supernatant liquid is again drained off. This process of washing and draining off continues until the starch is fairly white and much of the astringent and bitter taste of the same is lost and then it is allowed to dry in the sun. The dried stuff cracks well and crumbles into small pieces. The stuff is marketed as such in the local shandies. Merchants from Salur attend these shandies and buy it in the season @ 10 to 12 (addas) measures per Rupee and sell the same in the local market at 5 to 6 measures a Rupee. Much of it is exported to Vizianagaram and Vizagapatam markets as well. This is usually adulterated locally with rice starch or maize flour (Maida). These latter are mixed with water to make a thick paste and dried in the sun and broken to pieces to resemble the pure Palagunda. But experienced merchants can find out the difference between the adulterated and pure stuff, by the characterestic flavour of the latter. Palagunda also comes to the market from the Raipur side and this too is invariably adulterated as stated above.

While digging out the rhizomes, a few are left in the soil at each clump, for the next season's growth. With the advent of the monsoon, the crop grows luxuriantly and is again harvested in the months of January & February as stated above. No attempts at manuring the crop or any other cultural operations are made. Under proper cultural practices this should form a paying cottage industry and it is worth while trying to grow it in the plains where conditions permit. Improvements can also be suggested in the matter of preparation of the produce for the market. Instead of rubbing the rhizomes on stones they can be pounded in wooden or stone mortars and the pulp washed in water and filtered, and, the filtered stuff prepared for the market as usual.

SELECTED ARTILCE

Science and the Indian Peasant.

By SIR E. J. RUSSELL, D. Sc., F. R. S.

Director of the Rothamsted Experimental Station.

The main facts of the agricultural situation in India so far as the peasant is concerned are set out in Table I. From this it appears that the population is increasing more than the area of land sown to crops; and, further, there is an increasing tendency to grow more saleable crops and less food crops, i. e., to get money rather than food out of the land.

TABLE I. Areas of Land Cultivated, and Utilisation per Head of Population, British India.

	Area in million acres.				
	1915—16 to 1919—20	1920—21 to 1924—25	1925—26 to 1929—30	1930—31 to 1934—35	1936—37 to Provisional.
Net area sown	220·7	222·0	226·4	229·1	231·9
Irrigated area	47·4	47·0	47·9	49·9	51·7
Food crops	210·6	209·5	208·7	214·7	216·7
Non-food crops	42 6	43·8	49 4	47·6	50·8
Fallow	54·2	51·1	49·6	49 8	48·6

Areas per head of population.	1903—04 to 1907—08	1908—09 to 1912—13	1913—14 to 1917—18	1918—19 to 1922—23	1923—24 to 1927—28	1928—29 to 1932—33
Net area sown	0·883	0·906	0·918	0 879	0 868	0·841
Food crops	0·829	0·862	0 879	0·833	0·803	0·785
food crops omitting sugar	0·818	0·852	0 862	0 822	0·792	0 774
Non-food crops	0·053	0·043	0·045	0·045	0 065	0·057
Population in Millions	273·6	243 8	245·3	246·9	259·2	271·5

The total of Food and Non-food crops exceeds the net area sown because some of the land is sown twice in the year.

On an average only 84 acres of land are used to produce the food of 100 heads of population, and in some of the more densely populated provinces only 66 acres, as compared with the 220 acres needed to feed 100 heads of population in Great Britain. Here, however, we need so much land because we eat so much meat : a vegetarian diet requires much less land and in consequence the diet in India is very largely vegetarian. Rice is by far the commonest foodstuff ; then come the millets; and finally, a long way behind, comes wheat which is further distinct in being confined to Northern India. The areas for the five-year period 1930—35 were, in million acres :—

Million acres : British India.*

Rice	80·4
Millets	39 2
Wheat	25·7

The grain crops for human food thus form about 77 per cent. of the total sown area. Fruits and vegetables occupy about 2 per cent of the area sown, sugar 1·4 per cent. and other miscellaneous foods bring the total up to 82 per cent., while the remaining 18 per cent. includes 4 per cent. fodder crops, and 14 per cent of oil seeds, fibres and a few others. The comparison with English agriculture is very striking, grain crops occupy only about 7 per cent. of the cultivated area in England and Wales ; on the other hand fodder crops for animals which form only 4 per cent. of the cultivated area in India constitute some 25 per cent in England and Wales, to say nothing of all our grass land, which adds another 60 per cent., making a total of 85 per cent. of cultivated land devoted to the production of animal food.

