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1920

Agricultural Research Institute, Pusa

Notes on Practical Salt Land Reclamation

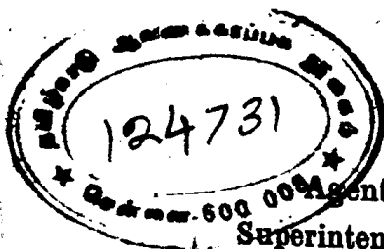
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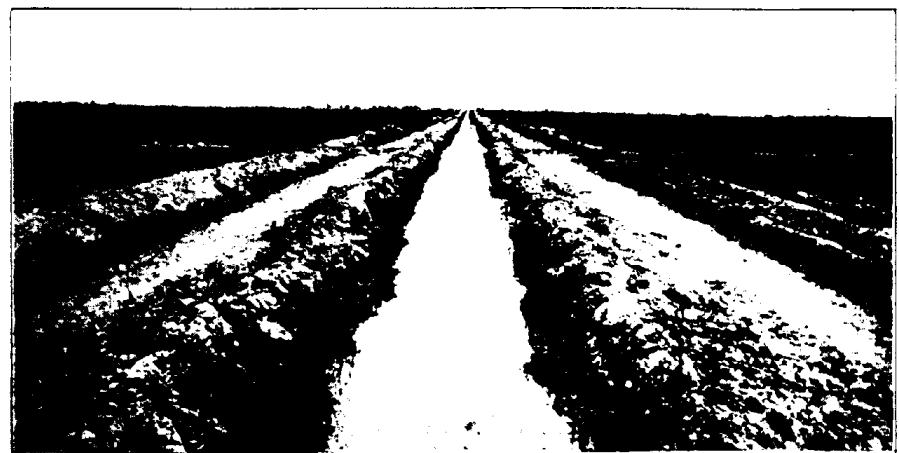
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VIEWS ON THE RECLAMATION STATION, DAULATPUR, SINDH.

Notes on Practical Salt Land Reclamation.

[Received for publication on 21st May, 1919.]

CHAPTER I.

Alkali Land Reclamation.

THE question of alkali, *kalar*, *reh* or *usar* land has received a certain amount of attention in India from agricultural and irrigation authorities, but the subject is bound to force itself into greater prominence as modern perennial irrigation works extend.

Alkali land is so called when it contains a greater or less amount of water-soluble mineral salts which exert a harmful influence on vegetation. The question is often bound up with water-logging and leakage from irrigation canals.

Arid land all the world over, on which the annual rainfall is not sufficient to leach the soluble salt out of the surface soil, suffers from damage due to alkali.

The alkali damage is frequently not visible for some years after the opening of a new canal system, and then the water or want of silt is blamed.

While the chemical aspect of reclamation is of great importance, the practical technique is of still greater importance. This is frequently lost sight of in India, and where alkali problems crop up it is a mistake to consider that these can be solved solely by laboratory findings.

A brief survey of practical reclamation work in Egypt and India should be of value in order to give a definite idea of the most promising lines of work.

Without a soil survey it is impossible to state what area of land is affected in India. Sind is, however, probably in worse case than any other part of India, having an average annual rainfall of under 10 inches. In the Punjab the damage caused by alkali conditions is probably less and still less in the United Provinces.

CHAPTER II.*

Alkali Conditions in Sind.

In arid America, field parties of the Bureau of Soils have mapped the soil and studied the alkali conditions of a number of typical irrigated districts covering over 3,000,000 acres of land. They have found that on the average about 13 per cent. of the irrigated lands examined contain alkali in sufficient quantities to be either harmful to the growth of crops or to prevent entirely profitable cultivation. Sind has 30,000,000 acres, half of which are scheduled as cultivable and 4,000,000 are cultivated annually under irrigation. It is not possible to say what the per cent. is in Sind of alkali or *kalar* land without a proper soil survey, but it would probably be found not to be under the above percentage.

In 1916 the Government of India called for report from experienced local irrigation and revenue officers regarding the prevalence of *kalar* or alkali in Sind, and the following is a resumé of their opinions :—

Mr. H. C. Mules, Collector of Karachi :—

“In former days grants of *kalar* land were made on very easy terms with a view to their reclamation. They were thoroughly washed, i.e., flooded, and the water held on them by ‘bund’ for a year or two, then rice was grown. The finest rice lands in Sind, producing a quality of rice known far beyond the boundaries of the province, are known as the ‘mail’ in the Larkana District, near Goharo. These lands were formerly rank bad *kalar*. Some very bad *kalar* lands were granted many years ago on a reclamation lease to the late Seth Ramchand of Khorewah, a very enterprising zemindar who in course of time obtained excellent results. There are concrete instances but the same kind of thing is going on all over the country on varying scale.

“A very striking instance of the movement of subsoil salt induced by the action of irrigation channels or floods is to be seen at Jacobabad. For one who remembers Jacobabad in the early seventies the change is very remarkable. Then the land in cantonments was sweet, the wells were sweet and the water good, the gardens were remarkable for their luxuriant growth and the vegetables raised therein were every bit as good as the best English vegetables. Now the whole place is salt, the wells are many of them useless, and the gardens have died away. But you have only to ride beyond the limits from which floods were excluded to find the lands which were flooded, washed and subsequently irrigated,

* This chapter is reproduced from the *Bombay Department of Agriculture Bull.* No. 64 of 1914.

bearing splendid crops. And I may say that hundreds of villages have been similarly affected. It is quite common to find the village site rank *kalar* and the surrounding fields sweet and productive.

