when it proceeds to prey upon the pest, reducing it to impotence. A vast amount of experimental work has been done on the subject by some of the ablest entomologists in the world, and some striking successes have been obtained, notably in the Hawaiian islands, by introducing the parasites of a pest, but elsewhere there have been numerous failures.

In St. Kitts the sugar cane borer appears to have been considerably reduced by the parasite *Lixophaga diatraeae*, and pests of other crops have been successfully controlled in New Zealand, California and Cuba. In Canada the larch saw fly and another saw fly (*Diprion frutetorum*), the oriental Peach Moth, and, on the Pacific slope, the Hawthorn Scale (*Lecanium coryli*), all accidentally introduced from other countries, have been successfully controlled by parasites.

On the other hand in the United States the Gypsey Moth and the European corn borer, both introduced pests, remain major pests even after years of work and the expenditure of millions of dollars on introducing parasites. And in Mauritius the parasites *Tiphia paralella* introduced from Barbadoes, while reducing the intensity of attack of the root pest of sugar cane (*Phytalus Smithi*), still left it a serious problem.

Generally speaking the successes have been obtained in islands or, if on Continents, with introduced pests. I have failed to find any good instance of a native pest being satisfactorily controlled by an introduced parasite in a Continental region. The problem of the sugar cane borer in India falls within this last category : it is an indigenous pest of an indigenous crop and India is a Continental region.⁽¹⁾

Of course this does not mean that no success ever will be attained, but simply that success cannot be confidently counted upon, and the work if begun must be continued over a period of years without expecting speedy results ; meanwhile efforts in other directions should continue.

No good direct method of control for borers, however, is known and in view of the heavy loss they cause it is very desirable that an expert should visit India and report on the question whether biological control should be attempted ; if so, on what lines, and whether any other methods would offer any better chance of success.

Control of insect and fungus pests is not simply a matter of scientific investigation : it involves difficult educational and administrative problems. Some degree of compulsion is necessary ; and since there must be speedy and uniform action it is essential to have some central control in addition to that exercised by the Provincial Departments. Pests spread regardless of political boundaries and rapid action against them may have to be taken.

(1) A full account of the present position of the subject is given in a recent book "The Biological Control of Insects", Harvey L. Sweetman, Cornstock, Pub. Co., Ithaca, N. Y., 1936.

Accounts of outstanding successes are given by T. H. C. Taylor, "The Biological Control of an Insect in Fiji", Imp. Inst., Entom., 1937. Also S. D. Tothill, T. H. C. Taylor and R. W. Paine, "The Coconut Moll in Fiji", Imp. Inst., Entom., 1930.

Locusts bred in Baluchistan fly into Sind and Rajputana and breed again ; they may fly into the Punjab, United Provinces and Bengal and breed, and the hoppers may do great damage. Control in these provinces, however, is cumbersome and expensive ; it should if possible be effected at an earlier stage. The rust of wheat comes from the hills of Nepal and the Nilgiris ; its minute spores blow down into the plains where they greatly damage the wheat. But control is possible only in the hills. The San Jose scale, a deadly foreign pest of fruit trees, got into Kashmir where energetic steps should at once have been taken against it : it is now spreading through Northern India. These pests often do more harm in the Province to which they pass than in that from which they have come and it is of course far more economical to control them before they arrive than to wait till they are in.

Two methods seem suitable for obtaining the technical information needed by the Central Control body :—

- (1) The Council could continue to make grants as at present for studying plant pests and diseases in the Provinces ; it could organise teams of specialists for particular crops, *e.g.*, cotton, sugar cane, etc., and it could arrange for the Imperial Research Institute to co-ordinate the results and to collect information showing whether the diseases and pests are increasing or decreasing. When the necessity for general action seemed indicated the Council could call together their experts and those of the Provinces concerned to draw up a statement showing what steps should be taken to limit the damage done.
- (2) Alternatively the Council could hand over the study of pests and diseases to the Imperial Research Institute, leaving that body to keep touch with the Provinces and to draw up from time to time statements showing what action should be taken in regard to particular pests or diseases.

In view of the circumstances that pests and diseases have to be studied in the areas where they occur it seems better to adopt the first of these alternatives and to keep the technical problems in the hands of the Council but using the Research Institute as the agency for collecting and collating the information accumulated.

In any case executive action in regard to pest and disease control should be entirely out of the hands of the Council. The Central Government should include it with infectious animal and human diseases, as requiring on occasion more general measures on uniform lines than is possible for the Provincial Governments to adopt.

The advice of the Council can, however, quite properly be sought by the Government as to the measures to be taken.

Weed control.

Various weeds are spreading and need serious attention : experimental work is required in the first instance to discover suitable control measures ; and then administrative action to see that the

prescribed methods are properly carried out. Among the worst weeds I saw were the water hyacinth, lantana, Kans grass, and, in Mysore, Touch-me-not (*Mimosa pudica*).

(3) THE BETTER CONTROL OF WATER SUPPLY FOR THE CROPS.

The water supply to the crops is of supreme importance in Indian agriculture and I recommend that the work in this direction should be strengthened.

Two types of problems are involved : dry farming and irrigation.

The dry farming problems are studied at a group of stations in Central India respectively under the Bombay, Hyderabad and Madras Governments. The fact that they are all engaged on one co-ordinated scheme in spite of the diversity of their forms of administration is a striking tribute to the unifying influence of the Council's activities.

The work would gain considerably if a good soil physicist could be brought into it and also an engineer, in view of the close association of dry farming with soil erosion. The possibility should be considered of linking the work of these Stations not only with the Poona Agricultural College as at present but also with the Bombay Irrigation Research Station, which would mean of course a widening of the scope of the latter. The needs are two fold : better ways of satisfying the requirements of the present approved dry farming methods ; and a fresh set of ideas on the subject. The workers at present are rather isolated, and if they could form part of a larger group their chances of finding new methods and ideas would be increased.

An All-India Irrigation Research Station.

The development of irrigation is one of the most remarkable features of modern India. Three sources of water are used :—

- (1) canals from the great rivers—either snow fed rivers, or rain fed, and therefore requiring storage arrangements ;
- (2) wells from the underground supplies in the plains ;
- (3) tanks filled by rain or streams trained down into them.

The area now irrigated is very large. Out of 227 million acres sown in British India in 1934-35, 50.5 million were irrigated ; practically half (26 million acres) from canals, and one quarter (12.5 million acres) from wells ; further schemes are being discussed. A striking development is the combination of irrigation works with the generation of electricity which promises to effect marked changes in the life of the larger villages and smaller town.⁽¹⁾

(1) The Meerut tube well scheme under the supervision of Sir William Stampe is a notable example of a well planned effort to combine water supply with electricity and with such amenities as bathing and washing facilities.

The supplying of water to the cultivator is the business of the irrigation engineer, and is usually well done in India. Two of the large provinces where irrigation is important, the Punjab and Bombay,⁽¹⁾ have Research organisations and other provinces have Research Officers who, however, are not infrequently charged with other duties also.

But the supplying of the water is only a part of the problem. A much more difficult matter is to use it advantageously so as to ensure permanent benefit to the district, and repayment of the heavy capital costs. When a great dam or barrage has been opened with much ceremony and flourish of trumpets it must always be remembered that the problems still remaining are greater than those already overcome because they are more continuous, more subtle, and much less under the control of the experimenter.

Three great groups of agricultural problems arise.

(1) Selection or if necessary production of new varieties of crops suited to the new conditions. New selections and hybrids are produced in many parts of India and interchange should be freely arranged between the various staffs concerned. The final selection must necessarily be made in the region where the crop is to be grown.

(2) The designing of new cropping schemes. Usually the water supply is not entirely continuous but more is available at some seasons than at others. The cropping has to be so arranged that the best use can be made of the water and of the man and bullock labour available. Much more attention should be paid to this troublesome problem of arranging a sequence of crops at once profitable to the grower and permitting the best use to be made of the water. The potential improvement is shown by the fact that even now some cultivators succeed in making the water go much further than others : some of the Punjab sequences are admirable : while some of the larger cultivators have worked out methods that deserve detailed study and trial elsewhere.

In canal irrigation the water must be taken when it is given and the cropping scheme adjusted to the supply available. In planning a new canal irrigation project, therefore, the proposed cropping scheme should be as fully and as carefully considered as the engineering details.

Where the water is supplied from tube wells greater control of the supply on the individual farms is possible, and therefore greater flexibility in the cropping scheme. Another set of problems then arises : the best times to supply the water to each crop and the optimum quantities to give.

These problems are fairly straightforward and present no special peculiarity.

The soil problems, however, are much more difficult, especially in regions of canal irrigation. Waterlogging and neutral salts can be dealt with, though the treatment may be very costly, but behind every large irrigation scheme there lurks the spectre of the alkali

(1) Irrigation is chiefly by canals in the Punjab and from tanks in Bombay. The Bombay schemes are largely concerned with prevention of famine.

problem, for which in its final stages no economic solution has yet been found. Well designed experiments would no doubt suggest methods of dealing with the incipient stages when action is possible, and these should certainly be undertaken as early as possible. Constant watch should also be maintained to ascertain whether the salted and waterlogged areas are increasing or decreasing. Photographic aerial surveys would probably be the speediest and most effective means of doing this.

It may be laid down as an absolute rule that no irrigation scheme should ever be carried out until a proper soil survey of the region has been made. Areas containing salt or liable to serious water-logging should only be brought into the scheme after consideration. This may necessitate a survey of the floor of the region, as described on page 128. A good preliminary survey reduces the risk of trouble to a minimum : but it is always there and on some of the existing schemes it is considerable.

All the various problems concerned are being studied at some or other of the research Institutions, but the work is scattered, it is uneven in quality and in scale, and it lacks unified direction. I strongly recommend the establishment of a Central Irrigation Research Station to undertake investigations on all agricultural problems associated with irrigation, and to supervise or be closely linked up with other irrigation investigations supported by the Council. The Station must be situated in the heart of a large irrigated area : the Punjab or Sind are obvious possibilities, probably the Punjab would be better as it could there be closely associated with the existing Institution at Lahore and with the college at Lyallpur.

But I cannot too strongly emphasise the difficulty of the work and the necessity for choosing the staff solely on the ground of their ability to do it. Suitable men are extremely scarce, and any restriction on the choice is likely to prove fatal to the scheme.

The Lahore Institute would remain as at present the centre for engineering research. It is so well staffed that it could probably widen its scope and undertake research on the surfacing of earth roads in rural districts, a subject which is not so remote from its present work as might at first sight appear. I suggest that the Council consider the advisability of discussing this possibility with the Irrigation Department.

(4) PREVENTION OF SOIL EROSION.

In natural conditions the soil is usually covered with a growth of vegetation which protects it against the disintegrating effects of wind and rain and so enables it to remain permanently in position. In general the higher the rainfall the denser the cover, and in wet regions where forest or grassland develops well the protection is very effective.

As soon, however, as the protecting cover is removed the soil is liable to be carried away by wind or by water—usually in India by water—and damage is caused in three distinct ways :—

- (1) the removal of the soil makes the affected area useless and it may lead to the scooping out of great ravines ;

- (2) the soil that is washed away may injure the land on which it is deposited, or it may silt up canals and rivers, and so lead to the washing away of river banks or even to floods ;
- (3) while the vegetation cover is intact the rain water soaks in, accumulating as underground stores or breaking out in springs and steadily flowing streams. With the removal of the vegetation cover it is no longer able to do this and instead runs off as flood water. The stores of underground water are therefore no longer replenished : wells, springs and little streams may all run dry. Floods take their place.

The removal of the vegetation cover usually results from an increase in numbers of human beings or of animals. Erosion is particularly liable to happen on sloping ground either in moderately wet or in dry regions. The usual causes of removal are :—

- (1) Deforestation.
- (2) Heavy grazing.
- (3) Seasonal concentration of migrant flocks on the alpine migration routes.
- (4) Ploughing or clean cultivation of sloping land.
- (5) Fire, as in jhuming.

The forest officers are so thoroughly familiar with the dangers of deforestation that they are not likely to allow improper cutting of timber where they have authority to stop it. Uncontrolled grazing, however, is a much more serious matter because the mischief is not at first obvious : it may become a grave danger and wider powers of control should be given to the officers in the interests of the villagers themselves.⁽¹⁾ Goats are in general regarded as the most destructive of all animals, ruining vegetation and soil alike, but buffaloes and cattle may be as bad or worse, especially in damaging trees. Rotational grazing can be so managed as to provide at least as much fodder as unrestricted grazing, without deterioration of herbage or erosion of soil.

Cultivating up and down the slope of a hill, or setting the lines of crops, *e.g.*, potatoes in this direction, renders the soil liable to very serious erosion. So also does the clean cultivation of tea or coffee plantations on sloping ground. Green cover crops are, from this point of view, much better ; they can be dug in for manure and so help the bushes to grow till they themselves cover the ground.

Jhuming as practised in Assam is liable to lead to erosion, and experiments could usefully be undertaken to reduce the risk.

Erosion is not confined to regions of high rainfall : it occurs also in dry regions. The rainfall when it comes is apt to be torrential and the protecting cover is only light so that once erosion begins it may become serious.

(1) Sir C. G. Trevor reports that in the Etawah region so good a grass cover developed after closing to grazing that erosion entirely ceased. Many other instances are on record.

Both in wet and in dry regions the remedy for erosion is based on the same principle ; the reduction of the velocity and the amount of water running off the surface. The crucial area is at the top of the slope : if water can collect here and start running down it is very difficult to check. Several methods can be adopted :—

- (1) Afforestation of the top slopes : one of the surest methods where this is practicable.
- (2) Putting the upper slopes into grass, or, if cropping is necessary, alternate grass and arable strips. This device has also served to prevent sheet or wind erosion. The grass affords effective protection provided excessive grazing is prohibited.
- (3) Ploughing along the contour lines instead of across them.
- (4) Bunding or terracing.

Bunding is in practice the most usual way of overcoming the difficulty and it has the advantage not merely of protecting the land against erosion but also of increasing the water supply to the crop.

Much bunding is already done in the erosion areas but a good deal more is necessary. In the United Provinces the construction of bunds is a regular famine relief measure ; it is indeed almost ideal for this purpose, being a capital improvement of great and permanent value.

In dry regions the tendency is for the peasants to put the bund up only at the bottom of the slope, but this is insufficient : small bunds should be set up at suitable and not too great distances ; in the North Central division of the Bombay Presidency this has been done by means of a tractor. For bunding, and more particularly for the construction of large embankments, the Bombay Agricultural Department has given advice and the Revenue Department has advanced money at moderate rates of interest in the Southern district since 1921.(1)

Cases are, however, recorded where bunding has done harm by causing the water to stand too long on the soil. Here some additional measure, such as contour ploughing, seems needed.

So far as funds have allowed, the Forestry Department has for many years been setting up embankments in the ravines within their control in the foothills of the Punjab so as to collect the silt and make approximately level surfaces on which trees can be planted. Large areas have been closed to grazing and left undisturbed in grass and some of them give revenue of as much as 16 annas per acre for grass cutting compared with 1½ annas per acre for grazing. These reclaimed areas absorb much of the rain water falling on them and so reduce greatly the violence of the floods. This of course greatly benefits the plains, for the canals are no longer so badly silted up and the rivers no longer erode the fields on their banks.

Only about one-tenth of the foothill region of the Punjab, however, is under control of the Forestry Department. On this a vegetation cover is maintained, but the rest is partly under some

(1) An account of the Bombay work on the subject is given in a Report to the Crop and Soil Wing of the Board of Agriculture in 1935, p. 259.



form of cultivation and partly used as hill grazing. No Government Department exercises much control, and mismanagement is common.

In dealing with soil erosion the need is for more action rather than more research. In spite of numerous and protracted investigations by competent workers in the United States and elsewhere it has not been found possible to discover anything more than very general relationships between erodability of soil and chemical or physical composition. The environmental factors are extremely important as also are the ways in which the soil constituents are built up into crumbs and the distribution of root residues in the soil. I see no point in spending time and money on approaching the subject from the laboratory end ; the problem is in the field and there it should be worked out.

The measurements of the amount of soil lost by erosion in India are only few and very variable : they range from 1 ton to 115 tons per acre, depending on the amount of cover and other conditions.

Protection against erosion should be a State responsibility and not left entirely to the individual. The cultivators in the critical positions may be unable or unwilling to spend money on the necessary protective works. In all Provinces where erosion is likely to occur an Erosion Conference should be held annually at which forestry, animal husbandry, and soil experts should meet the agricultural staffs and, after receiving from them reports on the districts where erosion is liable to occur, should discuss with them modes of checking or remedying it, dealing with each erosion area as a whole. The Minister should then have the power to carry out the recommendations, levying a rate on all land thus protected. The Tennessee Valley Authority in the United States is an example of the way in which a statutory body of this kind functions. It is achieving results hitherto regarded as impossible.

(5) BETTER USE OF MANURES AND FERTILIZERS.

Every writer on Indian agriculture has commented on the wasteful practice of making manure into cakes and burning it, but it goes on unabated for the simple reason that no other equally useful fuel is available : the manure cakes need no cutting up, like wood ; and they burn slowly. The only way of stopping the practice is to provide an alternative supply of fuel.

The rapid and almost complete change from the old village-made lamp to the machine-produced hurricane or bracket oil lamp raises the question whether oil stoves are ever likely to come into such general use for cooking in the villages as they have in the towns. We may best leave this to the future : in the meantime the most hopeful method is to plant quick growing trees near the village, preferably on the side from which shelter would be an advantage as protection against discomfort or soil erosion.

Castor and neem cakes are also much used as manure especially for sugar cane and this is justified since they are unsuitable for feeding to live stock.

Composting of waste materials is now a recognised part of the activity both of the experiment stations and of the village improvement associations, and we may expect some addition to the manurial resources of the country as a result. I could find little direct evidence as to the fertilizer value of compost as compared with oil cakes or artificial fertilizers, but from the low content of Indian soils in nitrogen and organic carbon, averaging about 0.05 and 0.6 per cent. respectively—about one-third the values in arable soils in England—it is inferred that organic manures are greatly needed. In any case, however, composting is to be encouraged in the villages on sanitary grounds even apart from any fertilizer value.