A remarkable feature of Indian agriculture is that the area under food crops per head of population has been falling ever since the period 1913-18, when it stood at 0·87 acres, a figure to which it had been steadily rising for at least ten years ; it was in 1928-33 only 0 78 acres, a figure lower than in any of the five preceding five year periods. On the other hand, the area under non-food crops, i. e., cash crops and others, has steadily risen as the food area has fallen, and in the 1928-33 period stood at 0·57 acres per head against only 0·45 acre per head during the 1913-18 period. Three possibilities present themselves. Yields of food crops may have risen, so that the total production of food is at least as great as ever; or the money from the cash crops may be used for buying food, thus possibly adding variety to the diet ; or the peasant may be getting less food than he was during the 1913-18 period. It is difficult to decide between these possibilities. Agricultural statistics in almost all countries are subject to error, especially statistics for yields. In large parts of India even the acreage figures are uncertain and figures for yield still more so shall not attempt to discuss whether yields have gone up or down, or whether the total human food

*Provisional figures for 36-37 are Rice 81·7, Millets 39 0, wheat 25·2.

production per head is better or worse than in 1913-18. The more important question is whether the present food production per head is adequate, and, if not in what directions it needs improving, and how this can be done.

The question of adequacy of diet is one for medical authority and not for an agriculturist. The present Viceroy is deeply concerned with the welfare of the peasant and is encouraging full investigations into this question. A Human Nutrition Research Institute has been set up at Coonoor in the Nilgiris under the very able direction of Dr. W. R. Aykroyd, and he has provisionally suggested as the average daily requirement of a man in India, 2,600 calories, 65 grams of protein (10·4 grams of nitrogen), 45-60 grams of fat, 20 mgs. iron 0·6 gram calcium and 1 gram of phosphorus. The uncertainty about the average yields per acre makes it impossible to estimate accurately the total quantities of food produced in India, but from a number of sample enquiries it is reasonable to think that the total production satisfies both the total calorie and the total nitrogen requirements, though with little margin of safety. Dr. Aykroyd, however, emphasises the importance of biological value of proteins as well as nitrogen content, and shows that animal proteins are biologically more efficient than vegetable proteins; he suggests that they should form at least one-fifth of the total protein in the diet. Milk, even skim milk, he points out, is the best for growing children, but eggs, fish and meat are all good sources.

These foods are almost certainly consumed in inadequate quantities. More serious is the lack of vitamins, especially of A and B; this is confirmed by the prevalence of the deficiency diseases caused thereby; Keratomalacia caused by deficiency of vitamin A; stomatitis due to deficiency of Vitamin B, and low haemoglobin content of the blood due to iron deficiency. The agricultural problem is thus threefold: (1) to increase the total production of foods so as to widen the margin of safety; (2) to increase the production of milk and other animal products so as to improve the biological value of the proteins; (3) to increase the supply of vitamins, of calcium, phosphorus, and other mineral substances.

So far we have been dealing only with averages over the whole country. But India is very vast, and it comprises many widely different regions and groups of people, and it would not be easy to ensure that every part and every class should be self-sufficing in the matter of food production. There must always be exchange between one place and another and hence it is important to increase the value of the cash crops so that the peasant may have the necessary money to buy the things he is not himself producing. This then gives the agriculturist his fourth task: to raise the value of the cash crops; which means improving both their quantity and quality.

These tasks may be achieved in two ways: by increasing the area of cultivable land or raising its level of output; and by improving the crops. Both methods are being adopted. There is still a considerable area of land in British India not yet cultivated, but a large part of this could be cultivated only with difficulty: –

Utilisation of land area, 1935-36, British India.

	Million acres.
Net area sown	228·7*
Culturable waste, other than fallow ...	153·1
Area uncultivable	146·0
Forest	89·8

The more hopeful method is to improve land already in cultivation so as to increase the yields and to widen the scope of cropping. The most efficient method of doing this is, in general, to irrigate it, for of all causes of infertility in India, shortage of water is the most widespread and serious.