“It will, I think, be found that the way to eradicate salts is to wash them out. Wherever there is good head of water and a reliable supply this is possible. But, of course, it is essential to drain off the water used for the washing; take the instance of ‘puncho’ water. It is by no means uncommon to hear officers speak of this system of passing off water after it has stood on the rice for a little while as a waste of water. It is not so; the cultivators know perfectly well that the water gets sour and must be passed away before it becomes so and injures the crop. Therefore depressions and low grounds are used for the reception of ‘puncho pani’, and the crops receive constant fresh supplies. In the same way it is necessary to pass away and renew water used for washing the land.”

Mr. G. E. Chatfield, Colonization Officer, Jamrao Canal :—

“Salt or *kalar* land is to be found in the Jamrao tract, as in the rest of Sind, in large quantities. The salts are of different kinds and have different effects, some being almost harmless and others noxious to cultivation, some easily soluble in water and others not so. Native cultivators call them by different names (‘white,’ ‘red,’ ‘black’ *kalar*) and have hazy knowledge of their effects.

“In the Jamrao tract there are large stretches of *kalar* lands, which are regarded as uncultivable. Much of this land would be cultivated were it ‘flow’, but owing to the tendency of *kalar* to seek the highest lands such large *kalar* patches are usually ‘lift.’ Besides these, there are small sporadic patches of *kalar* scattered over the whole tract, so closely that scarcely any village, however excellent the soil, is without them. From a comparison of the land which is under perennial irrigation with the surrounding land, I should say that these patches had always been there and that irrigation is not responsible for the appearance, though it increases their size. It is difficult to observe sporadic patches of this kind, but from the general complaints of cultivators as well as from what I have actually observed in certain parts of the tract (e.g., near Mirpurkhas and in Dehs 87, 88, 89), it seems that in many places *kalar* is spreading with irrigation (percolation, on the other hand, brings up *kalar* where none was previously found, and the land on either side of the canal minor and water course is almost invariably rank *kalar* for a considerable distance). Against this I must add that in many villages the *kalar* is certainly being washed down out of the soil by means of irrigation.

“In comparing Jamrao lands with those on inundation canals it must be remembered that the latter are generally lift lands or rice lands ;

For when the Sindhi can get flow he will generally grow rice. In rice lands *kalar* is a matter of small importance, and in lift villages the water is generally sufficient for a mere fraction of the whole area, which fact enables the zemindar to pick and choose his land. Villages on the Central Hyderabad canals contain many waste numbers which are not taken up on account of *kalar* but which would be taken up were these villages brought upon the Jamrao canal.

"About the causes of the appearance of *kalar* I have little to add. In lands which have never been under irrigation it is nearly always present, though in varying quantities, and with irrigation it sometimes increases and sometimes decreases according to the nature of the sub-soil. The only remedy known in Sind is to wash down salt into the subsoil with heavy waterings. For this purpose it is usual to start with some crop which can stand a certain amount of *kalar*. The crop which is preferred is rice; some of the inferior millets (*e.g.*, *sao* *), wheat and *jambho* † are also grown in such cases.

"I cannot record any very brilliant successes in the reclamation of land on the Jamrao, though some lands have undoubtedly been improved by cultivation in Digri and Jamesabad.

"Rice is undoubtedly well suited to *kalar* lands and the heavy flooding which it requires improves the land immensely. This crop is forbidden in the Jamrao and could not be permitted without a great loss of revenue. Neither is it a remedy suited otherwise to the tract; for while heavy flooding sweetens the land flooded it causes the salt to rise in the adjacent lands. Moreover, the worse stretches of *kalar* are usually too high for flow irrigation.

"In rice districts, such as the south of Hyderabad, of which I had formerly charge, it is only the worse kind of *kalar* which is regarded as uncultivable. But where much salt was present in the soil it was found necessary to change the water very frequently. This was effected by letting out the water from the cultivation into the ditches and depressions which surrounded the fields; unless this was done frequently the crop was believed to suffer.

"Much land on the Jamrao is undoubtedly deteriorating under irrigation and becoming *kalar*. Much land has not been taken up because it contains *kalar*. Much that has been taken up is not paying for the same reason. The recent rise of cultivation on the Jamrao is chiefly due to the giving out of fresh lands in 1905, and in any case would scarcely affect the question."

* *Panicum Crus-galli*.

† *Brucra sativa*.

Mr. G. McC. Harrison, Superintending Engineer, Indus Left Bank Division :—

"There appear to be three kinds of alkali known in Sind :—

"I. *Rapri kalar*, or chloride of sodium, from which salt was manufactured before for use in Sind. Oil-seeds will grow on lands infiltrated by this kind of alkali.

"II. *Bhanothi kalar*. This is generally found where old village sites once stood, or where leaves and other debris decay. This is probably sulphate of sodium from which Glauber's salt was once manufactured near Sehwan old fort. Such *kalar* is collected and used as manure for crops. Its area is insignificant.

"III. *Dudh kalar*, or carbonate of sodium, is seen in arid high level lands. Rice can be grown on these lands if there is plenty of water."

It would undoubtedly be of the greatest use if an alkali map of Sind were prepared. In the tract of the proposed Rohri-Hyderabad canal such a map will be extremely useful; here there are no doubt isolated portions of land which owing to alkali are useless for any or only rice cultivation. In such portions minor canals or distributaries could be left out altogether or designed for rice cultivation.