Green manuring is included in the schemes at several of the stations and should be tried wherever paddy is grown.

Until about ten years ago there was little systematic experimental work on artificial fertilizers, the relatively small amounts used being taken almost entirely by tea growers. From 1926 onwards, however, the large fertilizer organisations dealing with India have attempted with some promise of success to develop the use of fertilizers for general agriculture: the South, I am informed, is more "fertilizer minded" than the North.

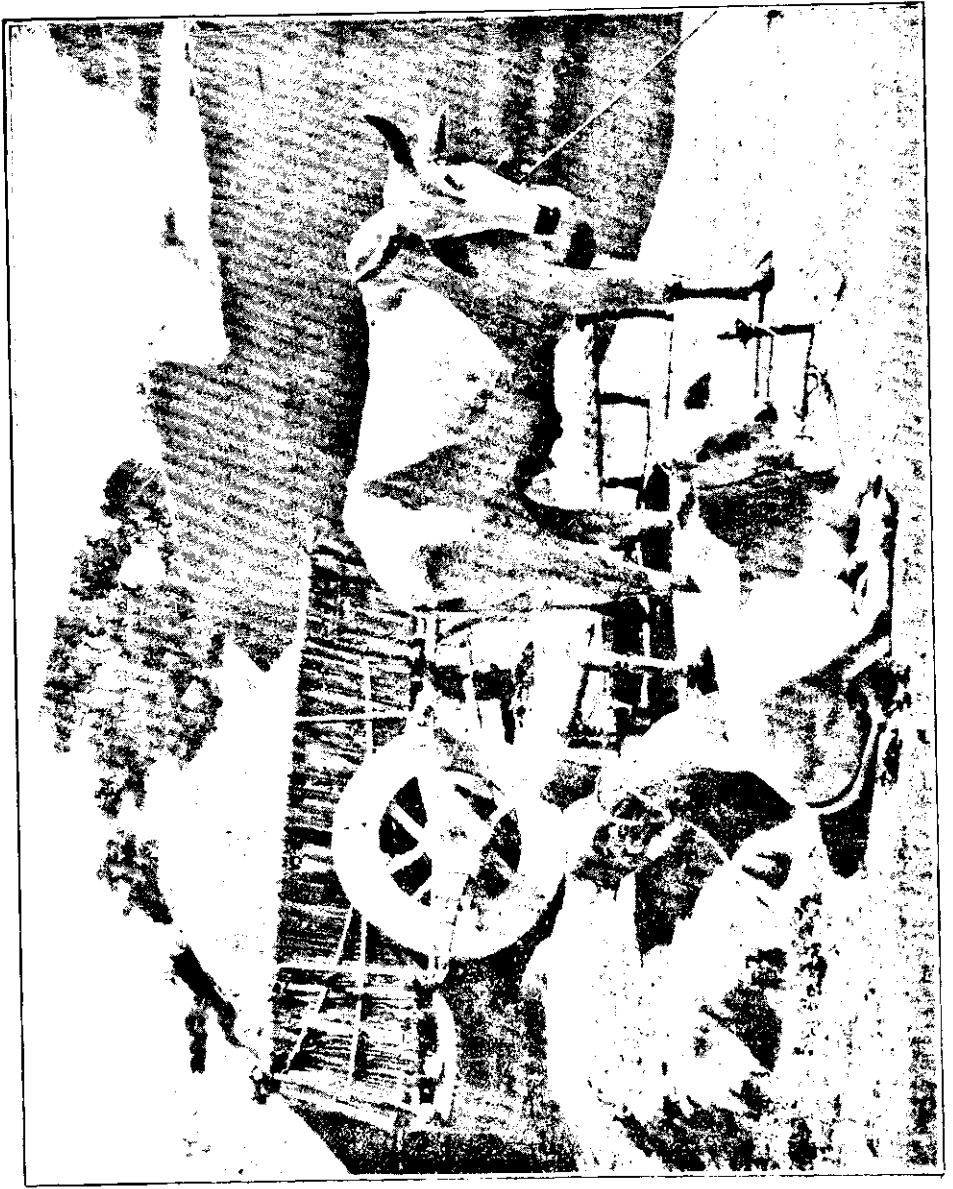
The results given by fertilizers depend almost entirely on the water supply. In regions of precarious rainfall or inadequate irrigation, artificial fertilizers usually fail and organic manures are erratic in their action. With good moisture supply artificial fertilizers are more effective. Nitrogenous fertilizers usually give the largest returns. In some of the experiments one maund of sulphate of ammonia in addition to the normal light manuring gave the following additional maunds of produce:—

55	sugar cane.	1	tea.
5	sugar.	4.5	paddy.
15	potatoes.	3	wheat.
1.2	leaf tobacco.	1.6	seed cotton.

Concentrated organic manures, oilcakes, fish manures, hoof meal also gave good returns. Phosphatic fertilizers (superphosphate) usually acted well especially in the crystalline tracts of Peninsular India, but only when in combination with nitrogenous fertilizer. Potassic fertilizers are effective for certain special crops such as tobacco.

Little is known as to the most suitable time of application of the fertilizer: at the time of planting appears to be best except for sugar cane for which two instalments are given. Little information is available about the proportions of nitrogen, phosphorus and potassium required for different soils and crops or the proportions in which organic manure should be used.

Speaking generally the fertilizer and manurial trials at the experiment stations need to be more systematic so as to show the



The unimproved cart and cattle.

relative value of different forms of nitrogen and of different dressings per acre. They should not, however, be confined to the station but some simplified form should be tried as widely as practicable on cultivators fields and the chemist should receive samples of the soils so that he may see if any relation exists between the field results and the data given by the recognised methods of soil analysis. It would be of considerable advantage if this work could be done in association with the large fertilizer organisations who have already collected considerable information on the subject and who have a wide experience of the types of experiment possible.

Some provinces, *e.g.*, Madras have already effected a certain degree of co-operation.

(6) BETTER IMPLEMENTS AND CULTIVATION.

Considerable efforts have been made in recent years to improve the implements, but there is scope for much more work on this subject especially on the developmental side. The new implements are not always more effective than the old when these are worked in the best way possible, but they are lighter, require less labour of man and of bullocks, and they do their work more rapidly. It is difficult to over estimate the value of these advantages. Economy of bullock power means that the large cultivator need not possess so many bullocks and so can better feed his milch cattle ; and speed of work means that operations can be done just when necessary, and when therefore they are most beneficial. This more rapid cultivation would be of advantage in keeping down weeds and in improving the moisture supply in dry regions.

Numerous experiments have been made in the technique of demonstrating the value of the new implements : references to some of these are made in Part II.

So far the new ploughs seem to have been taken up more rapidly than anything else. I saw various improved water lifts demonstrated but not in ordinary use. The greatest task of all, however, is the improvement of the bullock cart, at present a cause of strain on the road, the bullock and the other travellers. Ball bearings and subsidised rubber tyres are being tried, but the problem may be much diminished by the development of motor transport.

Co-operative societies where they function are probably the best means of spreading improved implements.

(7) BETTER SYSTEMS OF CROPPING.

These are discussed in Part II.

I was much impressed by some of the good sequences of crops in the Punjab and the United Provinces : experience generally is in favour of rotations rather than single cropping. Rice is of course the great difficulty : alternative crops and sequences are easier to arrange on light than on heavy soils, especially those liable to be loaded.

CHAPTER 4.

Special difficulties confronting Indian agriculture.

(1) THE ABSENCE OF AN EDUCATED CLASS FROM THE VILLAGE.

As compared with other countries India suffers specially great difficulties in the speeding up of agricultural improvements : illiteracy : debt : the inertia that comes of malnutrition and illhealth : the excessive numbers of livestock : the efforts of social customs (using the term in its widest sense) and of social structure and the fact that there are something of the order of 700,000 villages ; and it cannot be expected that these difficulties will easily be overcome.

Perhaps the most serious of all the difficulties confronting Indian agriculture is the lack of an agricultural aristocracy and of an educated agricultural middle class. Many of the great advances in Western agriculture are due to men of this type : highly competent agriculturists, rooted in the soil, with a thorough knowledge of crops and livestock and a shrewd idea of how to get the most out of their land. It is quite certain that without them the West would have been in a far poorer position than it now holds. In Great Britain an improvement effected in the experiment stations can be at once put out into practice : some large farmer is prepared to try it at his own expense as soon as he is satisfied as to its value, and he almost invariably finds some simpler or better way of using it. But these good farmers also themselves devise improvements, which are sometimes better than those of the experiment stations. Indeed the experiment stations think themselves fortunate if they can obtain yields as good as those of the best farmers, and their best hopes of success are to overcome some special difficulty or to develop alternative methods of achieving some desired end. The staffs of the experiment stations are compelled to keep in touch with practical men or they would find themselves outclassed in the struggle for agricultural improvement.

The existence of these educated class gives a social attractiveness to life in the country.

Unfortunately India has nothing corresponding with this educated class. The landowners are largely town dwellers and many of those who reside in the village are not themselves farming on any important scale. There are of course exceptions : I met some enterprising large farmers⁽¹⁾ and energetic Zemindars who were practising agriculture well and serving as models for the surrounding cultivators. Men of this kind deserve commendation and recognition and efforts should be made to increase their number.

Equally important is the need for increasing the number of educated farmers. It is unfortunate that the colleges have been able to do so little in this direction. Perhaps the greatest difference

(1) Especially in the irrigated regions of Sind and the Punjab and also in North Bihar : a number of these are European. The tea and coffee planters are of course in a different category.

between the agricultural colleges in India and those of the West is that most of the western students go back to the land to do practical farming while the Indian agricultural graduates seek some non-practical post, where their influence on practical farming is very small. An old Hindu proverb states that agriculture is the best life and service the worst : the modern tendency is to reverse this and to rank Government service as the best life and agriculture as the worst. This explains the relatively small effects exerted by the Indian colleges on the cultivator's practice. Until good students from the agricultural colleges settle on the land as farmers the Colleges cannot be expected to exert much influence on village life. At each centre I visited I enquired how many College students were farming : occasionally figures were given to me and I enquired for names and addresses, so that I might write for information, but my letters were mostly either returned or unanswered, and in all my journeys I met only two or three college trained farmers. *Per contra*, the few young Zemindars whom I found taking pains with their farming had in general not been to an Agricultural College.

Yet the College trained farmer should be a great asset in a district : indeed one of them told me that as a non-official he had special advantages in introducing better varieties of seeds, green manure crops, proper rotation, manuring, more economical utilization of water, fruit culture, beekeeping, and co-operative marketing. He had succeeded with his farming and desired to extend the area of his land, but met with the difficulty that only common grazing land was available and the villagers objected to giving this up. It is possible that my experience was exceptional. The subject is, however, so important that an enquiry should be made as to why so few agricultural students settle on the land, and to suggest ways of increasing the numbers.

Lack of facilities is undoubtedly one reason and indeed I was informed that in Oudh some of the large landowners who are prepared to employ graduates as farm managers have no difficulty in obtaining them. But this outlet is insufficient to solve the problem.

Several experiments in land settlement are being tried. An "Auxiliary Farm" has been set up at Dadu in Sind for agricultural students who wish to take up practical farming : two men are given a holding of 32 acres for two years : they must themselves do the cultivation under the tuition of the staff. At the end of that time, however, they must find other land.

In Bombay a scheme is in operation under the Forestry Department whereby a cultivator is allotted land for a definite period of years on condition that he plants it with trees, and, at the end of his period, quits the holding. This scheme is applied to the poor landless classes but it seems possible that something on similar lines but of longer period might be set up for agricultural students.

While the settling of individual trained men in villages would be of advantage to the villagers it might be very dull for the men themselves owing to the lack of social life. An experiment made in the Punjab deserves special mention because it avoids this difficulty : it consists in settling literate young men in newly created villages

It began in 1927 when the late Sir Fazl-i-Husain returned from a visit to Switzerland and France much impressed by the high standard of living on the small farms there ; and feeling that village life in the Punjab offered no attraction to an educated young man, he proposed to establish two model villages in the canal colony for educated young men prepared to live there, to cultivate the land themselves and to set better standards of farming and of living. This was done. Each village had 22 settlers selected by the colleges—20 from the Lahore Art Colleges, 2 from Lyallpur Agricultural College, and each settler was to have two squares of land ($55\frac{1}{2}$ acres). Rights of occupancy were granted after 5 years provided all conditions were fulfilled, but no proprietary rights. One square (27.8 acres) was reserved for the village site, and 3 squares to provide a common income for the village.

In 1935 the Government extended the scheme to another 60 settlers, 18 ordinary and 42 agricultural graduates. 28 retrenched agricultural assistants have also been settled.

As an inducement to better farming 2 half rectangles ($12\frac{1}{2}$ acres) are granted to the two cultivators who in the opinion of the Agricultural Department deserve it best ; each one holds his rectangle for 3 years.

I had the privilege of discussing these schemes with His Excellency Sir H. W. Emerson, Governor of the Punjab, who informed me that they are working well, and it seems desirable to extend them.

None of these schemes is more than a small scale preliminary trial : yet if one of them succeeded in its object there would be possibilities of considerable development. Probably the best chance of success would be in the direction of specialised farming such as dairying, fruit growing, etc.

(2) THE BURDEN OF DEBT : THE BANIA.

In many of the villages that I visited where rural uplift was being done I was shown balance sheets purporting to represent the income and expenditure of various selected families. Almost invariably there was a deficit which I was informed was made up by borrowing from the bania and this process has been going on for many years. The Central Banking Enquiry Committee of 1930 estimated the total rural indebtedness of India at roughly 900 crores (roughly £675,000,000) and the Reserve Bank considers that the figure has increased since then. Whether the debt can ever be repaid is a question that lies outside my province : I am concerned only with the effects on agricultural output.

It is freely stated that the cultivator feels so depressed by his burden of debt and he is unwilling to bestir himself to adopt new methods as he will gain no advantage therefrom. There may be something in this : on the other hand the bania would in his own interest be expected to see that the land is made to yield its utmost so as to be sure of preserving his capital and the continuity of interest payment. The bania could be, and in some districts is, a potent

factor in the introduction of seed of new varieties. In the Reserve Bank Report for 1936 he is described as playing an important and indispensable part in the economy of the countryside, and the only agency for supplying the credit necessary for farm production, co-operative societies having failed to do this. If he could be enlisted in the cause of agricultural improvement he might be able to expedite matters.

(3) THE SLOW PROGRESS OF THE CO-OPERATIVE MOVEMENT.

In view of the enormous success of co-operation in improving village life in the west, hopes were naturally entertained that similar results would follow in India and accordingly great efforts have been made to introduce it. Unfortunately it has not in general succeeded. It usually took the form of credit societies, financed from a central bank, and while these societies had no difficulty in lending the money, they were generally unable to get it back again. Money that should have been restricted to short term credit for productive purposes was used for long term and non-productive purposes and so became immobilised. A large part of it will probably have to be written off as irrecoverable. Some non-credit societies were formed, but these attracted less interest and usually had but little success.

Yet it is no fault of the system : the conditions were not quite suitable. The outstanding instance of success in co-operation is Denmark, a land of small farmers : and it has given them a standard of living that is the envy of the civilised world. Four essential conditions of success are all present in Denmark :—

- (1) The village population is homogeneous : there is nothing corresponding with the caste distinctions ;
- (2) The cultivators are all literate ;
- (3) From the outset People's High Schools were set up where the cultivators were taught better living, both in the home and the village, and where ideas of corporate responsibility in village and national life were inculcated.
- (4) The Co-operative Societies are mostly trading societies, taking over the produce from the cultivator, working it up into marketable form and selling it for him. Also they supply him with all materials for use in the home and on the farm. They are mainly financed by the local savings institutes and banks, and the members are jointly and severally liable for the loan. In their capacity of depositors at the local savings bank the members of the Co-operative Societies themselves provide a substantial part of the funds : it is their own money that is lent to members, and in consequence each borrower feels himself under the necessity of repayment.

Unfortunately none of these conditions is satisfied in India and so long as this is so the Co-operative movement is under great

difficulties. Something has, however, been achieved and the case is by no means hopeless. A certain measure of success has been obtained in the Punjab as a result of strict official supervision and in the Bombay Presidency where a number of public spirited business men took an interest in the Societies and saw that they were kept on sound lines. The Bombay Provincial Co-operative Bank is under the guidance of Sir Chunilal V. Mehta and Mr. V. L. Mehta, and some of the non-credit societies have succeeded, notably the Cotton Sales Societies. I was informed also that the Visva-Bharati Societies are working satisfactorily ; here the leadership is from Sriniketan. So far as one can see there is still some chance for the co-operative movement provided strong external management is available and the credit activities can be associated with a thrift movement, the village savings going in to the society. Probably these conditions are only rarely obtainable⁽¹⁾, and excepting where, as in Bombay and the Punjab, a firm business directorate takes control, it seems unlikely that much can be expected from co-operative enterprises.

(4) THE FRAGMENTATION AND SCATTERING OF HOLDINGS.

Another very serious weakness in Indian agriculture is the fragmentation and scattering of holdings. The laws of inheritance lead to numerous ownerships and thus tend to make the holdings small, and custom scatters them over a wide range so that a cultivator may lose considerable time in going from one of his plots to another. Consolidation of the scattered holdings into one piece is extremely desirable, but the difficulties are very great. The problem is not peculiar in India : other countries have had to solve it but it has never been easy. In England consolidation was effected in the 17th and 18th centuries but only after serious trouble. In Poland it is being brought about now but with much objection from the peasantry. But it has to be done. Some officers appear to be more successful than others in persuading the cultivators to agree to exchange of land : men like this should be kept at the work and not transferred to other duties.

Special mention must be made of the good work being done by the Punjab Co-operative Land Consolidation Societies.