* Not including 51, 399, 765 of fallow

Irrigation is done in three ways: (1) by wells, (2) from tank, (3) from dammed up rivers, by means of canals. Nearly a quarter of the sown area in British India is irrigated, and of this about half is watered by canals and about a quarter by wells :—

British India.	Million acres. 1934-35	1936—37.
Irrigated by-Canals	26	
Wells	12·5	Provisinal.
Tanks and other methods ...	12	
Total	50·5	
Total area sown...	227	
Percentage irrigated	22	

All these methods of irrigation are ancient but the old method of irrigation from wells, when the lifting is done by bullocks, leaves perhaps the most abiding memory of Indian village life on one's mind. The monotonous journeying to and fro; the creaking of the windlass; the swishing sound of the water as it is discharged from the bag or bucket; these things one can never forget. The most striking contribution of science to well-irrigation has been the development of tube wells carried out to a notable extent in the Punjab and adjacent regions, where the subsoil carries plenty of water. This method has been well developed by Sir William Stampe and in places is combined with washing and bathing facilities, so that the well really becomes a centre of life for the inhabitants. Tube well irrigation is largely used for sugarcane and other valuable crops.

Irrigation from canals has been greatly developed under British rule, and indeed if the British connection with India had done nothing else, it would deserve to be remembered always for the enormous dams and irrigation systems we have set up, in order to ensure the maximum of beneficial use of the water that flows down from the Himalayas and other mountains, and might, if left alone, do great harm or at best only run to waste. I need mention only one: the great irrigation system in Sind, in which the waters of the Indus are distributed over a vast area of what would otherwise be of low productivity or even desert, converting it into fruitful land. The opening of the great Lloyd Barrage in 1932 had already brought into cultivation some 600,000 acres of land by 1935—36, besides adding greatly to the areas under cotton and wheat :—

TABLE 2. Cropping in Sind before and after the setting up of the Lloyd Barrage in 1932.

Crop	Acreage in thousands.			Production. tons in thousands		
	1913—14 1917—18	1923—24 1927—28	1933—34 1935—36	1913—14 1917—18	1923—24 1927—28	1933—34 1935—36
Cotton	264	339	649	...	...	...
Wheat	594	441	1,157	237	93	278
Rice	1,166	1,148	1,097	399	455	403
Juar*	617	549	466	187	118	103
Bajri†	679	1,064	854	164	150	99
All grain crops except wheat	3,188	3,276	2,921	814	807	669
Fruit and vegetable	44	46	49	...	...	...
Oil seeds	404	299	194	...	...	...
All crops	4,609	4.554	5,141	...	...	...

* Chiefly in Upper Sind.

† Chiefly in Middle and Lower Sind.

‡ Two years only 1934/35.

The production of cotton and of wheat has greatly increased: that of rice shows little change, but the millets and other grain crops have fallen off considerably, so that the total production of grain is less than it was. Nevertheless the cash value of the produce has much increased.

The setting up of an irrigation system is a task for the engineer, but when he has finished and retired with honours, the difficulties of the agriculturist begin. First is the question of seepage water. The canals are rarely watertight; they let the water ooze out and waterlog the adjacent soil. Many acres of agricultural land have been ruined in Sind, and whole villages have suffered subsidence. Then, there is the question of salt. Sooner or later salt nearly always appears in irrigated regions. It comes up from some lower layer of the soil where perhaps it had done no harm to the crops; it reaches the surface and spreads, killing every useful plant it touches. Both sets of problems are difficult and require for their study, a good deal more fundamental investigation than they are getting. Other problems are more definitely agronomical: such as the choice of suitable systems of cropping and varieties of crops; methods of manuring; optimum quantities of water and times of application.

But all these problems are difficult, and require the services of an exceptionally competent staff. Such men are rare, and they cannot be produced by mere training. Men not up to the necessary high standard may involve the cultivators in serious loss and do irreparable damage to the whole irrigation system. These irrigated regions properly managed are a great triumph for human enterprise but there lie always within them the seeds of great tragedy.