Mr. F. St. J. Gebbie, Executive Engineer, Jamrao Canal :—

"For some years past there have been vague complaints that owing to the evil qualities of the Jamrao water all the land is turning to *kalar*. I have asked many zemindars to show me land which, before the Jamrao was constructed, had no *kalar* in it and which has now become unculturable, but no one has yet done so.

"It is true that there is now a much larger area of *kalar* land in the Jamrao tract than there was before the canal was constructed; but that is due to the large area of what was formerly waste and is now being cultivated. A good deal of this waste land was *kalar*, but the *kalar* did not become visible till it was irrigated.

"I know of no remedy for *kalar* except careful cultivation and manuring. I have heard a great deal of growing rice to wash out the *kalar* but I have still to see a case in which this has been done and any other crop except rice grown on the land afterwards. The Sindhi in these parts is a great believer in this system; but it seems to me he makes such a strong point of it rather to try and get permission to grow rice than with any idea of really washing the *kalar* out of the land. All Sindhis are anxious to grow rice because it suits their lazy slipshod methods of cultivation.

"Provided that the people are satisfied with the supply of water as fixed by Government, *viz.*, one cusec for every 300 gross acres, there is no objection to allowing them to grow rice on the Jamrao; but they

will not be satisfied with this. They say that rice wants a constant supply and they cannot be given this under existing conditions. With the outlets and water courses as they are, the only efficient method of distributing water fairly to every one in a village is by 'share lists' as is done in the Punjab. But if any man is to get water constantly a share list cannot be prepared and he must get water at the expense of other cultivators in the village.

"Since the Jamrao was constructed about 57 per cent. of the cultivable area of village No. 18 has been cultivated annually and practically all by flow; but no *kalar* has appeared because there never was any in the soil. On the other hand, village No. 38, in which about 20 per cent. area is cultivated all on lift, is beginning to show *kalar* in many places."

In summing up the Commissioner in Sind stated:—

"The reports submitted scarcely give an adequate idea of its extensive prevalence throughout the province, owing to the non-existence of any statistics on the subject. Even materials for a rough estimate of any degree of reliability are not available. It is hardly possible to say more than that the occurrence of saline area, in every gradation from isolated patches to continuous barren tract many miles in extent, is one of the most familiar features in Sind; and the gravity of the evil is to be measured, not only by the diminution in the cultivated area and the injury to crops occasioned in localities where attempts are being made to control it, but also the permanent exclusion from cultivation of large areas of otherwise valuable lands."

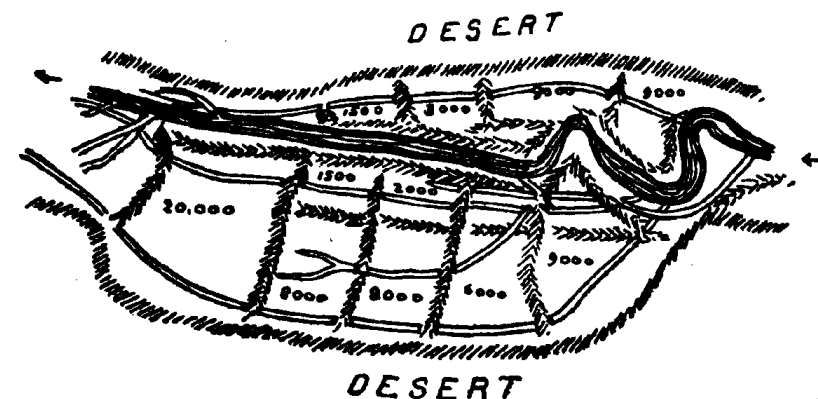
CHAPTER III.

Reclamation Work in Egypt.

Egypt with a cultivated area of about 6 million acres and with a population the density of which is one per acre, is only a fraction of the size of an Indian province. As the land is very productive, the agriculture and irrigation afford most useful study for the irrigated portions of North-Western India.

Formerly only the basin system of irrigation was practised in Egypt. This method consists of flooding the land in the basins to a depth of several feet at High Nile about the second week in August, and then when the river level sinks in October in letting the water back into the river.

The plan shows clearly a system of basins with the channels to fill and empty and the 'bunda' necessary. When the water is emptied the greatest care is used to prevent too rapid an escape which would scour out the new silt deposited.



A system of basins in Upper Egypt.

The figures show the area in acres of the different fields composing the system.

With the basin system only one crop can be taken per year and cotton cultivation is not possible. When the basin system was practised there was no damage from alkali. The large amounts of water used washed the salts well down into the subsoil.

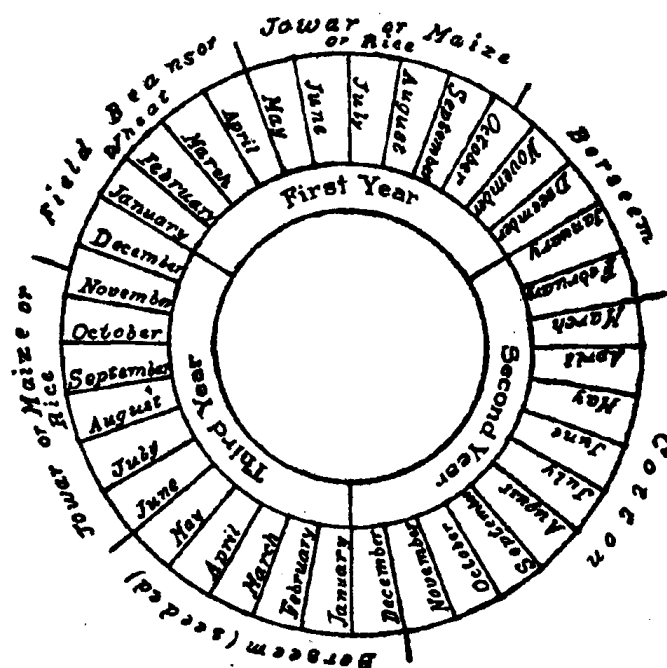
Damage from alkali began to be felt when perennial irrigation canals were substituted for the basins, but as a rule this was chiefly experienced in the low lands in the north along the borders of the Mediterranean. Land which is under the 6-foot contour line is apt to show signs of salt more especially along the large drains which run full at the time of high river. The northern land gradually tails into the great lakes, Lake Edkou, Lake Burlos and Lake Menzaleh, which lie between Alexandria and Port Said. These lakes communicate with the sea and the bordering land gets flooded with sea water especially during northerly winds.