Where consolidation of holdings cannot be achieved it may be possible to carry out the next best improvement and consolidate the cropping, straightening also the boundaries. This has been done in the tube well irrigation districts of the United Provinces (Meerut Division) and cropping has been greatly facilitated in consequence.

The fragmentation of holdings, however, is a more deep-seated matter and may be incapable of remedy. Yet unless some solution is found the rate of progress must be extremely slow.

(1) A good discussion of the position of Co-operation in India is contained in the Report of the Reserve Bank of India, Agricultural Credit Department, 1936.

Subinfeudation.—In the permanently settled districts another difficulty arises. The tenant does not hold his land direct from the landlord who pays revenue to the Government: in between there may be a long chain of intermediate holders, each of whom takes a little profit as his share.⁽¹⁾ It is not easy to estimate the effects on agriculture of a series of rent receivers who feel no responsibility either to the land or the tenant.

(5) THE LACK OF TECHNICAL EDUCATION FOR THE CHILDREN AND YOUNG PEOPLE.

The school garden is widely recognised as the best way of imparting technical knowledge to young people in the villages. A school without a garden is very apt to become an agency for taking young people out of the villages: with a garden it becomes a means of helping them to improve their life there. A few schools have gardens and at the Lyallpur College I saw a group of rural teachers working in the College garden with a view to introducing new material into their own courses. But in the main the schools are without gardens and it should be part of the rural uplift movement to establish one wherever this may be possible.

(6) THE LACK OF SUBSIDIARY INDUSTRIES.

The cultivator frequently cannot maintain himself and his family on the proceeds of his farming. He must either borrow or take on other work. During long periods of the year he has ample time for this, his farming labours being very unevenly distributed over the different months. In some places he may be able to earn money by carting, but this is bound to become more precarious as motor transport develops. Casual labour on the roads or in towns is also possible but a much better way if it could be developed would be the development of subsidiary industries in the village. The great difficulty is the marketing of the produce and I confess I see no way of overcoming this: outside of the village itself the demand for village-made things is largely sentimental. Agencies that make an appeal deeper than that of the salesman, such as the Visva-Bharati or Dyal Bagh, are able to keep their groups going, but in the ordinary way of business village industries cannot easily stand up against mass production. The solution of the problem is really in the hands of the women of India, for if they insisted on purchasing village-made articles the whole difficulty would disappear. The Women's Council of Bombay have, I understand, adopted this line of action.

There is, however, an important exception. The hand-loom industry is widespread and vigorous and appears to be extending, though not as rapidly as the power loom industry of the mills. Both

(1) For a remarkable example, see the Final Report on the Survey and Settlement Operation in the Bakerganj district, 1900—1908. In this district there are normally 8 and sometimes as many as 20 intermediate holders.

home and export trades seem to be well organised. The figures are :—

	Handlooms Millions of yards ⁽¹⁾ Cotton cloth.	Mills Millions of yarns Piece goods.
1930-31	1,390	2,561
1931-32	1,500	2,990
1932-33	1,700	3,170
1933-34	1,440	2,945
1934-35	1,460	3,397
1935-36	1,840 (provisional)	3,567 (provisional)

Another village industry, though much more localised is lac : this also is said to be well organised.

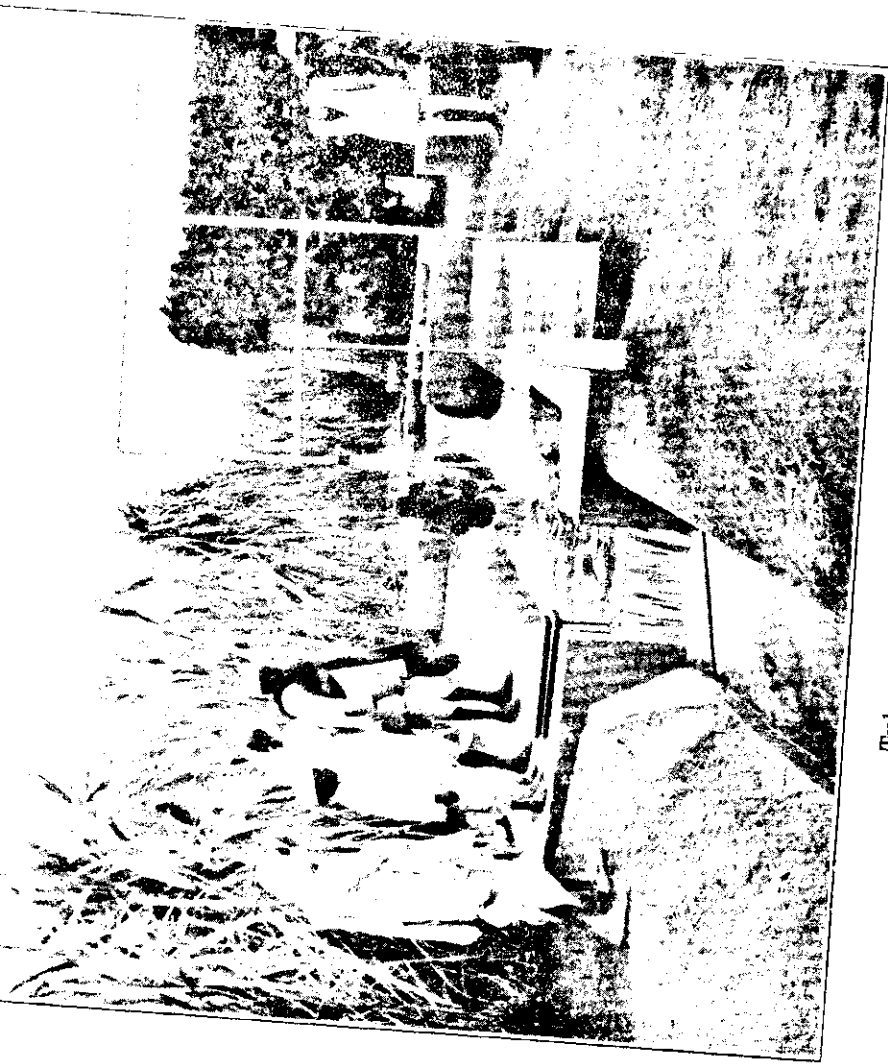
Poultry keeping is a promising way of supplementing the earnings from the holding. I heard good accounts of the work done by Mr. A. E. Slater, of the Mission Poultry Farm, Etah, U. P., who informed me that interest in poultry keeping is growing ; the demand for good poultry is increasing, and more Hindus are eating eggs than formerly. He thinks there are good prospects of success for poultry in the villages of the United Provinces. The success of poultry keeping turns on the marketing where transport facilities exist or could be created there would be the possibility of setting up of collecting stations such as the one organised by Dr. Hatch at Martandam, Travancore.

Beekeeping also offers possibilities which, however, are probably somewhat limited. It appears to be more promising in the hills than in the plains : e.g., in the submontane region south of the Himalayas running from Assam to the northwest frontier : also in the Nilgiris. It generally goes well with fruit culture. Several of the Provincial Entomologists and others are studying bees.

(7) THE LACK OF LEADERSHIP IN THE VILLAGES.

Many of these difficulties would automatically disappear if there were effective leadership in the village ; one sees fewer signs of them in those villages—unfortunately few in number—where the chief owner is also resident and actively interested in the development of the place. Mr. Darling quotes Sir Daniel Hamilton in the Sunderbans as an example of a landlord who organises for his tenants : he has formed them—they number several hundreds—into credit and marketing co-operative societies, the latter being authorised to pay to the former whatever the member owes. A similar lead could be given in other regions where they are large landowners provided they would devote the necessary time and trouble to the work. The village panchayat would be a means of carrying through any agreed proposals, and under an effective leader could render

(1) From the method of calculation adopted, which is based on yarn produced in mills and not exported or woven in factories, it is probable that the variations from year to year are exaggerated.



Drinking water.

**Tube well amenities : Meerut.
Bathing tank.**

Washing tank.

useful service. But we are always brought back to the same fundamental trouble : the absence of an agricultural aristocracy or educated agricultural middle class recognising responsibility towards the community, and so long as that continues the villages must continue to suffer.

The Improvement of the village.

The absence of the educated middle class agriculturist is intimately bound up with the unattractiveness of the villages : the malnutrition and unhealthiness, and the inertia engendered thereby. As things stand few educated men or women will voluntarily live in the village if they can find posts in the town.

The improvement of the village should therefore be an integral part of the programme for the improvement of agriculture.

Thanks to the personal interest of the Viceroy, the movement for village uplift is spreading widely and is attracting large numbers of workers of different kinds. This is one of the most hopeful things in modern India and much experience has now been gained as to the different methods of procedure. I recommend that at an early date a conference of selected workers be called for the purpose of putting their experience on record for the guidance of others. It is extremely easy for village welfare work to degenerate into sloppy sentimentality from which the villagers gain nothing whatsoever. The only safe foundation on which to work is accurate knowledge of the facts and careful studies of the probable effects of proposed remedial measures. The only hope of permanence is to implant in the villagers the wish and the readiness to do the work themselves. So long as the improvements are done or paid for by someone outside the village community it is more than likely that they will cease altogether when the help is withdrawn. Model villages set up by benevolent patrons are rarely permanent unless the spirit of improvement has been deeply inculcated into the people, and then there is hope for the future. Villagers have considerable leisure in which to do something for the community and once the custom starts they can achieve a great deal. Mr. Darling recently instanced a district in the Punjab where in the last three years the people had spent a considerable sum of money in improving the water supply and the sanitation. The progress already made shows what can be done, and it is very desirable that the work should be suitably organised ; always, however, preserving its essentially voluntary basis and retaining as far as possible the help of those generous and enthusiastic people who have done so much for it already.

The village school.

Now that interest in village life is spreading and schools are becoming more numerous it is essential that the education should from the outset be on sound lines. A purely literary method is not suitable : it tends to take boys off the land rather than to show them how they may lead a fuller life in the village. Reading about nature study or about the parts of a plant is of little use unless it be done in the field or the garden where the plant is before the pupil's eyes and

the things can be seen as well as read about. This is not the place for a discussion of methods of rural education, and indeed it must be admitted that they have been far less fully worked out than methods suitable for cities, but, as pointed out on page 65, it is widely agreed that a garden forms an indispensable part of a village school and that the gardens of the district should supply the material for the teaching of the scholars. Although this problem lies outside my terms of reference I cannot refrain from pointing out the desirability of enquiring into practicable methods for giving Indian village boys an education that will make them better men and better cultivators.⁽¹⁾ It would be a tragedy if the efforts now being made to educate the children should lead to the depopulation rather than the betterment of the village.

Bridging the gap between the Experiment Station and the Cultivator.

Reference has been made to the fact that the yields at the experiment stations and on the farms of European cultivators⁽²⁾ are not infrequently 50 to 100 per cent. higher than those obtained by surrounding cultivators : and also to the circumstance that the new selections and varieties which represent the highest achievement of Indian agricultural science are used only to a very limited extent. The ryot continues largely unaffected by the enormous efforts made on his behalf.

Once an improvement starts to come into practice it has some chance of spreading : the difficulty is to ensure the beginning.

The present method consists in setting up local demonstration farms and in doing plot experiments on the cultivator's land. Successes in the demonstration farm tend to be discounted by the circumstance that Government Departments can do things which cultivators cannot : and the plot method is limited to trials of new varieties, new ploughs, etc.

Better results would I think be obtained if instead of plots of an entire holding were used for demonstration, supervised by a cultivator and not by a paid Government servant. The best cultivator could be selected and required to run his holding on a plan that comprised all the improvements which the experimental staff considered ripe for introduction : in return for this he could be furnished

(1) The Achimota methods might be studied.

(2) Colonel Bruce of Brucepur, Lyallpur, has favoured me with the following figures showing his yields as compared with those of his predecessor :—

	<i>Maunds per acre.</i>	
	<i>Col. Bruce's yields.</i>	<i>Previous yields.</i>
Wheat	8—24	11
Cotton American 4F	7·5	6
Other varieties	13·5	5
Gram	8—24	11
Toria	not grown	6

free of charge or at a considerable rebate with the seed, and the loan of the implement to be demonstrated. A demonstration of this sort would have a vitality that is at present lacking.

I attach great importance to requiring the staffs of the experimental farms to make more of their experiments on cultivator's land. A weakness of some of the stations I visited was their somewhat closely self-centred life : much time and energy is devoted to the amassing of data the value of which it is difficult to see, and the work is confined to the Station. If some of this time and energy were devoted to experiments on outside farms the work would gain in value ; the experimenters would widen their experience and the cultivators would certainly learn something from them. Some payment would of course be necessary to compensate for disturbance of cultivation but the advantages would be considerable.

Much of the extension work, however, must be done orally and here of course agricultural officers differ greatly in efficiency. The really good extension officer, like the good research worker, is born, not made, and when one is found he should be kept at the work and should not need to seek promotion in some other direction. Dialogues, songs and other devices are all in use, and I shall long remember the crowd of villages gathered to hear the dialogue between the peasant who had failed to use his new plough correctly and the instructor who pointed out where he had gone wrong.

The possibilities of broadcasting deserve full investigation. Prices, addresses and dialogues can be widely disseminated in a variety of languages. All India Radio has already stations at Delhi, Calcutta, Bombay and Peshawar and proposes during this year to set up stations at various other places : Lahore, Lucknow, Dacca, Madras and Trichinopoly. Rapid progress is being made in the technique of broadcasting and it may become a most efficient agent in rural education. An integral part of a broadcasting scheme, however, is some means for giving prompt replies to enquiries : without this a great part of its value is lost.

CHAPTER 5.

The Machinery for dealing with these problems.

These problems are dealt with by the Agricultural Departments with the Imperial Council of Agricultural Research as the effective co-ordinating agency. The Council is organised on a wide basis with representatives of the contributing bodies and an expert administrative staff : it works through expert Committees composed of men having special knowledge of the problems concerned. I attended meetings both of the Committees and of the Council and was much impressed by the efficiency of the procedure which compares very favourably with anything I have seen elsewhere. During the short period of its existence the Council has accomplished a remarkable amount of good work and I do not see how its results could well be bettered.

In view of its success I suggest some widening of the scope of the Council.

The purpose of the research : the need for wider scope of the Council.

In pure science Research is an end in itself, and the workers' responsibilities end with the publication of his paper in one of the scientific journals. In agricultural research the case is different : it is not sufficient to point to the increasing girth of the Journal as the measure of success : the results must find some expression in the cultivators' or planters' fields or in the subsequent processing. It is much more difficult to make use of results than to get them, and in India the stage has been reached where the machinery for gaining more knowledge is working better than the machinery for utilising it. The Council should henceforward devote much of its attention to this problem of applying in practice the results already obtained.

At present the duty of applying the results devolves mainly on the Provinces, but some degree of centralisation is necessary, just as in the carrying out of research. The best method of dealing with this problem in my view would be to set up a Development Commission, whose function would be to work out systematic large scale plans for the improvement of agriculture and the raising of the standard of life in the villages, and to provide expert help and advice to the administrative Departments in carrying them through.

The Commission would deal with large groups of problems including—

- (a) Soil Conservation deterioration and loss of soil exhaustion and manuring, soil erosion, salt, alkali.
- (b) Crop Production, especially the planning of cropping schemes, the balance between cash, food, and fodder crops, the fusion of animal husbandry and agriculture.

the improvement of grazing land, the taking of action on the results of marketing and other economic enquiries.

- (c) The exploitation of discoveries or processes of commercial importance. The Commission would not itself embark on industrial enterprises but it would smooth the way for others to do so by helping to bridge the gap between the laboratory and the factory, and by giving information and advice to the Commercial body undertaking the work. Seeing that some kind of monopoly would usually have to be granted for a term of years the Commission would advise the Government on the technical side as to terms that could be accepted.
- (d) The multiplication and distribution of seeds of approved varieties of crops of named varieties of trees.
- (e) The improvement of village roads.

The Development Commission and the Council would be so closely associated that it would be most economical both of time and of money to combine them in one body and to give to the present Council the wider powers needed for the developmental work. This would necessitate the appointment of another member of the higher staff to take charge of the Development side, but working in close touch with the present staff : and more assistant staff in order to liberate the higher staff for the necessary planning and thinking : in particular (1) an Editor, competent to take over the management of the Journal, Reports, etc., published from time to time by the Council, (2) an Expert trained in Geographical Science, (3) an Expert trained in agricultural economics both Experts to prepare critical reports for submission to the higher staff.

With this shifting of emphasis from gaining knowledge to applying it there would of course be a change in the Council's expenditure. It should be accepted as a general principle that the Provincial Departments should bear a substantial part of the experimental work done on their farms and from which they will derive benefit ; and the Council's funds thus liberated would be used for Developmental work. Further funds would, however, be needed, and the grant to the Council would require to be augmented : it is always costly to take the first steps in applying knowledge. In addition the possibility should be considered of setting up a Development Fund out of which grants or loans could be made for the carrying out of works proved by the experiments to be both feasible and advantageous.

The provision of staff.

However perfect the plan, the success of the work fostered by the Council is limited primarily by the quality of the men who are to carry it out. I cannot too strongly emphasise the fact that capacity for doing good research work is very rare : it is an inborn quality which cannot be imparted but can only be developed. On the other hand the training needed for an assistant can be given to

anyone, and a large number of people possess the necessary qualifications of honesty, industry, and scientific or technical knowledge. Unfortunate many Universities make no distinction between the two classes, and the distinctive label does not come till a man is so settled in his line of work that he is unlikely to make any useful change.

There is little difficulty in recruiting for Assistant posts, and a B.Sc. degree of one of the stricter Universities would usually guarantee suitable preliminary training. The Universities differ greatly in their standards, but this is well known to competent selection Committees.

Before appointing a University man to an agricultural post it is desirable that he should have a period of post-graduate training at the Imperial Research Institute at Delhi where he should be attached as assistant to one of the staff and required to read some of the classical books and memoirs on the subject. He could then take up his work and if after a few years he shows promise of development he should be encouraged to go abroad for two years study leave.