The Punjab Irrigation Research Institute at Lahore is doing some very good work under Dr. E. McKenzie Taylor.

In regions where irrigation is impossible, but where crops usually suffer from drought, it is frequently possible to adopt special devices for making the most of the water that actually reaches the soil. These include the setting up of bunds and various cultivation devices grouped under the general name "Dry farming methods". They have been effectively studied in the Bombay Deccan.

The improvement of crop yields is effected by finding or breeding better varieties than those in common use, and by raising the level of production by better cultivation, more efficient manuring and management, and by better control of pests and diseases. I shall deal with the chief crops important to the peasant.

Rice is by far the most important crop in British India occupying 84 million acres out of the 215 million acres devoted to food crops. An enormous number of varieties occur in India of widely different types, some of them of great scientific interest, and much work has been done in classifying them, in selecting the more promising, and in breeding new sorts. The foundations were laid by G. P. Hector in Bengal and F. R. Parnell in Madras, and much subsequent work has been done by K. Ramiah at Coimbatore, and others. Rice is peculiar among grain crops in that many of its varieties are semi-aquatic and others entirely aquatic in their habit of growth, and this, of course, means that their manuring and cultivation are on quite unusual lines. The scientific problems associated with the growth of rice are thus of exceptional interest. They are also, however, very difficult, and the experiments have often to be carried out under very trying conditions; they involve puddling about during the hottest part of the day in gum boots in a muddy swamp infested with leeches and snakes, and made more disagreeable by mosquitoes and other insects. In spite of all this, a great number of investigations have been made, and a considerable acreage—3·6 million acres out of 84·3 million or 4·3 per cent of the total area is now sown with improved varieties. It cannot be confidently asserted however, that there is any increase in the amount of rice produced; apparently, the acreage has somewhat decreased, and it is sometimes stated, though on no good evidence, that the yields have actually not yet come to full fruition.

The *Millets* come next in importance to rice; many different sorts are grown, the commonest being Juar (*Andropogon sorghum*), Bajri (*Pennisetum typhoideum*) and Ragi (*Eleusine coracana*) : the acreages are :—

	Million acres 1936-37.		
	British India.	Indian States.	All India.
Juar	23·1	13·0	36·1
Bajri	11·1	4·0	15·1
Ragi	3·7	2·8	6·5
Total ...	37·9	19·8	57·7

The millets differ fundamentally from rice in that they are dry-land crops and may receive no water except what the rain brings, though of course, if irrigation water is available it is given. They are sown just about the time the monsoon breaks so that they may obtain all the rain that comes, and they are indeed the chief crops in the non-irrigated and dry farmed regions. This great contrast with rice, explains why the two crops so often appear as complementary where the acreage of one is high, the acreage of the other is low, and *vice versa*.

Until recent years, there has been little scientific work done on the millets in India, but investigations have been started at Coimbatore, at Indore and also in connection with various dry-farming schemes. A few improved varieties have been found, but they have not spread, and the peasant has as yet derived but little benefit from the labours of the scientist.

Wheat. In regard to wheat, however, the story is quite different. Here, however, the problem was different. When the British scientific workers started investigations on wheat, their purpose was to select varieties suitable for the British market, so that the export trade might be improved. The Howards were the founders of the modern work on wheat in India. David Milne studied the Punjab wheats and other workers have followed; their efforts have been so successful that some 20 per cent. of the wheat area in 1934-35 was sown with improved varieties. The word "improved," however, needs some explanation. Quality in crops is an ambiguous term: the layman often thinks it means high nutritive value; actually it generally means commercial desirability, which in the case of wheat is suitability for the English miller who will use it for blending and is not concerned with its nutritive value. In so far as Indian wheat is intended for the British market, this is obviously the standard to take. But the consumption of wheat in India is increasing, and it is estimated that some 45 per cent of the total Indian production is now consumed in the villages. In view of this changing market, obviously Indian requirements in India the wheat is not made into loaves, but into chappatties, something entirely different. It might be urged that India cannot spare grain for export, but against this, is the cogent argument that an export trade in good years affords a sure guarantee against famine in bad years. I shall not argue this question of policy, but only point out the desirability of discovering the properties needed for the making of good chappattis, and if necessary, producing and cultivating varieties of wheats possessing them.