Lake Aboukir, one of the smallest of these lakes, has been reclaimed and as most of the reclamation work in Egypt is similar in character, a study of the history and methods of the work is of interest.

The other lakes represent an area of over a million acres. When this area is taken in hand after provision is made for the necessary irrigation water by works in the upper sources of the Nile, a tract of excellent cotton and general agricultural land will become productive. This work would be an excellent field for the new Empire Development Board. The agricultural population of Egypt would rapidly take up the land when in a fit state at very remunerative prices. There is no harder working and painstaking agriculturist than the Egyptian "Fellah" when he is working on his own land and for himself.

The high production of agricultural land in Egypt is remarkable, crop succeeds crop and there are no fallows. Yields of seed cotton of 2,000 lb. per acre are nothing remarkable. A rough method of estimating the return of agricultural land used to be to multiply the average yield of the land in 'kantars' (say 315 lb.) of seed cotton by £15. There is land averaging up to 10 kantars which thus would be worth £150 per acre.

An example of cropping of good agricultural land spread over 3 years is as follows:—



Typical 3-year rotation.

It will only be by the adoption of suitable intensive rotations and the largely increased use of leguminous fodder crops and keeping and feeding increased number of live stock that the yields of irrigated land in North-West India will approximate more nearly to those in Egypt. At present the average yields per acre in the Punjab canal colonies, especially on the older colonies, are very small and evidence seems to point to the fact that yields are decreasing. The various Agricultural Departments have taken the matter up seriously and their recommendations together with the necessary co-operation of the Irrigation Department will have effect in time. The Board of Agriculture in 1917 recommended combined action for the different provinces affected by means of a central research station, and this would be the best solution of the matter which is of the greatest importance from every point of view.

CHAPTER IV.

Aboukir Company's Reclamation Work.

The reclamation of Lake Aboukir was started by an English Company in 1888. Some 30,000 acres were taken up on the site of the lake of that name about 10 miles from Alexandria. The land was a dry salt plain in the hot weather and a shallow salt lake in winter. As the soil was a sticky black clay and seemingly very impervious to water many doubted the feasibility of the reclamation. The percentage of soluble salt in the first three feet averaged over 6 per cent.

The first step was the provision of a sea-wall to prevent any sea water from flooding the land, especially during the period when northern winds blow across the Mediterranean.

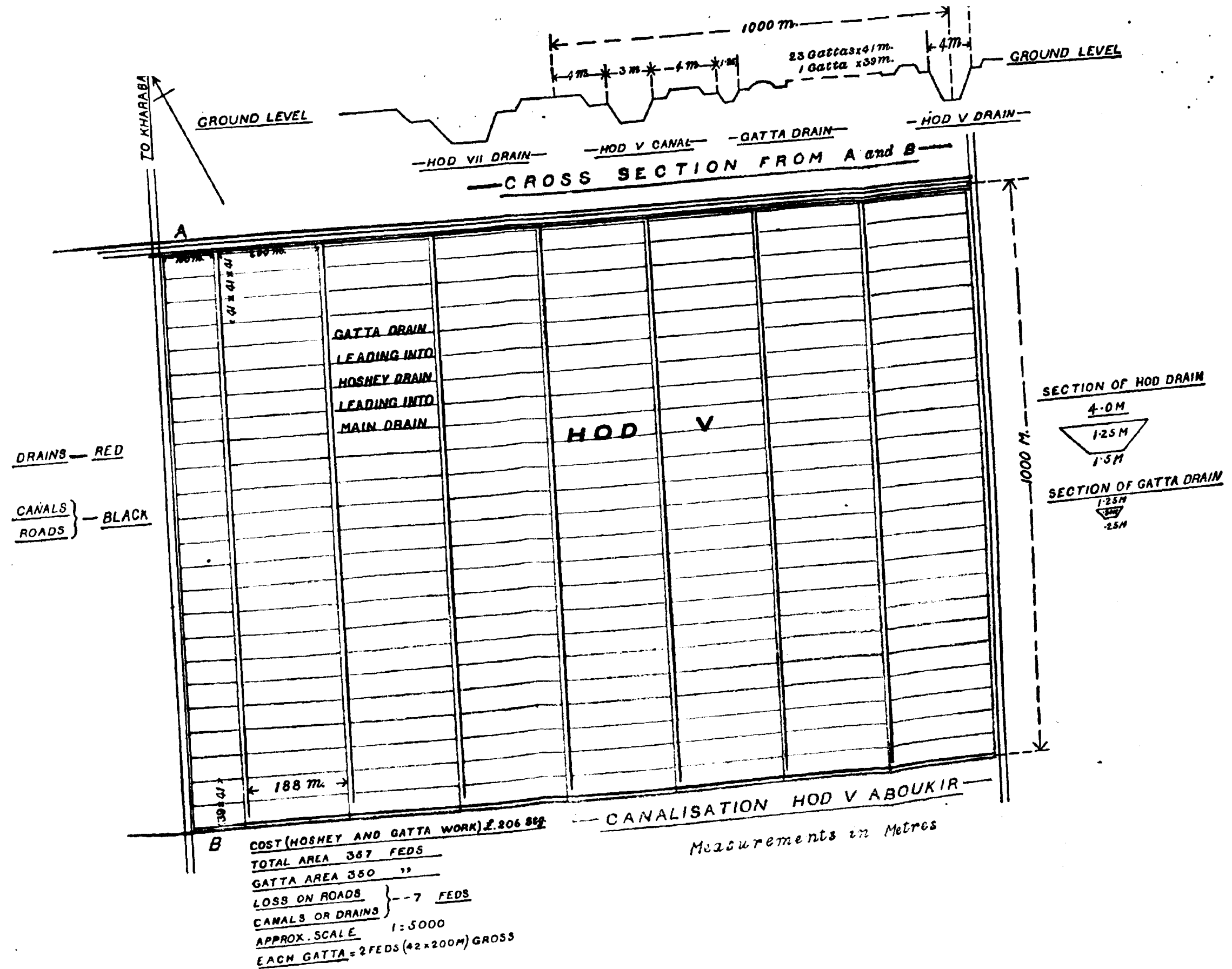
Then the canalization was taken in hand. The main drains and canals were dug and the minor earth-work completed for those blocks which were first started. The land being below sea level the drainage water had to be pumped up into the sea. The object was to keep the subsoil water level at a minimum depth of 2' 6" below surface level. The main drains had to be of sufficient depth to get a flow from the minor drains.