The difficulty of finding really good men for the higher posts is very considerable under any circumstances, even where the choice is absolutely free ; directly any limitation is set it becomes intensified. University degrees afford little guidance.

Selection Committee sometimes attach considerable importance to a Ph.D. degree. The value of this degree, however, depends largely on how and when it is taken. In itself it does not necessarily show a man to be a competent research worker or to have had a sound scientific training : it only means that he has worked in a laboratory where research is being done, and he was able under guidance to write a thesis conforming to certain standards. Here again, unfortunately, the standards are very variable, not only as between different Universities but also as between different subjects in the same University, and there is no way of discovering what the particular standard was. The D.Sc. degree of one of the stricter Universities is safer, but it is by no means an infallible sign of ability.

Testimonials also differ greatly in value. Much more useful information is obtained by asking the Professor under whom the candidate worked to furnish in confidence a report on his abilities as a research worker and his suitability for the post.

Numerous students from India go to Great Britain for post-graduate training. Usually they go too young. The change from an Indian to an English University Institution is so great that it should not be undertaken till a man has attained a certain maturity and experience of life and work, and till he knows what is likely to be most helpful to him in his subsequent career. With some notable exceptions the men who have gained most from post-graduate studies in Great Britain have, in my experience, been those who had previously held a post in one of the Indian Institutions, and who had done so well as to justify the privilege of study leave. They know exactly what kind of training they desire : they have sufficient experience and breadth of knowledge to be able to find their way

about the laboratory and the library, and they fit better into a research atmosphere and gain far more from it than if they come direct from completing their College course. They seek, of course, to obtain a Ph.D. degree, but they gain much more ; they learn something about the standards of work in a recognised good laboratory they meet and learn to know men of outstanding ability and distinction, while the serious attention they are able to claim enables the staff to form a shrewd opinion of their merits as investigators.

I recommend that the Council should set aside a small fund to assist senior men of proved merit to go overseas for training.

The Status and permanence of the Staff.

The Council's schemes are all temporary and in consequence the men actually doing the work are hampered by a feeling of insecurity and exposed to the temptation of making a good show of results in the hope of an extension of the grant.

It is impossible to avoid the element of temporariness, but its effects could be mitigated in three ways.

- (1) A Provident Fund could be set up, which all members of the Staff would be compelled to join. The Cotton Committee have already a fund of this kind and their experience would no doubt afford valuable guidance to the Council.
- (2) A Register of satisfactory and efficient research workers could be established, on which a man who had successfully completed the investigation assigned to him by the Council could have his name inscribed. This could be brought to the notice of Departments, organisations or private employers wanting good men.
- (3) A selected cadre of proved research workers could be gradually formed, who would be given permanent posts and who could be transferred from place to place to carry out the investigations fostered by the Council.

I recommend that all three methods be adopted, and I am convinced that the moral effect on the men would be reflected in the work. No one can do his best when he is worried by fears of the future.

CHAPTER 6.

The Imperial Agricultural Research Institute, New Delhi.

The purpose of this Institution is to carry out investigations of fundamental importance to India agriculture in the same kind of way as is done at the Rothamsted Experimental Station or the Agricultural Research Departments at Washington. The difference in conditions is that Rothamsted is by far the oldest of the British Stations while the Delhi Station is the newest of those in India : and that the Washington Research Departments are under the control of the Federal Department of Agriculture of the United States while there is no such body in India. These differences give a special character to the Delhi Institute and they involve it in certain difficulties so that its position and functions need defining.

Among the Indian Agricultural Research Stations the Delhi Station occupies a special position, being controlled by the Government of India and placed under the general charge of the Honourable Member for Education, Health and Lands. The same Minister has charge of the Imperial Council for Agricultural Research so that the Council and the Institute may be regarded as parallel organisations, both responsible to the same Minister, but neither directly connected with the other.

The Research Institute is the direct continuation of the Pusa Institute, which almost from the outset was found to suffer from its isolated position, a difficulty that seems to have become intensified as time went on. After the destruction of the Pusa laboratories by earthquake in January 1934, it was decided to transfer the work to New Delhi and to build the new laboratories there. The difficulty of isolation is therefore completely overcome. Certain other weaknesses discussed in the various Reports on the reorganisation of Pusa have also been remedied, and the reorganisation of the Institute seems now to be satisfactorily accomplished. But meanwhile there have been some important changes in the position of agricultural science in India.

When Pusa was founded in 1904 it was the only centre for general agricultural research in India. Individuals such as Drs. Martin Leake, Barber, Hector and others were doing excellent work in their respective provinces, but their work was entirely personal and was in no way associated with an Institution. Pusa was intended as a centre where investigations fundamental to agriculture all over India could be carried out, and where agricultural officers might obtain trustworthy information on any important agricultural subject. In its early days the Institute was fortunate in attracting some exceptionally able scientific workers : the Howards, E. J. Butler, H. M. Lefroy and others, and in some respects it completely fulfilled the hopes of its founders : the wheats bred by the Howards, the masterly studies of the fungus pests by Butler and of the insect pests by Lefroy, are works of which any station could be proud. But these were all in the nature

of personal triumphs, and it is well-known that Pusa as an Institution did not attain the high commanding position in agricultural research that had been expected.

The new Research Institute begins under conditions very different from those in which the old Pusa started. There have been marked changes in at least three directions. The chief co-ordinating agency in agricultural research in India is undoubtedly the Imperial Council for Agricultural Research. It possesses the greatest of all powers in a modern state, the power of the purse ; it receives applications for assistance in research from all provinces and contributing states, it has fuller knowledge than any other body or individual of the problems of Indian agriculture and of the men who are achieving good work however quietly and unostentatiously it may be done. It combines therefore knowledge and power, and it is able to influence both the direction and the execution of research by the way it allocates its grants and the conditions it attaches to them. This powerful influence is likely to persist.

Further, agricultural research is no longer confined to one Station. The Provincial Departments have organised their own agricultural institutes, some members of which, with assistance from the Council, are making useful researches, and they feel no desire nor indeed have they any need to turn to a Central Institute for help or guidance. Several of the Universities have interested themselves in agricultural science and are carrying out fundamental investigations on plants and soils. Some of the other Departments and non-official organisations have their own research laboratories such as the well equipped Irrigation Research laboratory at Lahore, the Cotton Research laboratory at Matunga (Bombay), the cotton field station at Indore, the Tea Research Station at Toeklai and others. These have picked out for themselves some of the most important subjects and they are doing their work so well as to leave nothing over for a Central Institute.

Finally, the Imperial Agricultural Bureaux, and Institutes of Entomology and of Mycology, located at various institutions in Great Britain, and maintained by the various Governments of the Empire, including India, act as clearing houses of information on agricultural matters, identifying plants, insects, fungi, etc., and supplying information on the various branches of agriculture. These Bureaux have highly expert staffs and access to large libraries and herbaria : the need therefore for another clearing house of information at Delhi is much less than it was a few years ago.

In view of all these developments it might at first sight appear that there is little room for a Central Research Institute. If the Institute confined itself to the study of fundamental problems basic to the work of the Departments without having secured the intellectual leadership, its results, even if sound, would run the risk of being ignored so that the work would have little practical effect. Intellectual leadership is won only by merit and only slowly : it cannot be achieved by administrative arrangements.

The Institute may yet win this leadership : it has magnificent buildings ; some prestige descends from the old Pusa ; and it is known that, in the selection of Staff, merit and competence are the chief determining factors, personal and communal considerations having no such commanding influence as in some of the Provincial appointments. All this is in its favour. It can best attain leadership by rendering valuable service to all concerned with the development of agriculture in India. But in the meantime the important question arises : how can the new Institute best aid in the development of Indian agriculture ?

The present work of the Institute.

The purpose of the present work is to provide a scientific basis for the activities of the various Provincial Departments of Agriculture. There is no intention of duplicating their work, or of carrying out investigations which they are able to make, but rather to undertake work of such wide application that it need only be done at one centre to serve all India ; and the fundamental studies for which they have neither the time nor the staff.

There are considerable difficulties in putting this design into practice. The fundamental studies cannot as a rule be separated from the practical problems to which they relate : usually the work must be done in the district concerned. Studies detachable from the field-work become indistinguishable from plant physiology, physical chemistry, genetics and other sciences more properly investigated at the Universities because of their intimate relation with teaching. It is of course possible to spend many life times on the study of any natural object and still not to exhaust the possible programmes of investigation : but the work soon becomes remote from practical agriculture and therefore unsuitable for an agricultural experiment station unless constant care is taken to keep it in the field as well as in the laboratory.

The detailed work of the Station is discussed in a later section of this Report. The various activities of the Institute fall into three groups :

- (I) standardisation of methods for other stations to use :
- (II) making collections of insects, fungi, soils, etc., and also a register of varieties of crops : all these to be available to the Staffs of Provincial Departments :
- (III) investigations of agricultural scientific problems which seem to be near to practical application.

In regard to standard methods, the Institute has no power of compelling other stations to adopt those that it recommends, it can only point out their advantages.

The making of collections is very useful in assisting Departmental officers to identify any insect or fungus new to them. In case of uncertainty the last word will always remain with the

Imperial Institutes of Mycology and Entomology in London, where the staff have access to the type collections and to collections of living cultures, and which also act as clearing houses of information for the whole Empire. It would be very costly and quite unnecessary to attempt to duplicate their functions, and the Air Mail service is now so efficient that there would be no saving of time even if the attempt were made. Some of the provincial officers with whom I spoke preferred to apply direct to the Bureaux for identification and information rather than send to Delhi.

The future position and work of the Central Research Institute.

In view of these various considerations it seems clear that the most useful place for the Institute in the schemes for developing Indian agriculture would be in close association with the Imperial Council of Agricultural Research, recognising frankly the leading position which the Council has secured. The Council could undertake either the entire charge of the Institute or the supervision of its programme of work : this is a point of administration as to which I express no choice. But the Council should be empowered to require that the Institute's research programme included specified problems which it deemed important for Indian agriculture, even if this necessitated the cutting out of items which the staff would like to have included but which in view of the Council were of insufficient practical significance. The Council can, for example, and in my opinion should, insist that certain recognised methods of sampling and analysis shall be used for all investigations aided by it—without of course excluding any other methods which the workers may prefer—and that field experiments of all kinds shall be carried out in such a way that the results can be subjected to statistical examination with a view to estimating their validity.

This necessitates, however, thorough examination of the methods before they are made obligatory for grant-aided researches and this work could be done better at the Central Institute than anywhere else.

Among problems which in my view should be taken up by the Institute at the earliest opportunity are the following :—

(1) Methods of sampling of soils⁽¹⁾ and of all of the important crops for analysis.

In general it will be necessary to work out two groups of methods, one for rapid approximate analysis, and the other for more refined investigations where some scientific principle is involved. The work must be done in association with the statisti-

(1) The difficulty of sampling a soil is rarely realised. Usually a sample is described as having been taken to a depth of 6 or 9 inches but this ignores the fact that a 6 inch core taken on a day when the soil is compact is very different from a 6 inch core taken when the soil is in loose or swollen condition. Serious discrepancies may thus be caused in estimating the quantities of substances like nitrogen and nitrate, the content of which varies with the depth.

cal experts, who must be able to accept the methods as giving valid estimates of significance of the results in view of the heterogeneity of the material.

(2) Standard methods of analysis and of crop examination to be used for all co-ordinated schemes. Individual workers would, of course, still be at liberty to use their own methods, but the standard methods must also be used to ensure comparability of the results.

Both (1) and (2) would necessitate considerable laboratory and field investigation : it would not be permissible simply to write down arbitrary methods and insist on their use. Numbers of alternative methods would need to be examined experimentally, and the Institute must be able to set out and justify before expert critics the reasons for its selection. International methods should as far as possible be adopted unless others are definitely better.

(3) Collection and examination of soil analyses made in different parts of India with a view to the preparation of soil maps. Until the standard methods referred to in the preceding paragraph are universally adopted it may be necessary to analyse again some of the soils, and numerous examinations would be needed in order to find how far soils examined by different workers are similar and how far they differ. This would necessitate the setting up of a small soil Committee consisting entirely of the leading soil experts of India to act as the correlating body : the Chairman of the Committee would not necessarily be a member of the Institute staff. A considerable amount of valuable material now exists in various parts of India ; following up the recommendations of the Royal Commission on Agriculture a number of surveys have been made both by Agricultural and by Irrigation Departments. All the data should be collected and collated.

(4) Comparisons in field experiments of the relative values of nitrogen in green manure, farmyard manure, compost, oil cakes and sulphate of ammonid. Estimations of the recovery of nitrogen by the crop, and of the changes in moisture, ammonia and nitrate contents of the soils of the different plots. The work must be done in the field, the treatments being properly replicated and the plots randomized in the usual way, and the sampling to be so done as to give on each occasion a valid estimate of the error of the sampling.

(5) Collection of insect and fungus pests, and of other insects and fungi associated with crops even if of no present economic importance. The collection and compilation of records of occurrence at periodic intervals at a number of centres where it is known that the observations are trustworthy. To this should be added information obtained from the Imperial Institutes of Mycology and Entomology at London and the whole should periodically be put into the form of short bulletins which busy

Provincial officers could read, and which would inform them of any apparent increase or decrease in the pest, and of results of attempts to obviate or to overcome the attack.

(6) Population studies of insects as discussed above. The methods of sampling and estimating must be worked out experimentally in association with the statistical experts: methods of recording should be devised suited for use at all the stations. The results should then be collected and fully worked up at the Imperial Station.

The Tea Research Station at Tocklai should be consulted as to methods of recording the incidence of insect and fungus attack.

(7) Collection or registration of varieties of crops, fruits and vegetables grown in India.

It is unnecessary to duplicate existing collections of importance, but the varieties should be included in the records.

(8) Selection and breeding of plants for which there is no adequate provision in the Provinces, *e.g.*, potatoes, or for which Delhi or its substations are particularly well suited, *e.g.*, the Brassicæ at Karnal. Co-operation with plant pathologists in plant breeding experiments, *e.g.*, for producing rust resistant wheats.

(9) Continuation of the selection and breeding of sugar cane at Coimbatore on its present lines.

(10) Co-operation with the Health Department in investigations likely to improve the quality of the dietary of the villagers: *e.g.*, practicable methods of making good the deficiencies of the customary diets: the effects of proved mineral deficiencies in soils on the nutritive value of cultivated food stuffs.

(11) Co-operation with the Marketing branch in making or arranging for investigations likely to improve the market value of Indian agricultural products. This work should be confined, however, to investigations likely to come to a successful issue: vague investigations in "quality" should either be avoided, or done on a large scale as described on page 23.

(12) Keeping in touch with the workers engaged on the Council's schemes, lending them books and current journals (so far as these would be replaceable if lost) containing papers of importance to them.

Irrigation and dry farming methods are of such vital importance and present so many difficult problems requiring investigation in the regions concerned, that I recommend separate treatment for them (page 220). The Institute would continue as at present to admit post graduate workers but it should be empowered to insist on a high standard of attainment before entry. There are

numerous facilities in India for ordinary tuition in agricultural science, and it would be unfair to the Staff and a waste of their resources, if they had to teach facts and methods that are included in a good College course.

The above programme differs in several respects from the tentative proposals put before me when I visited the Institute.

I have omitted all subjects not directly applicable to the production of crops under present circumstances : such as pure cytology, microbiology and physiological studies of insects and fungi. I recognise their interest, and should welcome their inclusion, especially if members of the Staff are personally interested in them, provided they can be studied without prejudice to the work on the items set out above. But, I consider the need for improving the yield and quality of the cultivators' produce is so urgent that all other problems should stand aside. In the present day conditions in India the Experimental Stations both Central and Departmental must be judged by the extent to which they help to raise the standard of life in the villages.

The Staff of the Institute : The Director.

The position of the Institute in relation to the Universities and the Departments of Agriculture depends on the quality of the work done there, and this in the end depends on the quality of the Staff. The Director and the Heads of the leading sections should if possible be men of international repute who would be respected for their own merits by the workers at other Institutions. This, of course, is easier to lay down as a principle than to accomplish as a fact.

It has been proposed that the Director should also be Head of a Department but this arrangement while no doubt suitable as a temporary measure during a period of financial depression, is not in my view suitable as a permanency. There is always the danger that heads of other sections may consider that their claims to share the available funds are being set aside in order that the Director may better finance his own section. Further, the directorial duties cannot fail to interfere with the duties of head of section and to take up time that would normally be devoted to research. Additional work devolves on the chief assistant, and although this may to some extent be met by additional payment, the fact remains that he is charged with the responsibility of special supervision without the prestige which for the scientific man is often more important than the extra pay.

Finally, the Director should be one of the most useful of the group of thinkers and planners helping the Council in its new developmental duties. He should be a scientist of wide repute and having such personal qualities that his help and criticism would

be welcomed by the men carrying out the Council's research schemes. He need not be an agriculturist but he must be distinguished in some science basic to agriculture. It is not necessary to go outside of India to find a suitable man.

The present Staff of Research Workers engaged on the Council's Schemes.

I greatly admired the energy and enthusiasm with which many of the research workers engaged on the Council's schemes were carrying out the tasks allotted to them, in spite of great difficulties. It is of course pleasant enough to do research at a University where there is an intellectual atmosphere and a social life rich in amenities, where libraries and the other accessories of learning are available. But many of the Council's workers are in lonely places where they are cut off from any possibility of discussing their results with competent critics, away from libraries and the stimulus that comes of association with men distinguished in the arts and sciences. And yet in spite of these difficulties and of occasional depression through a feeling of isolation they are achieving good results. Many of the difficulties are unavoidable : they arise from the circumstance that the work must be done on the spot and cannot be transferred to a College. They could, however, be considerably mitigated by more frequent visits from experts who could go over the results in detail and discuss them with the worker. The interest taken in the periodic visits of the Council's experts shows how valuable these discussions are, and the Council might well consider the advisability of extending them by periodically sending some other qualified person to Stations where his special knowledge would be helpful. Visiting Experts should pay particular attention to the more remote and inaccessible stations, and should stay at each place long enough to go into the details of the results, advising what lines should be followed up and what can be left for the time being. It is difficult to over-rate the value to a research worker of a quiet talk in his laboratory or on his field plots with some one enjoying sufficient prestige to command his respect, who is taking the trouble to understand his results, and who can deal helpfully and sympathetically with his difficulties. Such visits would necessarily be infrequent, yet their influence would, I am sure, be profound, and a young man proud of his work would be greatly encouraged by the knowledge that his visitor had recognised its good points, and had indicated ways in which improvements might be effected.