Special reference should be made to the work on rust now being done in Northern India by K. C. Mehta.

Barley. This crop, like wheat, is of importance only in parts of Northern India; it occupies only about 6½ million acres in all British India, most of which (4·17 million acres) comes in the United Provinces. Of the rest 1·2 million acres are grown in Bihar and Orissa and 0·6 million acres in the Punjab. The barleys are of the 6—rowed type, and as these are used by English brewers, efforts have been made to breed barleys suitable for the English market. These have met with considerable success, and the Experiment Stations have sent over to this country samples which have been favourably reported on by the expert Committee of the Institute of Brewing. As in the case of wheat, however, large-scale industry has not kept pace with the plant breeder or selector and the commercial lots coming to this country fall far below the quality of the plant-breeders' samples.

We now turn to the cash crops. The two most important are cotton and sugar, but I shall confine myself to sugar partly for considerations of time, but chiefly because I studied it in more detail during my Indian journey. India is the second largest consumer of sugar in the world; the first is the United States, which in 1934—35 consumed 5·87 million metric tons; the third is the United Kingdom with a consumption of 2·28 million metric tons; while India comes in between.with a consumption of 3·35 million metric tons. An assured and abundant supply of sugar is essential to India's happiness. Some 80 per cent of the sugar is eaten as gur, or Jaggery as it is called in the south; this is the yellowish or brown mass produced on evaporating the juice of the sugarcane in an open pan; there is a certain amount of clarification. Gur has always been made in India. But about a million tons of white sugar a year are consumed also, and much of this till recently was imported. Now, however, it is practically all made in India. The production of sugar is shown in Table 3:

TABLE 3. Sugarcane crop. Acreage and Production.

Province and States	Area (in thousand acres) 1935—36	Area: Average of five years 1930—1 to 1934—5	Yield (in thousand tons of raw sugar (gur)) 1935—36	Yield: Average of five years 1930—1 to 1934—5
United Province (including Rampur states)	2 249	1,597	3.336	2,063
Punjab...	473	446	358	336
Bihar	465	313	668	371
Bengal	325	224	560	330
Madras	131	114	360	322
Bombay (including Sind and Indian States)	121	99	313	256
North-west Frontier Province ...	58	49	63	55
Mysore	50	38	53	36
Hyderabad ...	59	38	99	60
	3,931	2,918	5,810	3829

*From Department of Commercial Intelligence and Statistics, in India Trade Journal Supplement, May 21st 1936.

The figures were still higher in 1936—37 though they appear to have fallen in 1938—39. The establishment of sugar production in India on so firm a basis is the direct result of the breeding experiments started by Dr. Barber, and especially his happy crossing of *Saccharum spontaneum* with the sugarcane, which yielded new varieties of great vigour and power of growth. This work has been ably continued by Rao Bahadur Venkataraman and in consequence, India is now provided with a number of varieties suited to the various regions. These new sorts have almost ousted the old ones; some 80 per cent. of the area planted with sugarcane is under new varieties. Notable advances were made in the cultivation methods by G. Clarke at Shahjahanpur (1912—1930). Much of the success of the sugar industry is due to the improvements effected by technical chemists and engineers in the factories under the stimulating influence of Sir Harcourt Butler, and there is still scope for further efforts.

Fruit and Vegetables. I have spoken earlier on the shortage of vitamins in the ordinary diet of the peasant. An obvious remedy is an increase in the consumption of fruit and vegetables. A wide range of fruits can be grown in India; ordinary European fruits in the hills of the north and tropical fruits in the plains. Much work is now being done on the subject, though it is not clear that the area under these crops has yet increased. No area figures are available, but it is estimated that about 2½ million acres are devoted to fruit.

Milk and livestock. There is a fair consumption of milk in parts of the Punjab and some of the hill districts, but in general, the consumption is far too small. It is stated that the average daily ration of milk in the Punjab is 10 oz. while in Bengal, Madras and the Central Province it is only 2 oz. or less. This is bound up with the general livestock problem which in India is very difficult and is complicated by the fact that the Hindus regard the cows as a sacred animal and refuse to kill ineffective animals; in consequence the meagre supply of animal food has to be spread over a large animal population, many of which give no adequate return.