The Company had many difficulties at first, and it was only after years of experience that the technique was perfected and reliable methods standardized that the reclamation work became successful and the Company enabled to pay large dividends which it has done ever since.

The drainage pumps gave difficulty at first; the pumps at the ends of the main drains would suck dry before the water in the minor drains has begun to flow. This difficulty was got over by the provision of drainage outlets into Lake Mariouties the level of which was kept down by a Government pump installation to 8 feet below sea level to provide drainage for the surrounding country.

The 'gatta' or plot of 2 feddans (1 feddan=about 1 acre) is the unit of canalization. The series of plots is the 'hoshey' and the 'hosheys' make up the 'hod' or village. Each 'hod' is treated separately for labour, management and account purposes. Each 'hod' has a foreman or 'holi' responsible for all matters in the 'hod' and an 'esbah' or village is built in a convenient site. This 'esbah' is usually stone built and contains 'magazines' or stores, court for cattle and workmen's rooms and threshing floor.

The plan and section of a typical 'hod' is attached and clearly shows the principles of the canalization.



The first work after the earth-work is finished is levelling. This is done by wooden scoops working after ploughs. It is very important work and the plots must be made quite level. Permanent bunds may be made in the centre of the plots if there is much difference in level between the two ends. Levelling must be carefully supervised. There is no operation in which more money can be wasted. These scoops or 'khasibehas' have been described in Pusa Bulletin No. 73 on "New Agricultural Implements for India."

As the cost of levelling varies with the square of the distance of the 'lead,' short leads should be the rule.

After levelling water is let into the plots and the final levelling given by a long board drawn by cattle through the water.

Water is only allowed for flooding purposes during high Nile. It is however essential that while washing the plots should be kept full, i.e., 3-4" deep. If the plots are simply irrigated and then allowed to dry they get worse than they were before, owing to evaporation. If the plots are kept properly full the salt on solution is washed into the sub-soil and goes off by the drains. There is no surface washing and any case of broken bunds by which water can get direct into the drains is strictly against rules. Also each plot has a separate inlet for the irrigation water and no plot receives water from another plot. After washing for a couple of seasons the plots begin to sweeten up. It is however sometimes necessary to run a drain up the middle of each plot if the improvement is slow. The first crop sown is 'denebah' (*Panicum Crus-galli*) which is a useful fodder. When the land can grow really good berseem (*Trifolium alexandrinum*) the cultivators will buy or rent it eagerly.

Some of the land is sold to the actual cultivators on ten yearly instalments. The instalments are calculated to be equal to the value of the yearly cotton yield. The cultivator has the other crops to live on in the meantime, and as he eventually becomes the owner of his land the system is satisfactory for both sides and works well in practice.

The above is only a brief outline of the work, it is in fact a highly specialized branch of estate management and requires a combination of agricultural and civil engineering.

The cost of the reclamation work depends on special circumstances; it may vary from £5 to £15 per acre.

Typical analyses of the soil are appended. It may be noted that all observers dwell on the fact that the soil in actual practice is much more pervious to water than would be supposed by the mechanical analysis.

There are a number of other reclamation works on much the same principles, they have not all been successful; there is the Kom-el-Akhdar concern on which a French Company is said to have spent a

million pounds on 10,000 acres without achieving success. The soil was not different from others which have been successfully reclaimed. It is probable the failure was due to Western methods being adopted without modifications necessary to the East.

Considerable expectations were based on tile drainage for reclamation in Egypt but only small works have been carried out so far. The advantages of this method are the speed and thoroughness with which the work can be completed and the saving of actual land.