Still further benefit would accrue if arrangements could be made on the recommendation of the visiting expert for the worker to spend a certain period of time in some other laboratory where similar investigations were in progress or where methods likely to help him were being developed. A detailed programme would be drawn up in consultation with the Heads of the laboratories

concerned, and submitted to the Council, who, if they approved, would take the matter up with the Departments.

Technical Conferences between the workers in similar subjects are already arranged : I should like to emphasise their value. The Council might consider the advisability of holding some of these conferences at the Imperial Research Institute, Delhi, in the laboratories where methods or technique could be demonstrated instead of being simply discussed.

Proposed permanent cadre of proved research workers.

Some of the men now engaged on the Council's schemes have shown definite capacity for doing good work and it would be a great loss if they were simply released at the end of the period. It is undesirable and indeed impossible to retain all, but a select group should be put on a permanent basis, working usually at some out-station where they get down to the actual field problems, but regarding the Central Institute as their home. The posts would be permanent, but a man would not necessarily remain in this cadre indefinitely, for from it would be recruited men for administrative or executive posts requiring technical knowledge. A man's research life is not usually very long : in general—and with some notable exceptions—however good he may be, he sooner or later gets into a groove out of which he will never again emerge. It is no misfortune when a research man who has the gift for administrative work undertakes it after having opened up a new field of enquiry.

The organisation of the Council's business.

I attended meetings of the Council and of various sub-committees and was much impressed by the evident effectiveness of the procedure. At first sight the Council seemed large but I could suggest no way of reducing their numbers.

In view of the widening of the scope of the Council's activities which I have proposed it will obviously be impossible for the Council to concern itself with individual schemes : it should deal with principles and major issues rather than details, and while it would place the large problems in some perspective it would necessarily leave to the higher staff and the sub-committees the detailed shaping of schemes and allocation of funds thereto.

The method adopted by the Council of appointing sub-committees of experts to discuss and report on the various divisions of their work is admirable and suitable for extension.

The expenditure of the Provincial Departments.

Reference has several times been made to the successful work of some of the Provincial Departments. The figures of provincial

budget estimates for 1936-37 on account of the Departments of Agriculture in the various provinces are shown in Table 16.

TABLE 16.

Province.	Total area sown, Million acres.	Expenditure on Agricultural Department.	Expenditure per 100 acres sown. (total sowing).	Expenditure per 100 persons.
		Lakhs of Rs.	Rs.	Rs.
N. W. F. P. ..	2.5	4.77	19.1	..
Assam	6.7	8.12	12.1	9.4
Madras	37.5	41.75	11.1	8.9
Burma	19.1	18.09	9.5	..
Punjab	29.8	28.52	9.6	12.1
Bengal	27.9	25.65	9.2	5.2
U. P.	43.4	36.70	8.5	7.9
Bihar .. ..	..	13.20	..	..
Bombay	34.1	22.46	6.6	10.9
C. P.	27.5	9.42	3.4	6.1

The Council's Resources.

The Council's work has been financed on generous lines by the Government of India and it has received substantial grants from other sources. The effect of the foregoing proposals will be to diminish the expenditure in some directions and increase it in others, but if a total income of the order hitherto received should continue to be available much of what I have proposed could be carried out. During the next few years, however, the Council would need additional special grants if progress is to be as rapid as is desired.

PART II.

PART II.

Work directly carried out by the Council.

In general the Council does not itself undertake investigation. There are, however, two directions in which it has done so : costs of production of crops, especially cotton and sugar cane ; and the statistical control of agricultural experiments.

(1) Cost of production of crops.

This investigation is in the hands of Mr. R. D. Kapoor, who after graduating at Lyallpur travelled with the purpose of studying economics at Columbia and New York ; agriculture at Cornell ; and agricultural economics at Cambridge under Dr. Venn. The cost is estimated at Rs. 5,25,800 of which only half is borne by the Council, the other half coming from the Indian Central Cotton Committee.

The general plan is to select 24 districts all over India where sugar cane or cotton is an important crop ;⁽¹⁾ to choose six villages in each district and eight holdings in each village. A Recorder is placed in each of the villages to keep close watch on the selected holdings, entering up all the work done, by whom it was done, and the number of hours taken. A District Supervisor is in charge of each six recorders, and is required to spend at least 20 days per month in the villages. A provincial officer checks the work of the supervisors.

There are thus 1152 holdings under observation, and the staff includes 144 recorders, 24 district supervisors, in addition to the central staff.

The common difficulty of assessing the value of a peasant's time was met by enquiring into the local wage rates and charging the hours at these rates. The rates vary considerably in the different districts ; for a man working 8-10 hours a day the wage in Sind is 6-8 annas : in the Punjab 3-4 annas : in Madras 1 anna 6 pies to 2 annas. As the enquiry proceeds it will be interesting to see whether the rates per unit of crop produced vary as much as the rates per day, or whether, as often happens elsewhere, the rates even out, the cheaper labour being less effective than the dearer.

This is the first enquiry of its kind in India, and the results if valid should be of value both to the Agricultural Departments and in relation to the work on Rural development and village improvement. The work should certainly be continued, but a close study of the data should be made quite independently so as to ascertain whether they have been correctly used.

A first inspection of the figures suggests that cotton is profitable in the Canal Districts of the Punjab and in parts of Bombay and Madras : sugar cane is profitable in the United Provinces, in Bihar and parts of Madras, while in the Punjab it only just pays :

(1) The districts were scattered widely : there were 3 in the Punjab, 3 in the United Provinces, 3 in Madras, 4 in Bombay, 3 in the Central Provinces, 3 in Bihar and Orissa, 2 in Bengal, and one each in Sind, Hyderabad State, Baroda State, and Mysore State.

wheat is profitable in the canal colonies of the United Provinces and the Punjab but not elsewhere. "Unprofitable", however, does not mean, as it would in Great Britain, that the grower had lost money, but only that he would have been better off had he spent the same time as a labourer at the standard wage assuming he had been able to obtain the work. It will be interesting to ascertain also whether the peasant has himself discovered the relative profitability of the various crops and extended his acreages accordingly.

It is understood that this scheme comes to an end when the present enquiry is completed.

(2) Statistical control of agricultural experiments.

Rao Bahadur M. Vaidyanathan, the Statistician to the Council received his mathematical training at the Madras University where he specialised in Statistics. His duties consist in assisting investigators in designing their experiments, both in crop and animal husbandry, and in examining the results; in reporting on articles submitted for publication in the Council's Journal, and in advising the Council on statistical matters generally. At the time of my interview he was closely watching some 56 schemes in various parts of India: in addition he is studying methods of sampling and methods of crop forecasting; and he is aiming at preparing Statistical Tables for field workers. He has also prepared and published a summary of all the recorded manurial experiments made in India.

All these subjects are of great importance. It is impossible to over-estimate the need for statistical control of agricultural experiments, particularly in ensuring sound design of experiment and effective methods of sampling. It is significant that in his review of the fertilizer investigations the Statistician had to reject a large number of the experiments because of faulty design.

This trouble is not likely to recur, as the improved methods worked out at Rothamsted have been eagerly taken up by Indian investigators, and in any case the Council now insist that all designs of crop and animal husbandry experiments must be approved by their Statistical adviser before any grant can be made. In some instances the experiments had actually been begun before the Statistician was consulted, and all he could do then was to save what he could of the results. At the risk of apparent loss of time this should not be permitted: a faultily designed experiment can never give satisfactory results no matter how often it is repeated or how carefully the work is done.

An instance came to my notice where another statistician had also been consulted and he had suggested a different design for the experiment, which caused some comment at the time. There is nothing unusual in this, and no harm at all in having alternative design for consideration, but as an act of courtesy each Statistician should know that a second opinion is being asked, and from whom. The final decision rests with the Council, but in case of serious discrepancy the two statisticians should be invited to give detailed reasons for their choice.

In view of the circumstances that the subject is new and outside the range of training and experience of many of the workers, it is very desirable that Rao Bahadur Vaidyanathan or some highly competent officer should periodically visit the various stations where research under the aegis of the Council is done, in order to ensure that the experimental schemes as they develop can still bear statistical examination and that the significance of the results can be estimated. It is particularly important for experimenters to realise that no amount of statistical treatment can ever make a bad experiment into a good one. Statistical science can sometimes mitigate the loss of value due to some accident, as when it shows how to extract a result in spite of the loss of crop from one of the plots, but the need for salvage operations of this kind should be sedulously avoided.

Much work needs to be done on methods of sampling. Agricultural materials, soils, crops and animals, are very variable : no two are alike : and it is impossible to say how much of the difference between a treated and an untreated sample is due to the treatment and how much to the heterogeneity of the material. Sampling therefore becomes an operation of fundamental importance, and a considerable amount of experimental work done in the past, and some that is still proceeding, to which I refer elsewhere, is seriously vitiated by faulty sampling. The method must be suited to the material and adequate for the problem : but considerable investigation needs to be done in order to work out model methods for the various types of investigation now proceeding.

Another subject needing serious attention is the improvement of the agricultural Statistics. The figures for acreage are, or can be made, fairly accurate, but the estimates of yield are very uncertain and some experienced agricultural officers have gone so far as to assure me that they are worth very little. When checks became possible for yields of cotton the values recorded in the agricultural Statistics were found to be about 25.30 per cent. too low. In view of the great interest now being taken in the nutrition of the villagers it is important to know whether the recorded yields of food crops are subject to a similar error.

This problem is really only another example of sampling. Other sampling problems concerned with rural welfare are discussed on page 157. The subject is rapidly developing and I note with satisfaction that Rao Bahadur Vaidyanathan is to proceed to England for one year to familiarise himself with the latest developments and to discuss Indian problems with various experts there.

The present staff consists of Rao Bahadur Vaidyanathan and two assistants only and in my view it needs strengthening. More computers and compilers are required : they can be obtained without great expense. But the senior staff will need to be increased in the near future. Further reference to this matter is made in discussing the work of Professor Mahalanobis in Calcutta.

Statistical work of this kind is necessarily continuous, and I recommend that the section be made permanent.

IMPERIAL INSTITUTE OF AGRICULTURAL RESEARCH.

(See page 74.)

ACTING DIRECTOR : RAO BAHADUR B. VISWANATH.

The Institute is organised in five sections :

(1) *Agricultural Section.*—In charge of Mr. Wynne Sayer. Good work has been done in building up a high class pedigree herd of Sabiwal cattle, on which Dr. Wright is reporting. Mr. Sayer also proposes to study power farming.

The main farm area comprises one compact block of 475 acres and a further area of 50 acres. In addition land is available at Karnal, 70 miles to the north of Delhi, and easily accessible by rail or road.

(2) *Chemical Section.*—This is in charge of Rao Bahadur B. Viswanath. A soil survey of the farm is being made with the view of relating the cropping capacity of the soil to the crop yield. If this investigation can be adequately carried out it may yield results of considerable interest; but it implies the collection of a considerable quantity of yield data of known validity.

The possibility of making a compost from forest litter is being studied.

The effect of farmyard manure on the quality of the seed is studied : it has been claimed that seed from plants receiving farmyard manure produces better plants than from unmanured plants.

It is known that large plump seed gives larger and more vigorous plants than small shrivelled seed, one factor being the difference in food supply for the embryo and the plantlet. In this investigation it will be necessary to separate the effect of size of seed from any specific effect that farmyard manure may be exerting.

The nitrogen content of the soil is studied with the special purpose of finding whether it remains approximately constant during the year or whether it is liable to seasonal fluctuation. This question is of considerable scientific interest though it probably has no practical significance. The investigation has been carried out at a number of centres and a number of analyses have been made.

The actual figures obtained at the different times of sampling all differ, being sometimes above and sometimes below an average value ; the differences are only small but they are greater than any likely error of titration. It is assumed that these fluctuations represent real changes in nitrogen content of the soil, but this assumption is not justified : no two samples of soil from the same plot of land contain quite the same percentage of nitrogen and unfortunately the results do not show how much of the recorded fluctuation is due to differences in the soil itself. The method of sampling is faulty in that it gives no measure of the soil heterogeneity and in consequence nothing can be deduced with certainty from the results. A better sampling technique is needed.⁽¹⁾

(1) Several possible errors are discussed in a paper by A. Sreenivasan and V. Subrahmanyam, "Some Factors Influencing Studies on Nitrogen Fluctuations on Soil Plots", Proc. National Inst., Sci., India, Vol. III, No. 2, pp. 233—239.

On the applied side work is being done on gur and on the clarification of sugar.

A laboratory has been set up for the special study of micro-chemical analyses. The purpose is to develop methods which can be used by various departments here and in the Provinces.

The Micro-biological laboratory is in charge of Dr. Joshi. He is at present studying the supposed photo-nitrification stated by Dr. Dhar to occur in soil. (See page 118.)

Further, he is studying the dissociation of bacteria supposed to be associated with mosaic disease. Some of the dissociated forms are filter passers : a matter of some theoretical interest. Other problems include the bacterial control of milk and the bacterial oxidation of sulphur, an action that would presumably occur if composts were made of sulphur and bones for the purpose of preparing super-phosphate.

(3) *Botanical Section.*—At the time of my visit Dr. B. P. Pal was Acting Imperial Botanist. He is investigating problems of plant breeding and genetics. Some of the work, such as the breeding of potatoes resistant to blight, is done in the fields at Pusa.

He proposes to set up a register of the different varieties of wheat in cultivation in India and to give them standard names. This work appears to be well done.

(4) *Mycology Section.*—Mr. Galloway was still in charge at the time of my visit but he has now left and Dr. M. Mitra is Acting Head. The general programme comprised two parts :

- (I) The maintenance of a collection of the chief fungi of importance in India : this is in two parts : the herbarium specimens and the living specimens, though it was recognised that this latter would be difficult and costly to maintain because of the continual sub-culturing necessary.
- (II) Practical control of fungus diseases : this work, however, is not to overlap with work in the Provincial Departments.

With the appointment of a new Head of the Section it would be well to reconsider the scope of work and the name of the Section. "Plant Pathology" would in my view be a better name than "Mycology" and would better express the scope of the Section. Since the original section was set up it is now recognised that plant diseases are caused by a variety of agents, not only by insects and fungi : there are also bacterial, virus and physiological diseases. All these should come within the scope of the Section. It is no longer necessary that the head of the Department should be a mycologist : he should be a plant pathologist, and if necessary should have a mycological assistant.

(5) *Entomology Section.*—Dr. Pruthi is in charge of this Section with Mr. P. V. Isaac as second entomologist. He has three main lines of work :

- (I) A collection of insects associated with Indian crops and fruits whether of present economic interest or not, it being recognised that an insect harmless now may be harmful

in a few years time. A record of the occurrence of these insects with notes is also kept.

- (II) Studies of the life-histories of Indian insects. The provincial entomologists study only recognised pests.

Sheets are prepared showing the occurrence and damage done by the pests, and methods of control are discussed.

In view of the fact that some of the Provinces have no entomologist⁽¹⁾ this work is likely to be very useful.

- (III) Studies of vegetable insecticides and fish poisons. (See page 196.)

It is proposed also to study bees.

In addition the Agricultural Section is provided with a statistical assistant, Mr. P. V. Krishna Iyyer, for carrying out its routine work.

The Schemes of the Imperial Council of Agricultural Research.

Three of the Council's schemes are being carried out at the Institute : they are all connected with sugar cane.

- (1) Mosaic and other diseases of sugar cane ;
- (2) Insect pests of sugar cane ;
- (3) Chemistry of sugar cane.

(1) MOSAIC AND OTHER DISEASES OF SUGAR CANE.

This work was begun in 1932, at first under Dr. S. Desai, but now in charge of Dr. B. L. Chona ; and the amount of the grant is Rs. 18,596 annually for 5 years and Rs. 12,000 non-recurring : the total being Rs. 1,04,980.

(i) *Mosaic disease*.—A good deal of attention was at first paid to Mosaic disease but this is not now regarded as serious at any rate in Northern India. Even an 80 per cent. infestation caused only a 10-15 per cent. reduction in yield, and under normal conditions in practice, the infestation rarely exceeds 10 per cent., and sometimes is only 1 or 2 per cent.

The observations have hitherto been mainly on the medium Coimbatore varieties ; they are now being extended to the thicker varieties, but there is at present no indication that the results will be different.

It is never safe, however, to assume that Mosaic diseases are unimportant. They form an obscure and difficult group and they have the peculiarity that two known diseases can combine to form a third, new to plant pathology and capable of causing considerable trouble. Further, new varieties of cane may be produced which, while desirable in other ways, are susceptible to Mosaic disease. Constant watch must therefore be kept : but this is not a matter for the Council ; the Imperial Agricultural Research Institute is a suitable body for this purpose.

(1) E.g., Bengal, Bihar, Sind.

In view of the relative unimportance of mosaic disease of sugar cane there seems no particular need for continuing the work on the properties of the virus. Studies on this subject are being made elsewhere but until some striking fresh development occurs it is hardly necessary to repeat on sugar cane work already done on potato or tomato virus.

The work is in any case more appropriate for a University well equipped for plant pathology, and having available good chemical and medical laboratories so that the help of experts in other subjects can be obtained whenever necessary. It is essentially a problem for a team and not for an individual.