Dr. Norman Wright recently reported on this milk question so that it is unnecessary for me to discuss it. Scientific work on the subject is being done, subject to the limitations inherent in the problem. One hopeful line is the improvement of the grazing lands in the forest areas as this deals also with another difficult problem, soil erosion, which, however, lies outside the scope of this lecture.

The effect of the improvements resulting from scientific investigations. Table 4 shows the approximate areas sown with improved varieties. The greatest success has been with sugarcane. But wheat and rice represent a considerable achievement in view of the large acreage involved. It must be remembered that there is no honest seed trade in India which can take over the multiplication and distribution of improved varieties of crops. as is done in Great Britain; all this in India must be done by the overworked officials of the Department.

Time does not permit any description of the advances made by scientific, workers in knowledge of the fertilizer requirements of crops, or in methods of cultivation but these have been considerable. Under the Imperial Council of Agricultural Research, further great improvements may confidently be expected.

The full result of the scientific work, however, is not shown in this Table but rather in the high levels of yield and quality obtained at the experiment stations. These are not infrequently double or treble the yields obtained by the peasants. The great problem in Indian agriculture is not so much to acquire new knowledge as to bridge this gap between peasant practice and experiment station achievements.

The Causes of Frustration of Agricultural Science in India. There are several reasons for this wide gap, but in my view the two most potent are the poverty of the peasants and the lack of an educated agricultural middle-class.

There are, of course, many zamindars and other landlords and farmers who take a direct interest in their land and their people, and who do much to raise the standard of farming. But they are exceptional, and broadly speaking there is a serious lack of leaders in the agricultural community to take over agricultural improvements from the experiment stations and put them into practical form modified to suit the local conditions. The educational system has not produced this type of man and although there are agricultural colleges, the students only rarely take up farming.

TABLE 4. Approximate proportion of area sown with improved seed.

Crop.	Total acreage.	Acreage under improved seed.	Percentage.
	Million acres.	Million acres.	
Sugarcane	4·10	3·27	81·7
Jute	2.18	1·3	58·6
Wheat	33·61	8·5	25·3
Cotton	26·00	5·04	19·20
Rice	83·43	4·58	5·5
Groundnuts	5·86	0·22	3·40
Millets	38·69 *	0 34 ‡	Not calculated as figures
Gram	16·90	0·33 ‡	are incomplete

*Including Jawar, Bajra and Ragi only.

‡ Not separately reported by some provinces.

In their defence it must be said that the acquisition of agricultural land by an outsider is often difficult, and the villages are singularly unattractive places in which to live. Poverty, dirt and disease are still rife in spite of years of effort to get rid of them. But at last the efforts are beginning to tell; a widespread movement for improving village life is being fostered, not only by the British but also by the best of the Indians themselves, and is spreading over the country. Already many of the villages have been cleaned up; wells have been walled in; the streets freed from garbage and other refuse which is now used to make compost heaps; mango trees have been planted and the roads improved. We can only hope that, when the villages become fit for educated people to live in, they will go and live there. Already a beginning has been made in the Punjab for example, steps have been taken to settle graduates on the land and some 8,900 acres of land have been colonised by 162 educated young men, of whom 89 comprise the entire cultivating population of four villages and the remainder are scattered in pairs, over villages where it is hoped they may exert a profound influence for good. But in the meantime, many of the agriculturists are too poor to be able to undertake any but the simplest changes. Many of the peasants are very shrewd, with a considerable knowledge of their soils and crops. But they are hampered by ineffective cattle and implements, by lack of manures and by lack of money. Special methods are needed for passing the knowledge gained at the experiment stations over to the peasant and showing him how to use it in his daily work so as to reduce the poverty which at present so much hampers progress. What India needs now is not so much new scientific knowledge about general agriculture, but fuller use of existing knowledge and the working out of methods to reduce the present wide gap between the ordinary cultivator and the experimental farm. Fortunately all parties seem to have agreed on the vital necessity of improving the lot of the peasant, and we can look forward with confidence to the result of the many beneficent agencies working to this end. (*Journal of the Royal Society of Arts*, No. 4512 May 1939).