The disadvantages are the cost and the fact that the salt gradually destroys the tiles. There is also the danger of the washing water getting direct entrance to the drains through cracks and holes which would cause great damage. The saving of land is more apparent than real as after the land is reclaimed many of the drains can be filled in.

A point of great practical importance is that the land should be properly reclaimed before it is given out to cultivators. If the salts are not properly washed down into the subsoil before ordinary crops are grown the only result is loss to all concerned.

Analyses of soils from Lake Aboukir, made by Breazeale of the American Bureau of Soils, from the United States Department of Agriculture, Bureau of Soils Bulletin 21 :—

Constituent	7544, 0 to 12 inches	7545, 12 to 24 inches	7546, 24 to 36 inches	7538, 0 to 6 inches	7539, 0 to 12 inches	7540, 0 to 6 inches	7541, 6 to 12 inches	7542, 0 to 6 inches	7543, 6 to 12 inches
Ions :—	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Calcium (Ca)	15.45	2.63	1.44	13.46	10.12	17.16	9.72	9.16	0.0
Magnesium (Mg)	Tr.	Tr.	Tr.	Tr.	3.73	Tr.	11.87	Tr.	Tr.
Sodium (Na)	17.63	33.18	34.62	15.35	15.17	7.73	6.37	18.84	27.91
Potassium (K)	1.65	2.48	2.81	4.82	4.61	8.24	3.59	5.89	6.00
Sulphuric acid (SO ₄)	34.65	12.32	8.78	46.54	32.97	53.62	7.08	41.27	44.58
Chlorine (Cl)	30.06	48.41	50.79	14.17	30.11	6.01	57.51	12.24	7.58
Bicarbonic acid (HCO ₃)	0.56	0.93	1.86	5.66	3.29	7.22	2.96	13.10	13.84
Conventional combinations :—									
Calcium sulphate (CaSO ₄)	49.10	9.12	4.80	45.68	34.30	58.25	11.29	31.00	..
Calcium chloride (CaCl ₂)	2.77	..	..	..	..	..	17.76	..	..
Magnesium sulphate (MgSO ₄)	..	..	..	..	10.08	..	..	..	..
Magnesium chloride (MgCl ₂)	..	..	..	..	5.03	..	46.54	..	..
Potassium chloride (KCl)	3.13	4.72	4.06	9.23	8.79	12.54	6.86	11.14	11.52
Potassium bicarbonate (KHCO ₃)	..	..	..	..	..	4.30	..	..	..
Sodium chloride (NaCl)	44.23	76.18	79.71	16.17	35.50	..	13.57	11.36	3.52
Sodium sulphate (Na ₂ SO ₄)	..	8.70	7.89	21.13	..	18.56	..	28.60	65.98
Sodium bicarbonate (NaHCO ₃)	0.77	1.28	2.55	7.79	4.50	6.35	3.98	17.90	18.98
Per cent. soluble	10.54	9.01	5.80	1.69	1.82	1.16	4.11	0.92	1.47

The following table gives the results of mechanical analyses of samples of soils collected in Egypt :—

Number	Locality	Description	Organic matter	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.001 mm.
			P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
7538	Aboukir tract	Loam, 0 to 6 inches	0.65	0.52	0.40	0.38	18.42	35.86	23.46	16.16
7539	Do.	Loam, 0 to 12 inches	0.50	0.02	0.08	0.16	23.34	42.68	21.00	12.52
7544	Do.	Clay loam, 0 to 12 inches	0.89	0.14	0.30	0.18	2.32	4.14	35.08	57.44
7545	Do.	Clay loam, 12 to 24 inches	0.69	0.00	0.10	0.06	3.86	15.90	30.72	49.30
7546	Do.	Clay loam, 24 to 36 inches	1.04	0.00	0.04	0.04	0.92	5.76	51.28	41.64
7540	Do.	Clay loam, 0 to 6 inches	0.29	0.46	0.68	0.42	6.26	8.28	31.40	51.08
7541	Do.	Clay loam, 6 to 12 inches	0.44	0.20	0.28	0.32	3.52	5.42	37.30	52.48
7542	Do.	Clay loam, 0 to 6 inches	0.24	0.30	0.42	0.36	3.68	9.48	28.28	57.02
7543	Do.	Clay loam, 6 to 12 inches	0.83	0.20	0.56	0.24	1.76	8.74	25.76	62.62
7555	Kom-el-Akhdar	Clay loam, 0 to 12 inches	0.45	1.84	5.80	4.20	21.94	15.84	7.48	42.10
7556	Damru	Clay, 0 to 12 inches	2.46	0.60	0.88	0.20	0.58	4.98	37.08	55.46

Reclamation Work in India.

Dr. Leather analysed a large number of salt samples and mapped areas of salt lands in canal areas of the United Provinces. The results are published in a United Provinces Government blue book¹. The late Mr. J. Hector Barnes² reclaimed a plot of salt land near Lyallpur in the Punjab and did a considerable amount of laboratory work in connection with it.

The history of the Daulatpur reclamation station is fully described in Bulletin 64 of the Department of Agriculture, Bombay (1914). This station consisted of 400 acres of light salt land. The reclamation work was not carried out so far as it might have been, but it was conclusively proved that the Egyptian methods were applicable to Sind. The difficulty in carrying out this work to a conclusion was that till the Indus Barrage is completed there is only enough irrigation water for the good land. So having proved the fact that reclamation on standard lines presented no difficulty the Sind Agricultural Department had to switch on to more urgent work.