For those crops for which it is serious the best way of dealing with the disease is to grow resistant varieties, and this would probably hold for sugar cane also if ever the disease gave trouble in India. Meanwhile it is necessary to test all new varieties for resistance to mosaic disease : a suitable technique has been worked out by Dr. McRae and Rao Bahadur Venkataraman.

(ii) *Red Rot*.—This disease is much more important especially on the thick varieties : indeed it is probably the most serious sugar cane disease in India. The remedy consists in a more careful selection of the sets, all those showing redness on cutting being rejected. There is a reddening caused by saprophytic organisms, following the attack of the borer, and in consequence the rejections of all red sets may involve some loss, but it is safer to incur no risk. Two other rots are studied.

(iii) *Stinking Rot*.—(*Bacillus pyocyaneus* var. *saccharum*, Desai) apparently a bacterial disease though its cause is not yet known, and *Top Rot*, which is apparently caused by *Fusarium*.

In addition to these studies of disease two other pieces of work have been undertaken :

- (1) a survey of the diseases of sugar cane in the important cane growing regions of India ;
- (2) a handbook of the diseases of the sugar cane, describing them and showing how they should be treated.

It is very desirable that these should both be completed.

Insect pests of sugar cane.

Entomologist in charge : P. V. Isaac.

This investigation began only in 1936 : a grant of Rs. 96,000 has been sanctioned.

The programme of work includes four sections :

- (1) Field work on insect pests at Delhi, and at the sub stations of Karnal, Pusa and Coimbatore.
- (2) The collection of parasites on borers, Pyrilla, and White fly with a view to investigating the possibility of biological control.
- (3) The investigation of indigenous parasites, and the importation and trial of exotic parasites.

(4) Bionomic work on pests, and the collation of information.

So far the work has been confined to sugar cane borers :

Steam borers—*Argyria sticticraspis* and *tumidicostalis Diatraea venosata* and *auricilia* and *Chilo zonellus* ;

Top borers—*Scirpophaga nivella* and *monoatigma* ; and

Root borer—*Emmalocera depressella*.

These same insects are also studied at Muzaffarnagar, at the Punjab stations, and elsewhere. The Delhi Institute can properly carry out investigations at Karnal, but Coimbatore is far away and already a provincial entomological staff is at work there. If all these entomological investigations are carried out independently there is likely to be considerable overlapping and waste of effort, but under a central staff the necessary co-ordination could readily be effected.

Possible biological control of insect pests.

In the Central Scheme of Research on Insect Pests of Sugar Cane it is proposed that considerable attention be paid to the possibility of biological control. This is at first sight an extremely attractive method of dealing with insect pests ; hitherto its successes have been mainly in dealing with introduced pests or in islands or areas naturally isolated by mountains or deserts. It is discussed on page 50.

The investigation of the pests in the field : population studies.

At the present stage it is very important to make a fuller study of the insect and fungus pests in the field, noting their first appearance on the crop ; whether they die out, just persist, or continue to increase ; noting also the changes in external conditions : temperature, moisture supply, condition of the plant, percentage of sugar and brix (as read by the small instrument now available for use in the field) : with the view of discovering the conditions that vary with, and perhaps make for, the spread or suppression of the pest. While the observational work is going on there should be attempts to obtain and to count " samples " of the insect population so as to gain a more definite idea as to how the numbers are changing.

In conditions such as those obtaining in the sugar cane areas all the common insect and fungus pests of the crop are almost certain to occur every year in some or other of the fields, but the conditions are not necessarily always suited to their development. With a fuller knowledge of the conditions under which the pests increase, and of those under which they decrease, it should be possible to make changes in the cultivation of the sugar cane that in normal seasons would carry it through without important loss.

The search for resistant varieties of sugar cane must of course continue. This is not a permanent method of control, for after a while the insect pest usually adapts itself to the new variety, but for a time it affords a measure of protection and meanwhile selections of other varieties can be proceeding. The insect pest problem is

much more difficult than that presented by fungus pests. Considerable success has been attained in seeking for varieties of crops resistant to fungi, but so far the success obtained against insect pests have as a rule been only temporary.

The machinery for dealing with the pests and diseases of sugar cane.

The simplest method of dealing with the pests and diseases of any crop is to put a staff of entomologists and plant pathologists in charge of the work and to free them from other duties. Specialisation is essential if the crop is really important. The setting up of a Sugar Committee provided with funds for investigating the problems of sugar cane production makes it possible to establish a central specialist group of workers for dealing with pests and diseases and to provide also the local staffs who can make the necessary continuing observations and experiments: I strongly recommend that this be done as soon as possible.

The central staff would be housed at the Delhi Institute where the records would be worked up, but wherever a disease or pest was threatening to do serious injury they would transfer to the Station concerned.

The assistance of the factories could also be secured in making surveys similar to a valuable one recently completed by Dr. Haldane of the Begg Sutherland group of factories.

Cytology.

GRANT : Rs. 29,360, to be spread over 5 years.

A scheme has been put forward and is still under discussion for investigations into the cytology of Indian crops.

Cytological studies give valuable information to the plant breeder about the genetics of crops, and at the larger experimental stations where much hybridisation is done it is desirable that someone, preferably the plant breeder himself, should have learned the technique of making cytological examinations and extracting the information they can yield. This work must be done at the Stations where the crops are bred and studied: it cannot be carried out anywhere else.

The question of supporting cytological investigations at a University is on a different footing. These might result in new knowledge of the principles of cytology, and, of course, they would stimulate the training of men and women in the subject, and so would indirectly benefit agriculture.

Karnal.

Sub-Station of the Imperial Research Institute. Botanical Station of the Imperial Council of Agricultural Research.

(Visited November 12th, 1936.)

Like several other experimental farms I visited, this farm was not started as an agricultural station but by some other public

authorities, who, finding it unnecessary or unsuitable for their needs, passed it on to the Agricultural Department. In this case the founders were the military authorities. The farm has till recently been divided into two parts :

- (1) a Botanical station of the Imperial Council of Agricultural Research for experiments on cane sugar and wheat ;
- (2) an extension of the farm at the New Delhi Research Institute to give the agriculturist more land for experiment and to provide further accommodation for the cattle. The distance from New Delhi is 70 miles but it can be traversed by motor-car in about 2 hours as the road is very good. Karnal is in the Punjab, but almost on the border of the United Provinces

In this report I deal only with the first of these sections.

Sugar cane Substation: Sugar cane investigations.

These were started in 1931 and are in charge of Messrs. R. B. Venkataraman and G. V. James with a Technical Assistant. The annual cost is Rs. 12,500 with a non-recurring grant of Rs. 32,000 : the sanction is for 8 years making a total of Rs. 1,32,000.

These experiments form part of a joint scheme of work carried out on uniform lines at several centres in Northern India. Three major problems are investigated :

1. Varieties are sought which are better suited to the local conditions than those in actual cultivation.
2. Cultivation and manurial experiments are made with the selected varieties to discover means of economically increasing their yields.
3. Attempts are made to lengthen the working season for the factories by increasing the yields of early varieties and the keeping qualities of late varieties, thus making their cultivation more attractive to the cultivator. A special advantage of the early varieties is that they enable the cultivator to catch the early market for gur.

At Karnal the Coimbatore seedlings only are tested : no crossing is done as only a limited number of varieties flower here. No difficulty is experienced in bringing the seedlings from Coimbatore. The journey takes about 72 hours but arrangements are made for the seedlings to be watered and tended *en route*. Over 1,700 have already been tested. It has now, however, been found possible to germinate seed at Karnal ; " fluff " is brought from Coimbatore and the canes raised : all stages of the selection can therefore now be done here.

The seedling canes are grown first in short rows where all are rejected that possess such objectionable characters as a sprawling habit of growth, or liability to certain diseases ; the survivors are then grown in plots and subjected to further selection. This method is adopted at all centres.

The canes are planted in March, somewhat later than in many other places : they do not start growing till May or June and the cold

weather stops their growth in November ; thus there are only about six months of vigorous growth.

The water supply is mainly from the rain, but about four times a year irrigation is necessary, the water being supplied from the canal.

The selection work is carefully done and the general arrangements seemed to be quite satisfactory.

As at other centres experiments are also being made on the manufacture of gur with a view to obtaining a brighter looking product ; trial was being made of Hibiscus as a clarifying agent. This affords a satisfying way of utilising the experimental canes besides showing the local cultivators how to improve their own product.

Botanical Sub-station.

The Botanical Sub-station has been set up for experiments with a variety of crops on rather wider lines than usual elsewhere.

The work is carried out by Messrs. Kashi Ram and R. B. Ekboti and the total grant sanctioned is Rs. 2,63,930.

Experiments on Wheat.

These experiments were started in 1930 and their purpose is to test the suitability of the Pusa hybrid wheats, especially the late maturing sorts, for the cooler regions of the north and north-west.

Some changes in the wheats are also being attempted. The Pusa varieties usually grown here are beardless but the cultivators prefer a bearded wheat as being less attractive to the numerous birds and other animal pests that steal the grain. Consequently trial is being made of bearded wheats, and some are being bred for this purpose.

This work is carefully done and should be continued.

Rice.—A collection has been made of strains and varieties of rice from the Punjab and Western United Provinces and 40 pure lines have been isolated : some of these are now being tested on large plots.

Gram.—Improved varieties are sought by selection and hybridisation.

Other crops are also under experiment.

Karnal has now become an out station of the Central Research Institute at Delhi and the Council has transferred its grant to the Pusa sub-station.

Pusa Sub-station.

Although the main research work of Pusa has been transferred to Delhi it is obviously important to retain a botanical sub-station in north east India and accordingly the Council is maintaining there a Botanical Sub-station. This should also, however, if my proposals are accepted, be taken over by the Delhi Institute.

Agra.

Rusts of wheat and other cereal

(Visited November 16th, 1936.)

This work was started by Dr. K. C. Mehta, of the Agra College, in 1923, but grants from the Council were first given in 1930-31 for a period of three years : these were subsequently extended. During the course of the investigation a hill station was found to be necessary : a second laboratory was therefore set up at Simla.

The annual grant is Rs. 41,920 with a non-recurring grant of Rs. 9,000 making a total for the three years of Rs. 1,04,980.

Rusts are among the worst of the fungus diseases of wheat, and cause serious losses in all the important wheat producing countries of the world. Three types of rust are common on wheat :

- (1) Black rust (*Puccinia graminis* Pers.) which causes serious damage in Australia, Canada and the United States.
- (2) Brown rust (*P. tritricina*, Eriks.) also common in Australia.
- (3) Yellow rust (*P. glumarum*, Eriks. and Henn.) the commonest rust in England, but not found in Australia.

All three attack wheat in India but barley is susceptible to black rust and yellow rust only. The yellow rust is found only in the north, as it cannot tolerate hot weather, while the brown and black rusts occur wherever wheat is grown. These rusts occur in a number of physiological strains differing in their power of attacking the different varieties of cereals, some being much more potent than others. Fortunately only few of them occur in India : 6 out of 144 known strains of Black rust, only 3 of which, however, are widely distributed : 5 out of 65 known strains of Brown rust occur, but only two commonly ; and 6 out of 25 known strains of Yellow rust, but only 3 of these are common : a total of 17 out of 234 known strains. Dr. Mehta attributes this paucity of strains to the rarity of the alternate host plants, barberry and *Thalictrum*, on which new strains have been shown in America to originate by hybridisation.

There is a clearly marked difference between the plains and the hills in the incidence and persistence of rust. In the plains rust does not appear till January or February, although the wheat is sown in October or November, and the conditions throughout the intervening period are favourable to the disease. The infection is therefore late, and obviously not from any local source. In the hills, on the other hand, rust may occur at any time during the growth of the crop and it is always found there earlier than on the plains.

The rust fungi are propagated by spores, which, when ripe, are blown about by the wind. If the spores come to rest on the leaf of a wheat plant, and moisture is present, they germinate and send out a thread-like hypha which penetrates the leaf and so enters the plant. There are several kinds of spores, but the most important for disseminating the disease on wheat are the uredospores which constitute the reddish yellow powder seen in summer on the leaves of infected wheat plants. The uredospores, however, are not very resistant either to heat or cold, and are readily killed by the intense heat of the Indian summer, or by very cold winter weather. A more

resistant kind of spore, the teleutospore, can survive severer conditions but cannot directly infect wheat. The teleutospores of black rust can only infect barberry, and those of brown rust infect *Thalictrum*; on these alternate hosts a third kind of spore is produced, the aecidiospore, which can infect wheat again.

It had always been a mystery how rust survived from season to season on the hot northern plains where most of the wheat is grown in India. The uredospores are killed by the intense heat of summer and therefore cannot survive in the plains, and other spores seemed ruled out by the absence of the alternate host plants in or near the plains. No alternate host plant for yellow rust is known and the alternate host for black rust, *Berberis vulgaris* and that for brown rust, *Thalictrum flavum*, are found only at altitudes of 8,000--12,000 ft., and are not known to be rusted till March or May, whereas the wheat in the plains is rusted in January.

A study of the occurrence of rust in various parts of India showed that the disease spread from the hill districts, the Nilgiris in the south and Nepal in the north. Uredospores are produced in these districts from September to December: they are blown by the wind and infect first belts of wheat on the foothills, and at a later date, the wheat growing out on the plains. Dr. Mehta has prepared a map showing that in Southern India infection with black rust began in September in the Nilgiri hills, most of the crop being affected: it spread to centres further north where it appeared in January and February. In Northern India infection of brown rust and black rust began in Nepal at the end of December (40 per cent. infection) while in Benares it did not appear till the middle of January.

In association with the Meteorological observatory at Agra he studied the wind currents (following the lines adopted in Canada and the United States) and showed that the winds blowing from the centres of infection were carrying uredospores. Shortly after these spores reached a particular wheat area, the first infection could be found in the crops. The spores were produced in cool conditions and carried by wind at high elevation, so that they escaped the heat and remained viable.

The rusts differ somewhat in their tolerance of hill conditions depending upon their temperature relations: uredospores of yellow rust survive all the year round at high altitudes (above about 7,000 ft.) but they cannot survive the summer at lower altitudes, though they may survive the winter. On the other hand the uredospores of the black and brown rusts can survive the summer at both lower and higher altitudes, though they survive the winter only at the lower altitudes.

This accounts for the occurrence of rust in the plains, but it does not explain how the rusts survive in the two centres of infection, the Nilgiris and the Himalayas. Dr. Mehta has gone into this question of over-summering of the fungus in these regions and concludes that on account of the comparatively cool summer there the uredospores survive on self-sown wheat plants and tillers, which are always present in quantity.

Dr. Mehta suggests that these sources of infection could be put out of action by suspending the cultivation of wheat and barley in

the hill districts for two or three years : in the absence of alternate hosts the fungus would, he states, simply die out. The areas under wheat and barley in the hills are only small but such drastic action is hardly likely to be taken and indeed it might not answer as alternate hosts though not recorded may still be there. Instead of complete prohibition a good deal could be done by prohibiting the April-May sowings in the Nilgiris and the Palnis, and the August and September sowing in the northern hills, and by destroying rigorously the "volunteers" and tillers that appear after harvest, and carry on the rust.

A more feasible method would be to grow only rust resistant varieties of wheat and barley in the hill districts. The breeding of varieties resistant to every one of the prevalent physiological races of rust has hitherto proved impracticable in the United States and Canada, but may be easier in India where so few of the physiological races occur. Attempts have been begun to breed resistant varieties : this work is done at Simla.

As soon as a suitable variety is found it should be brought into general use as speedily as possible. Funds from some Central source would probably be needed for the purpose as the hill districts if they had nothing to gain by the change might feel under no necessity to make it.

Sir Rowland Biffen has observed that small doses of lithium salts enable wheat to withstand rust. Experiments should be made to see if this holds good under Indian conditions, and if so whether it can be put to any practical use.

Dr. Mehta's work appeared to me to be well done and worthy of the support it has received. It is an application to India of the investigations initiated by Dr. Stakman and his co-workers in the United States on Rust epidemiology and Dr. Mehta has shown considerable ingenuity in making the necessary modifications in procedure. He has wisely kept to one problem, and so has been able to make much more progress than if he had scattered his energies in several directions.

Other institutions visited at Agra.

While at Agra I took the opportunity of visiting several other institutions which, however, are not receiving grants from the Council, and therefore are not reported on here.

- (1) *The Agra College* : a teaching institution.
- (2) *The Upper Air Observatory*.—Here the officer in charge, Mr. Chatterji, explained the method of taking observations at high altitudes by means of kites, balloons etc. At present the practical application of this work for aviation and general weather forecasting but as the investigations develop they may be found to have important bearing on weather forecasting for agricultural purposes and hence the Council should keep itself informed of the progress made here.

- (3) *Bichpuri demonstration farm.*—Mr. C. H. Parr, the Deputy Director of Agriculture showed me the various trials going on. One of the most interesting is the growth of berseem as a catch crop on land that would normally be lying idle between the kharif and the rabi crops : this berseem is then fed to buffaloes to increase the milk supply.
- (4) *Dyalbagh.*—This colony of the Radhaswami Community was at the time of my visit under the leadership of Sahibji Maharaj Sir Anand Swarup,⁽¹⁾ and it affords an interesting example of a self-contained group of people living in the country in good conditions and supplying a considerable part of their own needs. They are attempting to build up a dairy herd, using Holstein and Scindi cattle as foundation and they have set up a milk factory which is too large for their own herd and can therefore take milk from the surrounding villages. Dr. Wright is reporting on this.

UNITED PROVINCES.

The agriculture of the United Provinces is more varied than in many other parts of India : there is no one dominant crop having the position occupied by rice in Bengal or wheat in the Punjab : there are several crops of considerable importance in the Province, but the distribution is not uniform, and segregation of crops occurs in the different districts. The western part is well irrigated by canals and tube wells : the eastern part is not, but its rainfall is higher : one gains the impression, however, that the country is poorer.

Sugar Cane investigations.