When the Indus Barrage and the new system of canals is completed, say, within the next 15 years or so, reclamation work will have to receive attention again.

² Barnes and Barkat Ali. "Alkali soils: Some biochemical factors in their reclamation." *Agric. Journ. Ind.*, Vol. XII, p. 368.

Analysis of Daulatpur soils

Salt	Square 64		Square 66		Square 68		Square 3		Square 5	
	Surface	2' down	Surface	2' down	Surface	2' down	Surface	2' down	Surface	2' down
Sodium carbonate	0-0167	0-02500	0-03757	0-03780	0-03750	0-04170	0-0292	0-0334	0-02500	0-00326
" bicarbonate	...	...	0-17920	0-17920	...	...	...	0-0450	...	0-02930
" sulphate	...	0-28380	0-01340	0-01340	0-28350	1-09400	0-0753	0-0648	0-22840	1-09200
" chloride	...	0-10270	...	0-08110	0-00600	0-08353	0-0895	0-0895	...	0-07570
Magnesium sulphate	0-0342	...	0-09840	...	0-05514	0-09110	0-0885	...	0-04420	0-06180
" chloride	...	...	...	0-01258	...	...	0-0101	...	...	...
Potassium sulphate	...	0-01075	0-00768	...	0-00491	0-01379	0-0199	0-0169	0-01690	0-01070
" chloride	0-0175	0-25180	0-08250	0-12920	0-17690	0-11560	0-1196	0-0684	0-06875	0-08400
Calcium sulphate	0-0356	...	0-12350	...	...	...	0-0134	...	0-04630	...
" chloride	...	...	...	...	...	...	...	...	...	...
Total soluble alkali	0-1040	0-07385	1-54858	1-36296	0-54365	1-40669	0-2959	0-2972	0-39155	1-26816

Salt	Square 7		Square 24		Square 26		Square 28	
	Surface	2' down	Surface	2' down	Surface	2' down	Surface	2' down
Sodium carbonate	0-02500	0-03543	0-02086	0-02930	0-02086	0-02919	0-02919	0-02919
" bicarbonate	0-69390	0-03540	...	...	...	...	...	0-20040
" sulphate	1-03500	0-11790	0-29710	0-43990	3-06100	0-02180	0-78200	0-48710
" chloride	0-11360	0-12970	...	...	0-32080	0-12830	0-04140	0-08390
Magnesium sulphate	...	...	0-14970	0-18400	0-32080	0-12830	0-04853	0-01436
" chloride	0-00358	0-00369	0-00614	...	...	0-01689	0-01392	...
Potassium sulphate	...	...	0-36280	0-29750	0-34870	0-03500	0-20400	0-22090
" chloride	0-23120	0-02041	0-11710	0-03700	0-22890	0-12120	...	...
Calcium sulphate	...	...	...	...	...	...	...	...
" chloride	...	...	...	...	...	...	...	...
Total soluble alkali	2-00398	0-64533	0-94370	1-01374	4-00715	1-24902	1-1894	1-04585

CHAPTER VI.

Conclusions.

The following are the opinions of the writer in regard to salt land reclamation work in India :—

1. Methods successfully adopted in Egypt are suitable for North-West India.
2. Washing the salt into the subsoil is the only effective method of dealing with the problem.
3. Surface washing and running the salt-impregnated water off periodically is a wasteful and unsatisfactory method except under very special circumstances.
4. In North-West India owing to the depth of the subsoil water, the drainage problems are simple and this generally renders the whole reclamation problem much easier of solution. The field drains are necessary to form units for levelling but the system of main drains is in the meantime unnecessary. Drains fill from beneath, and they will remain empty so long as the water can get down to the low subsoil level.
5. Careful levelling is essential. The small drains are useful to mark off the plots and to provide earth for the bunds. Water should be taken direct to each plot. It should never be fed from plot to plot, and while washing the plots should be kept full.
6. After washing the physical texture of the soil must be improved by suitable cropping; this is done in practice most easily by feeding cattle on the land on leguminous fodder crops.

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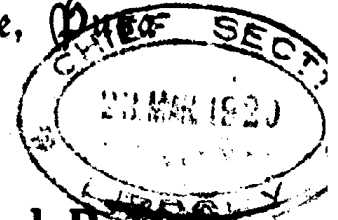
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Syngamus laryngeus in Cattle and Buffaloes in India

BY

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Syngamus laryngeus in Cattle and Buffaloes in India.

[Received for publication on 9th August, 1919.]

THE only published account of a *Syngamus* parasite occurring in cattle appears to be that by Railliet in the *Comptes Rendus de la Société de Biologie* for 1899, p. 174.

In the records of this laboratory there is evidence that the same or a similar parasite was found in cattle at Muktesar in 1897, but no account of it was published.

In 1916 it was observed independently by one of us (A. W. S.), and again in 1918 (A. L. S.)

This note is based upon the examination of worms obtained from animals, hill bul's and buffaloes, used for the production of rinderpest virus, and also from plains cattle of various ages and of both sexes killed in the slaughter-house at Bareilly.

Nearly two hundred buffaloes, one hundred plains cattle, and nearly five hundred hill bulls have been examined. Parasites were found in about 13 per cent. of the buffaloes and hill bulls, and about 15 per cent. of the plains cattle. The maximum number found in any one animal was 17 in the case of the hill bulls, 24 in the case of the buffaloes, and 16 in the case of plains cattle. As a rule, however, only one or two were found.