The United Provinces are by far the most important producers of sugar cane in India, no fewer than 1.8 million acres out of British India's total of 3.36 million acres of sugar cane being grown there. But the crop is very localised : it is mainly concentrated in three regions : the Meerut district in the West, Rohilkhand in the Centre, and Gorakhpur in the East. Each of these has a sugar cane experiment station : the chief is at Shahjahanpur in the central district. An important sub-station at Muzaffarnagar serves the western area, and a second sub-station at Gorakhpur serves the eastern region : unfortunately I could not visit this and therefore make no report on it.

The Council has made a grant of Rs. 1,01,260 to be spread over five years for work at the two stations Shahjahanpur and Muzaffarnagar : under Mr. R. L. Sethi, the Economic Botanist to the United Provinces. At the time of my visit, however, the investigations were in the hands of Dr. B. L. Sethi.

(a) Shahjahanpur.

(Visited November 23rd and 24th, 1936.)

Shahjahanpur is situated in the lower lying part of the Ganges plain : it has a moderate rainfall (38 inches in 1934 and 25.7 inches

(1) Sir Anand Swarup died in June 1937.

in 1935) most of which falls in June, July and August : the highest temperature (about 115°F) is in May and for some 50 days the temperature exceeds 105°F ; the lowest temperature is in January but frost is rare.

The experimental farm at Shahjahanpur is the oldest sugar cane experimental station in Northern India and the most important in the United Provinces. The programme of work includes field experiments and physiological investigations with some chemical control.

Field experiments.

Varieties.—It is not possible to breed sugar cane varieties at Shahjahanpur and in consequence varieties are received from Coimbatore. Of these, Co. 395 and 421 appear to be the best on richer soils and Co. 393 the most generally useful on poorer soils : indeed Dr. Sethi calls it the poor man's cane because it is somewhat thin and is therefore less liable to be attacked by various pests than the thicker canes : further it is drought resistant.

Of the early varieties Co. 350 and 385 are at present the best. They give less yield than the others but they ripen earlier and so they allow of better distribution of the cultivators' time and of course they greatly facilitate the working of the factory. At present the factory pays nothing extra for early canes, but in my view there should be a premium sufficient to make their cultivation attractive.

Both seed and seedlings are received from Coimbatore, and methods have been developed for germinating the seed and raising seedlings here. Any of these that reach the stage of large scale experiment are designated by the letters CoS : several appear to be promising. I was given an interesting table comparing the financial advantage to the cultivator of the new canes over the old desi varieties which easily explained the supplanting of the old sorts by the new :—

Per canal bigha ($\frac{1}{4}$ acre).

	Desi cane.		Improved cane.	
	Rs.	as.	Rs.	as.
Cost of seed, cultivation and manuring	51	6	55	10
Irrigation	7	4	7	4
Rent	10	0	10	0
Total cost	68	10	72	14
Yield, maunds	250		350	
Value of gur, 10% recovery Rs. 3 per maund	75	0	150	0
Profit	6	6	32	2

Manurial trials.—In these experiments comparison is made between organic and inorganic sources of nitrogen : green manure (*sauai*), farmyard manure, and neem cake being the organic, and sulphate of ammonia the inorganic source. The results show that nitrogenous manures increase the yield of cane, but potassic fertilizers do not, although they may effect the sucrose content and the purity

of the juice. The plots without manure yield about 600 maunds of green cane per acre, those with manure yield up to 1,000 maunds.

One interesting result is that green manure supplying about 60 lb. of nitrogen per acre seems to have the same effect as a dressing of 270 maunds of molasses per acre indicating that 1 ton of molasses supplies to the crop 6 lb. of nitrogen, *i.e.*, 0.3 per cent. of its weight. In view of the important problem of molasses utilisation this figure needs confirming.

There are several series of these experiments : they should be continued for two or three years longer and then replaced by a more comprehensive scheme which would give fuller information. A complex factorial experiment containing 3 types of watering (where the mechanical differences are not too great), 3 levels of nitrogen dressings, 3 kinds of nitrogenous manure : tested on 3 varieties would give very complete information as to the different reaction of varieties to differences in manuring and watering ⁽¹⁾. A suitable lay-out is given on page 106.

A good deal of analytical work is done on the cane and now that the preliminary tests are over I recommend that the question of sampling be thoroughly investigated. Chemical analysis is worthless, and may even be misleading, unless the sample fairly represents the bulk of the material, and in the case of sugar cane it is difficult to ensure this. The investigation should be done jointly by the Statistician and the Chemist : it would form part of the comprehensive investigation on sampling that I have recommended should be centred at the Delhi Institute.

Physiological Experiments.

The distinctive feature of the investigations here is that they include a physiological section recently started under the charge of Dr. Mathur late of the Imperial College of Science, London, and of the Rothamsted Experimental Station. This work at present consists of two parts : a detailed study in pot experiments of the effects of fertilizers on the growing plant, the lines being substantially the same as those developed by Dr. F. G. Gregory : and a study of the water relationships of the plant. These two problems are ample for one section and I strongly recommend that nothing more be added to the programme.

(b) Muzaffarnagar Sub-station.

(Visited November 19th, 1936.)

This sub-station serves the western part of the province : the upper "doab" between the Jumna and the Ganges, an intensively cultivated region well supplied with sugar factories which stretch in a chain from Saharanpur to Delhi.

(1) For admirable examples of experiments of this type, see the papers of F. Crowther, Bull. No. 25, Tech. Series, Roy. Agric. Soc., Egypt, 1936, "Experiments in Egypt of the Interaction of Factors in Crop Growth, III. The effects of variety spacing, nitrogen and water supply on Development of the Cotton plant and the rate of its absorption of nitrogenous Fertiliser".

The Station is about 180 miles north west of Shahjahanpur but stands much higher : its climate is drier and more severe : the annual rainfall is about 29 inches and the temperature range is from about 25° F. to 110° F. and in winter frosts are fairly frequent so that the frost resistance of canes can be tested here. The climatic conditions are not unlike those at Karnal, which is indeed is only about 50 miles to the west.

The farm has been established for some time but the Council's sugar cane experiments were started only in 1934. The two main purposes are to test canes received from Coimbatore and Shahjahanpur so as to see how far they are suited to this Gangetic canal area. Co. 385 appears at present to be the best early cane ; Co. 312 the best medium cane under moderate conditions of soil, irrigation and manuring ; Co. 421 and 331 seem promising in richer conditions, while Co. 331 seems better in water-logged soils.

Search is also made for good late varieties of cane but the local agricultural conditions are not at present very suitable for these, since the harvesting clashes with the harvesting of wheat. Moreover it is not yet clear that the factories would find later crushing profitable : their officers state that they have no control over the harvesting and high yields of immature cane are likely to be obtained by the grower and passed on to the factory. In spite of these difficulties, however, the production and selection of late canes must be continued : if later canes are to be grown at all the cultivator must obviously have the most profitable.

Mr. P. W. Marsh, the Commissioner for the Meerut Division, told me that the work done in the province on sugar cane varieties has got through to the cultivator so effectively that nearly the whole area is now under improved varieties.

Fertilizer Experiments.—These are on similar lines to those at Shahjahanpur and the results up to the present are of the same order, though only two years data are available, the 1933-34 crop having been largely destroyed by insect pests. The maximum effect is obtained with 60 lb. nitrogen per acre. Molasses applied as fertilizer gave the same results as an equal weight of farmyard manure, both being applied at the rate of 200 maunds (about 7 tons) per acre. Neither potassic nor phosphatic fertilizer increased the yields in these experiments.

The purity of the juice differs in the different varieties, but it tends to be lowered by nitrogenous manure.

The green manure experiments show that *sanaï* increased the yield of cane, and that it can conveniently and advantageously be grown after cotton and before sugar cane, instead of leaving the land bare as at present : this sequence : cotton : sugar cane, is not unusual in this region.

Other experiments deal with times of sowing, spacing, times of applying fertilizers, and various modes of irrigation. Five irrigations seemed to give the best results : 80,000 to 120,000 gallons per acre had been given to the highest yielding plots.

Entomological Investigations.

These are a special feature of the work at Muzaffarnagar : they are carried out by Mr. R. P. Gupta. Insect pests in these western districts of the United Provinces appear to be worse than elsewhere and with the spread of sugar cane cultivation the problems of pests and diseases have become still more serious. I was informed that in 1934-35 most of the factories in the Meerut division had to close down early in the season on account of poor deliveries of sugar cane. There were heavy infestations by the Stem Borer (*Argyria sticticrespis*) before monsoon rains, by the Top borer (*Sciropophaga nivella*) after monsoon rains by the Root borer (*Emmalocera depressella*) in August, by the leaf hopper and by the *Pyrilla* and white fly from the commencement of monsoon rains till the beginning of winter, in addition to attacks of termites. Something like a quarter of the crop was destroyed by stem borer in June before the actual cane formation began, and by harvest time the remainder suffered 50 per cent. or more infestation with top borer, in addition to the damage done by *pyrilla* and white fly.

Varieties differ in their susceptibility to attack and it is always possible to select canes less liable to suffer than others growing near to them. It remains to be seen how far this is a practicable method of control : if only a few growers used the less susceptible canes they might escape, the insects preferring the more susceptible varieties grown by their neighbours. But if all the growers in a particular region grew the less susceptible canes the insects might simply adapt themselves to the change and for want of anything better, attack the new canes. That, at any rate has been the usual experience elsewhere.

The programme of investigations includes (i) the study of alternative food plants from which infestation is possible ; (ii) the relation of time of planting to incidence of pest attack ; (iii) the relation of germination, tillering and growth to pest attack ; (iv) the behaviour of different varieties of cane.

It is very desirable to investigate fully the conditions under which the insect pests multiply and do damage. Spraying and direct control methods are impracticable and breeding of resistant varieties is of limited application, but a knowledge of the conditions under which damage is done may enable the agriculturist to advise as to methods for reducing loss to a minimum. Phosphatic fertilizers appeared to decrease susceptibility to attack by the top borer, but on the other hand waterlogging of the soil appears to increase the susceptibility. Second or third year ratoons harbour pests badly.

Various parasites of the borers have been found parasitising either the egg or the caterpillar, but it remains to be seen whether they can be made to play any important part in control. Some control of leaf hoppers (*Pyrilla*) was effected by collecting the adults and the nymphs in hand nets from the young crop and also by collecting egg masses from April onwards, and stripping and removing the dry leaves each month from September onwards.

NOTE BY MR. F. YATES, HEAD OF STATISTICAL DEPARTMENT ROTHAMSTED EXPERIMENTAL STATION.

Design for a combined experiment on varieties, quantities and forms of Nitrogen, and their interaction with irrigation.

Four Course Rotation, including two years Sugar Cane.

It is recommended that a factorial design including all combinations of three varieties, three levels of irrigation, three levels of Nitrogen and three forms of Nitrogen be adopted. This will give 81 treatment combinations, which can conveniently be arranged in a 9×9 quasi-Latin square in which the whole of each row is subjected to the same irrigation treatment. A square of this type is shown in the accompanying diagram, *a*, *b* and *c* being the three levels of irrigation, and *p*, *q*, and *r* the three varieties; the numbers 1—9 indicate the quantity and form of Nitrogen according to the tables:

quantity.

	n_0	n_1	n_2
S. A.	1	4	7
Cake	2	5	8
F.Y.M.	3	6	9

Thus 8 represents the double dressing of cake.

<i>b</i>	r8	r3	q1	q5	q9	r4	p7	p2	p6
<i>a</i>	r6	r7	q8	q3	q4	r2	p5	p9	p1
<i>x</i>	q2	q6	p4	p8	p3	q7	r1	r5	r9
<i>b</i>	q4	q8	p9	p1	p6	q3	r6	r7	r2
<i>c</i>	r1	r5	q6	q7	q2	r9	p3	p4	p8
<i>c</i>	p5	p9	r7	r2	r6	p1	q4	q8	q3
<i>a</i>	p7	p2	r3	r4	r8	p6	q9	q1	q5
<i>c</i>	q9	q1	p2	p6	p7	q5	r8	r3	r4
<i>b</i>	p3	p4	r5	r9	r1	p8	q2	q6	q7

If the lowest level of *n* is zero then treatments 1, 2 and 3 will be identical. If desired the levels of farmyard manure may be higher than sulphate of ammonia and cake, *e.g.*, farmyard manure at 0, 60 and 120 lbs. N. per acre and sulphate of ammonia and cake at 0, 40 and 80 lbs. N. per acre.

Study of the above design will show that all combinations of any two factors (except irrigation) occur once and once only in every row and every column. Thus the effect of any one factor (except irrigation), averaged over all levels of the other factors, is free from all row or column effects: the same applies to all interactions between two factors (including irrigation).

The advantages of factorial design are considerable in such a case as the present in which irrigation is likely to affect both the response to Nitrogen and the difference between varieties, and in which the different varieties are likely to respond differently to different quantities and forms of Nitrogen.

The experiment should clearly be a permanent one, being carried on for several years on the same plots in order to measure cumulative effects. As in all Rotation Experiments it would be best to

have one set of plots in each phase of the experiment, *i.e.* four 9×9 squares in all at each place. A reasonable compromise in this case, however, would be to use two 9×9 squares started at two-year intervals. Thus one square would be under sugar cane in every year. A set of such trials carried out simultaneously at three or more centres would make a really good experiment. In laying down additional squares either at the same place or in different places the square given above should be re-randomized by rearranging first the row (including irrigation treatments) and then the columns amongst themselves in random order. It will also be better if the four different keys given below are used in turn for the numbers 1—9. These keys being :

	I			II			III			IV		
	n_0	n_1	n_2	n_0	n_1	n_2	n_0	n_1	n_2	n_0	n_1	n_2
S. A. ..	1	4	7	1	7	4	1	3	2	1	2	3
Cake ..	2	5	8	3	9	6	4	6	5	7	8	9
F. Y. M. ..	3	6	9	2	8	5	7	9	8	4	5	6

Methods of computation are given in : Imperial Bureau Soil Science, Technical Communication 35. "The Design and Analysis of Factorial Experiments". F. Yates. (In the Press).

Cawnpore.

Research and Testing Station for the Indigenous System of Gur and Sugar Manufacture.

GRANT : Rs. 1,67,380 to be spread over 5 years.

In spite of the great developments of the cane sugar industry something like 80 per cent. of the sugar cane grown in India is worked up in the villages either into Gur or Khandsari sugar. The processes are very wasteful ; the mills are inefficient and the recovery from the cane does not usually exceed 60 per cent. of the total sugar present. It is of course impossible to hope for the high standard of efficiency attainable in a well conducted factory, but there is room for considerable improvement on the present methods.

A station has therefore been set up at Bilari in the Moradabad district with the purpose of improving the village processes, and it is proposed to study the possibility of using small vacuum pans in the village factories and of improving in other ways the making of gur and sugar.

A somewhat similar investigation is being carried out at Patna, but on a much smaller scale.

I had no opportunity of seeing this work but I recognise its importance having seen a good deal of the making of Gur in the villages.

Improved Juice Boiling Bel.

GRANT : Rs. 3,440.

This work was carried out at the Nagalia farm of Lala Har Sahai Gupta ; it is purely technological, and I am not in a position to express an opinion about it.

SUGAR RESEARCH INSTITUTE.

The Harcourt Butler Technological Institute, Cawnpore.

(Visited February 10-12th, 1937.)

This Institute, opened in 1921, adjoins the Agricultural College. It has four departments : General Chemistry, Oil, Sugar and Leather.

As soon as it was decided to develop the sugar industry of India, it was recognised that investigations would be needed on the technological just as much as on the agricultural side, and that sound disinterested advice must be available for the factories. Further, it was necessary to set up standards for different grades or qualities of the sugar and to arrange for specifications to which the factories must conform.

Accordingly the Council set up a Sugar Research Institute and placed it at the Harcourt Butler Technological Institute. The decision was sound, as the Institute has good facilities for technological work and has acquired experience in connection with other industries. These technological investigations should at an early stage be handed over to a Central Sugar Committee.

The Director of the Sugar Research Institute is Mr. R. C. Srivastava and the Staff consists of a Professor of Sugar Engineering now being selected ; the Professor of Sugar Technology, Mr. Van der Meyden, a very competent Dutch expert who has come here from Java ; four assistant Professors and two research chemists. The Statistical Assistant is Mr. P. V. Sukhatme.

Experimental Sugar Plant and Training of Candidates.

GRANT : Rs. 2,25,000 spread over 5 years.

The duties of the sugar technologist are to advise sugar factory owners on difficulties that have arisen in the course of their work, to advise promoters of new sugar factories in regard to the selection of the site, the lay-out, machinery, etc., and to carry out experimental work with the object of improving factory practice. In order that this may be done effectively an Experimental Factory has been set up at the Institute where factory problems can be studied on a semi-commercial scale.

Provision has also been made for the training of sugar technologists. Students are received from all parts of India but the Government of the United Provinces has the first claim to 20 per cent. of the places.

A Bureau of Sugar Standards.

GRANT : Rs. 32,610, spread over a period of 5 years.

It is impossible to establish the sugar industry on a sound basis in India unless standard grades of sugar can be agreed upon and duly specified. For this purpose a central body is obviously necessary and the Council has made provision for the establishment of a Bureau of Sugar Standards at the Sugar Institute.

The functions of the Bureau are :—

1. Preparing and supplying sugar standards.
2. Maintaining a Museum of supplies of sugar and other sugar products.
3. Publishing annual reviews dealing with the quality of Indian sugars and of competitive foreign sugars.

As soon as the procedure and methods have been worked out the Bureau will become an administrative rather than a research organisation and it should therefore no longer be supported out of the Council's funds.

Statistical Branch.

The statistical work of the Institute falls into two parts :

1. the collection of statistical data in regard to the industry :
2. advising in regard to the design of experiments made in the factories on various technological problems.

In order to avoid the possibility of apparently conflicting advice, designs of experiments should be circulated to the Council's Statistician and to Professor Mahalanobis for information and comment.

Utilisation of Molasses.

Approximately half a million tons of molasses are produced annually in India, and it is important to find some method of utilisation.

Four methods are being studied :

- (1) *For surfacing metalled roads.*—Considerable lengths of roads have been treated and the results seem promising, but it remains to be seen how long the effect lasts.
- (2) *As fertilizer.*—Experiments in several of the agricultural experiment stations have shown that molasses has distinct value as fertilizer in some circumstances, though not in others. Successes are recorded at Shahjahanpur, Muzaffarnagar, Nagina and Bangalore ; on the other hand, negative results were obtained at Padegaon and Risalewala.
- (3) *Conversion into industrial alcohol.*—At first sight this is the simplest method of handling the molasses, as it could be done at the sugar factory, and would help in the

spread-over of the work ; it requires no new organisation but only an extension of the existing factory organisation and it presents no specially difficult problems to the technologists, suitable methods being already well known. Indeed it is understood that the Government Central Distillery, Nasik Road, contracts for the whole of the molasses of some of the sugar factories. There are, however, economic and excise difficulties in the way of unlimited extension of this method.

- (4) *Preparation of a cattle food.*—A grant of Rs. 10,000 spread over 2 years has been given for investigating this possibility, the trial foodstuffs being prepared at the Institute and tested at several of the northern agricultural experimental stations.

Bagasse screenings from the cane are dried and mixed with boiled molasses and sources of protein such as Chuni, mustard cake or ground-nut cake, then pressed into cakes. These contain approximately 17 per cent. protein and 62 per cent. carbohydrate. No feeding results are available as yet, but European experience with this type of food shows that it can be made to give very good results.

Other possibilities.

Another method which I suggest should also be tried is to utilise the molasses for growing yeast. Some of these are good cattle food ; they are rich in protein and other valuable nutrients and there should be no difficulty in growing them at the factory. This method was used in Germany during the war and is attracting attention again, now that the policy of national self-sufficiency is developing.

At the sugar factory in Mysore remainder yeast grown in molasses was readily taken by farmers, (1) and it seems desirable to experiment with other types also.

In western countries molasses added to grass or other green fodder as it is put into the silo improves the quality of the resulting silage. Experiments on these lines should be tried.

In western countries also molasses has various other industrial purposes : it is used for making solvents and the shock absorber and " antifreeze " fluids associated with the motor car industry : as yet these uses are unimportant in India.

Oil Section.

GRANT : Rs. 90,000 for 3 years.

The work of this section consists in training students, in rendering technical assistance and advice to the industry and in carrying out investigations of technological importance, such as the bleaching of certain oils for technical use. The Council has decided to hand over this subject of Oil Technology to the Industrial Research Bureau, a decision in which I entirely concur.

(1) For American experience with this kind of yeast, see Broughton and Fry, Maryland Agric. Expt. Sta. Bull., 349.

Cotton-seed crushing : supply of decorticated cake for education and propaganda.

GRANT : Rs. 10,000 spread over 3 years.

This work is not yet begun. Its purpose is to take over decorticated cotton cake made at the Harcourt-Butler Technological Institute, and supply it to the Officers of the Agricultural Departments, for use in experiments and demonstrations on departmental farms.

At the present time the large amount of cotton seed produced in India is not fully utilised. A little is exported to Great Britain and other countries as raw material for the oil and feeding stuffs industries, but nearly all of it is fed direct to cattle, which involves wasting a good deal of the oil. The establishment of an oil industry in India would necessitate the creation of a market for the decorticated cotton cake and this requires much preliminary demonstration work among farmers.

Oil seeds crops are studied at the Cawnpore Agricultural College with a view to classification and improvement. The work is in some respects similar to that being done at Lyallpur and the workers should keep touch with one another.

Nagina Rice Research Station. (United Provinces.)

(Visited November 22nd, 1936.)

Paddy occupies $6\frac{1}{2}$ million acres in the United Provinces principally in the northern and eastern parts and the early varieties in particular are widely cultivated.

In spite of this large acreage, however, the United Provinces do not produce all the rice consumed, and there is in consequence an importation which the Department is trying to avoid by increasing the production in the districts irrigated by the recently constructed Sarda Canal.

The experiments are in general charge of Mr. R. L. Sethi, Economic Botanist (Sugar Cane and Paddy) to the United Provinces Government ; the local officer is Dr. B. L. Sethi, the Assistant Paddy specialist, with two research assistants, Messrs. T. R. Mehta and F. S. Gupta : the farm superintendent is Babu Sanjai Singh. The amount of the Council's grant is Rs. 1,39,660, spread over five years.

The Nagina farm was established in 1932 as the paddy breeding station of the United Provinces : it is about 50 miles east of Muzaffarnagar almost in a line with Karnal which lies 50 miles to the west. It is a district well-known for its early types of rice, including Basmati, claimed as the best table rice in India. It is about 34 miles from another rice experiment station, Kala Shah Kaku in the Punjab.

The work consists in seeking for early varieties of good yield and high quality. This necessitates the possession of a considerable collection of strains and fortunately one had already been started in the United Provinces by Mr. R. L. Sethi in 1924 : he collected some 1,200 samples from the different regions and from these isolated 135

types possessing constant characters. Others have since been added to the collection and now a considerable number of strains are grown at Nagina. The importance of earliness arises from the circumstance that rice is a kharif crop, sown in June or early July before the rains, and harvested from September to December according as the variety is early or late : if it can be cleared by October gram can be sown as a rabi crop : if by November, wheat or peas can be sown, but if it remains on the ground till December nothing can be sown and the land must be left idle till the following June, unless a green manure crop, *sanai*, can be sown in April or May. The sowing of an early variety therefore permits the growing of a rabi crop.

On the other hand late varieties give 10 to 20 per cent. or more higher yield than do the early varieties, and there are regions, *e.g.*, the submontane regions liable to flood and the eastern districts, where late varieties alone can be cultivated.

A further advantage of the early varieties is that they commonly escape the serious pest *leptocorisa varicornis*, locally called *Gandi*, which from mid August to mid October, but especially during September, attacks any young grain that is still in the green milky stage.

Earliness, however, does not invariably ensure immunity from *Gandi* : late varieties sometimes escape more completely through not being sufficiently advanced at the time when the insect is ready.

The only immune rice is the local *Sathi*, (60 day), a poor yielding early sort but with the great advantage over the good commercial varieties that the panicle is enclosed so that the insect cannot penetrate to the grain. This *Sathi* was crossed in 1929 with better yielding varieties so as to obtain new sorts combining high yield and good quality with the enclosed panicle and consequent immunity to *Gandi*. The F. 5 generation has now been obtained, and has yielded cultures, apparently fixed and pure, in which the panicle remains enclosed during the green milky stage and then opens out giving grain in large quantity and of high quality.

In connection with this selection and hybridisation Dr. Sethi has been intermittently carrying out cytological investigations. It is unreasonable to expect results in these conditions and if he is staying on I should recommend the appointment of a special assistant trained in cytology to do the actual work.

There are a number of manurial experiments which are well designed and well laid out. They show the value of green manuring with *Sanai* : this is superior to sulphate of ammonia which in turn is superior to nitrate of soda. Other experiments deal with the time of planting, varying also the age of the transplanted seedlings ; these indicate, as usual, that the late varieties ripen at roughly the same time whenever they are sown, *i.e.*, their time of ripening is fixed ; while the early varieties ripen earlier or later according to the time of sowing, *i.e.*, their period of growth is fixed. Earlier ripening of early ripening varieties can be secured by earlier sowing, but earlier ripening of late varieties cannot. Experiments are being made to see if earlier ripening can be obtained by vernalization, but so far the attempts have been without success.

The troublesome problem of the shedding of rice at harvest time, the result of each separate grain being on its own little stalk, is under investigation. The character is varietal and is probably controllable.

As happens not infrequently, the yields obtained on the farm here are 35—45 maunds per acre as against the peasants' yield of 15—20 maunds for early sorts and 25—30 maunds for late sorts. For wheat the yield on the farm is 20—25 maunds per acre as against the peasants' average of 11.

Work is also in progress on the hulling and cooking quality of rice and on the possibility of improving the storage. Consumers prefer rice that has been stored for some months and will not eat new rice if they can afford the older grain. A considerable quantity of rice is held in the villages and bazaars in tins, boxes, gunny bags, earthen jars, etc., for periods up to three years. Attempts are being made to improve the storage. This part of the work, particularly that dealing with hulling and cooking quality, is necessarily vague and indefinite and should be regarded simply as a minor adjunct to the breeding and selection.

The field work is well carried out. The records are elaborate and their collection takes up much of the time of Dr. Sethi and Mr. Mehta, with such assistance as they can get from their small staff. This is inevitable. But they are in addition called upon to work out the detailed computations involved in the statistical calculations. This is an uneconomic use of their time, and it would certainly be an advantage to give them help on this computing side. I understand that graduates could be obtained at a relatively low salary who would be sufficiently trustworthy and who, if provided with a hand calculating machine, could do all the necessary calculations.

It would also be an advantage to appoint an analyst who could under direction follow the changes in nitrate and ammonia content of the soils of the more important plots during the year : this might furnish the clue to some of the differences obtained in different years on the manurial plots.

The Council, has no experiments in the eastern part of the province.

Barley.

The barley grown in India is almost entirely 6-rowed ; the 2-rowed varieties which are usually in larger demand for brewing do not as a rule give sufficiently good yields to justify their growth. Barley is almost entirely confined to Northern India, and out of a total of 6½ million acres, more than 4 million are grown in the United Provinces and nearly 1½ million in Bihar and Orissa ; over 600,000 acres are grown in the Punjab and 130,000 acres in the North-West Frontier Province. Much of its importance lies in the circumstance that if well suited for malting, it commands a price far higher than it could obtain if sold for food, the difference being sometimes as much as 50 or even in special cases 100 per cent. Assuming prices of this order could be obtained, barley would

make a good cash crop, as it can be grown in the rabi season and without much expense.

For many years barley has been exported to England and samples have been periodically purchased by maltsters. But they had several defects : rather poor quality, serious contamination with weed and other seeds, and they have of late years been infested with the Khapra beetle, *Trogoderma granarium*⁽¹⁾, which if introduced into maltings in England, causes very serious trouble. In all the above named provinces experiments have been made for the improvement of barley varieties, and, in order to ascertain whether the new sorts were better than the old, a number of samples of barley were sent from the Experiment Stations to the Institute of Brewing, London, and examined by their experts. The reports showed that some of these samples were distinctly better than the usual market supply and if available in commercial quantities would probably find a ready sale.

In 1934, the Council made grants to the Departments of the above three provinces : Rs. 6,000 each to the Punjab, Bihar and Orissa and Rs. 4,600 to the United Provinces, to run over a period of 3 years for the continuance of this work. A considerable number of samples have been examined under this arrangement and the general trend of the reports is that while they do not come up to the high class English 2-rowed barleys, some would compare favourably with the 6-rowed Californian barleys, of which a considerable quantity is used in English breweries, while others of lower grade would be acceptable to distillers. The price obtained for the Californian barley is well above that for feeding barley, though not usually as high as that obtained by the first class samples of English malting barley.

The two types of barley, 2-rowed and 6-rowed, are not interchangeable and serve somewhat different purposes in the brewing process ; somewhat different properties are therefore required. Many brewers recognise in the Californian 6-rowed barley something which they call "sun" which they consider can be obtained only in countries where the crop has been grown in full sunshine ; further, the fibre in the grain either by virtue of its amount or of some special property facilitates work in the mash tub. Whatever the Californian properties may be, however, the experts of the Institute of Brewing find that the best of the Indian barleys sent recently possess them to a considerable degree so that some of the recent samples compare favourably with the best imported Californian barley.

Most of them, however, are not quite so attractive in appearance as the best Californian samples. The difference is largely on the surface, for the reports repeatedly state that the malt was better than had been expected from the appearance of the barley. The proteins in Indian barley apparently have less harmful effects on malting quality than those of the ordinary English or Californian barleys ; the Indian barleys modify better and yield higher extract than these other barleys of similar nitrogen content. Clearly in purchasing Indian barley the standards would

(1) This is the name usual in the publications of the Imperial Entomological Institute, but *T. khapra* is commonly used in India.

have to differ from those used in purchasing Californian barley. A little time would probably be necessary to allow the brewers to adapt themselves to these differences in appearance and constitution, and so long as Californian barley remains available in large quantities, it would probably be preferred by the average buyer, partly because the staff know how to deal with it, partly because of its better appearance.

There are, however, indications that Californian barley is not likely to remain in its present important position in the English market. Now that prohibition is repealed in America, the manufacture of beer is developing, and the demand for Californian barley is increasing both in the eastern and western States. In any attempts to take the place of Californian or Mediterranean barley the Indian barley would have a substantial price advantage in the 10 per cent. *ad valorem* duty imposed on non-Empire barleys, from which India is exempt, and moreover there are many brewers who would like to announce that theirs was an all-Empire beer. It is reasonable to expect that these factors should help materially in substituting Indian for Californian barley on the English market, if on its merits it deserved the place. The only important competitors so far are the Australian 6-rowed barleys, some of which are like the Californian, and those grown by British farmers who are now experimenting with 6-rowed barleys with a view to securing this market themselves. Suitable varieties hardly exist at present, but will possibly be found; it remains to be seen, however, whether the necessary qualities can be obtained in a season of but little sunshine.

It is difficult to say how large this market might become. At present well under one million quarters (= 200,000 tons) of Californian barley are used annually, and it is improbable that the whole of this could be replaced. Up to the present C-251 has been the best of the United Provinces' barleys, and there is little question that if consignments like the samples recently sent from Raya (Muttra) (1936 crop) could be supplied in quantity, they would find a ready market. But this same variety grown elsewhere was not so successful, and clearly the soil and climatic conditions play an important part.

Other samples were considered by the experts to be comparable with Chilian forage barleys which, while used by some maltsters in England, do not command such high prices as Californian.

I recommend therefore that the efforts for improvement should be concentrated on the 6-rowed barleys with a view to capturing the share of the market at present held by Californian barleys.

Unfortunately there is no simple test that can be applied locally and in consequence it will be necessary for some time to come to send samples to the Institute of Brewing for valuation. The nitrogen percentage and Bishop's Extract Scale⁽¹⁾ give a first approximation but if the work is being developed, it seems desir-

(1) Journal Instit., Brewing, 1936, Vol. 42, p. 107.

able to send an officer to England to study the market requirements so that he could make the first selections in India. It would, still be necessary to send the final samples to the Institute of Brewing before recommending their multiplication on a large scale. It must be emphasised, however, that no permanent trade in Indian barleys can be developed until the shipments can be guaranteed free from Khapra beetle.

There is a certain demand in India for malting barley, and some districts, such as Rewari and Farrukhabad in the United Provinces, are already well known in India for supplying good samples. The possibility of manufacturing malted foods should also be examined.

Fibre Plants.

Sunn Hemp, Cawnpore.

GRANT : Rs. 34,226 for 3 years.

Schemes dealing with Sunn hemp are in progress in the United Provinces, Madras, Bombay, Bihar and the Central Provinces, the general programme being similar at all the centres, though there are differences in detail. As the United Provinces are the chief producers and exporters of raw hemp in India special stress is laid on the retting and the treatment of the fibre. Preliminary experiments show that the existing methods can be considerably improved and the resulting fibre is worth much more than that now produced.

Utilisation of Linseed Fibre.

GRANT : Rs. 33,000 to be spread over 3 years.

The work has not yet begun.

In flax growing countries it is recognised that the production of flax cannot be combined effectively with the production of oil, as no variety of linseed is known which possesses the triple qualifications of producing high yield of oil, high yield of a good flax fibre, and good agricultural properties. The Indian oil varieties, however, produce a short fibre for which it is believed a market can be found. The purpose of this investigation is to investigate the possibility of extracting this fibre thereby making the crop more profitable.

If a definite outlet is found for the fibre this work could be undertaken, but if not, I recommend that the scheme be dropped.

The Cawnpore Agricultural College.

While at Cawnpore I took the opportunity of visiting the Agricultural College, an active institution where much teaching is done. It is claimed that an important percentage of the students go in for practical farming after they have completed their course.

The Experimental Farm.

(Visited, February 10th-12th, 1937.)

A large area is under experiment and an extended programme is carried out under the efficient supervision of Mr. P. B. Richards.

While here I saw the sad sight of a large area of arhar cut down by frost. It is rapidly becoming possible to issue frost warnings by wireless and it seems desirable to experiment with smudge fires and other devices for minimising frost damage, so as to see if they have any economic value in these regions liable to frost.

Fruit Research : Chaubattia Station.

It has long been known that fruit would grow well in the Kumaon Hills, and as long ago as 1870 a Government Orchard was started at Chaubattia ; others followed. Then, for a time, interest died down : it revived, however, with the development of cheap and relatively rapid motor transport, and from 1915 fruit growing became more active and the orchards are now increasing in number.

All the ordinary English fruit can be grown here and there is reason to believe that a good fruit industry could be developed.

The old Government fruit farm has now become the United Provinces station for research on temperate fruits and a grant of Rs. 1,60,780 spread over 5 years has been given. I was not able to visit it but reports on the work were submitted.

The soil investigations include studies of the suitability of the different soil types for different varieties of fruits, and attempts to trace out any connections that may exist between soil conditions and incidence of diseases.

The entomological work consists largely in making a tree by tree survey with the purpose of acquiring a detailed knowledge of the incidences of pest attacks and correlation of these with soil conditions. This method seems to me to be very sound and likely to give valuable results.

The Mycologist is studying certain specific diseases : collar rot of apples, etc.

The horticultural experiments include search for suitable apple stocks, methods of propagation and management, pruning, mulching, etc.

As far as it is possible to judge from the reports the lines of work seem to be satisfactory.

Light traps.—An experiment with light traps made at Ramgarh in 1932 was unsuccessful ; out of 224 adults attracted to light only 14 were females, the rest being males. This is a common occurrence. Dr. C. B. Williams at Rothamsted has, however, recently found that for certain moths in England the proportions of males and females captured depends on the height