With few exceptions, all were found attached to some part of the larynx. They have been found on the inner surface of the arytenoid cartilages, the bezel of the cricoid near its anterior edge, the vocal cords, the lateral ventricles and epiglottis (Fig. 1).

The observation of 1916 is not taken into consideration in the above statement regarding the usual situation of the parasite.

In that case the subject was a hill bull which had been used for some time for the preparation of anti-hæmorrhagic septicæmia serum.

The animal had been coughing frequently and had had a poor appetite for some days when it was noticed that particles of food were expelled from the nostrils during the act of coughing. This had continued for a few days when the animal died unexpectedly during the night.

Apart from extreme debility, which was probably due to the repeated injections and bleedings which the animal had had to undergo as a serum-maker, the general post-mortem yielded negative results.

The mucous membrane of the pharynx was, however, congested, and there were found adhering to it and to the back of the soft palate some ten or twelve pairs of worms. A few were also found attached to the mucous membrane of the larynx. It is probable that the parasites present in the pharynx set up some degree of irritation which was responsible for the symptoms observed during life.

As already mentioned, the parasite has been found in bulls coming from the Kumaun and Garhwal hills, and in buffaloes and cattle from the Bareilly District in the plains. That buffaloes in the plains are actually infected with the parasite independently of any infection they may possibly have contracted at Muktesar, is proved by the fact that a watch was kept at the Branch Laboratory at Bareilly during the cold weather among buffaloes purchased locally, and a number of specimens were found.

That the bulls did not acquire the infection from buffaloes in Muktesar is indicated by the fact that the percentage of infected animals is about the same in both species, and by the fact that bulls coming from the hills are kept in separate kraals from the buffaloes until they are brought into the sheds. As virus producers their life in the sheds is too short to permit of their becoming infected in such numbers.

These points establish the facts that both cattle and buffaloes are hosts of the parasites, and that the infection is about as common in the plains (at least so far as the Bareilly District is concerned) as in the hills.

Age appears to play no part in determining the infection as the parasite has been found in animals of all ages from 1 to 12 years old.

Morphology. The majority of the parasites are bright red in colour, but occasionally one or other or even both of a pair may be quite white. This is no doubt due to their having ceased to suck blood for some reason or other.

Railliet gives the measurements of the worms found in cattle in Annam as follows:—Males from 3 to 3.375 millimetres in length by 360 to 375 microns in thickness; females 8.75 to 9.8 millimetres in length by 550 to 570 microns in thickness.

The specimens which we have had for examination have given the following range of size:—Males 3 to 5 millimetres in length by 340 to 375 microns in thickness; females 7 to 20 millimetres in length by 450 to 675 microns in thickness (Fig. 2).

From this it will be seen that many of the worms examined by us were at least twice as large as those examined by Railliet.

Male worm. The male is approximately constant in thickness throughout its length (Fig. 3), but shews a slight abrupt constriction at the line of junction between the body and the caudal bursa (Fig. 4).

In no instance have males and females been found unattached to each other.

The cuticle does not shew any distinct cross striation in the fresh condition, but it can be made out obscurely in preserved specimens, and it is distinctly visible in specimens that are partially dry.

The anterior end is squarely truncated and shows the circular mouth.

At a distance of about 0.75 mm. from the anterior end the cuticle shews a small blunt tubercle on each side of the body (Fig. 5).

The caudal pouch is somewhat poorly developed as regards its size (Figs. 3 & 4).

Alimentary tract. The mouth is circular and is surrounded by a thin transparent membranous lip. From the examination of longitudinal sections it appears that this lip is composed of two layers between which there is a space which forms a closed canal round the orifice (Fig. 6. A). A similar canal encircles the parasite just posterior to this.

The buccal capsule is almost hemispherical in shape and is composed of thick chitinous material (Fig. 6. B).

At the bottom of the capsule, round the opening of the oesophagus, there are eight small elliptical holes (Fig. 6. C). Immediately external to these there is a ring of eight chitinous points projecting forwards into the mouth cavity (Fig. 6. D). From the base of each of these there arises a thick rib which runs up on the inner surface of the capsule.

It is a somewhat peculiar fact that only six of these ribs reach the margin of the capsule. One pair which are opposite to each other fade out when about two-thirds of the distance has been traversed (Figs. 7 & 8). In this respect the parasite is possibly different from that referred to by Railliet who describes the whole of the ribs as reaching the margin. The margin of the capsule is thus divided into six segments only, of which two are twice as large as the remainder. Examination of the capsule under a high magnification shews that throughout its extent it is beset with minute perforations set closely together (Figs. 6 & 9).

The oesophagus which has the usual club-like shape is particularly well developed. The intestine runs a practically straight course to the hinder end of the body.

The anterior part of the intestine is expanded in such a manner as to almost merit being termed a stomach. In fresh preparations this "stomach" is shaped like a peg top, the bulbous end being the anterior one (Fig. 10). In fixed specimens it is generally telescoped.

The minute anatomy of the intestine is the same throughout its length. Outwardly there is a layer of large cells whose margins are difficult to make out. These cells not infrequently have a frothy appearance as if crowded with fat droplets. On the inner face of these there is a thin layer of homogeneous material which stains intensely with eosin. The inner surface of this layer is covered with short rod-like structures set at right angles to it and packed closely together (Fig. 11).

When seen from the surface this layer has a mosaic-like appearance. Posteriorly the intestine opens into a funnel-shaped cloaca (Fig. 12).

Genital system. The striking fact in connection with the genital system of the male parasite is the complete absence of any spicules. The entire system appears to be represented by a single tube which is closed anteriorly and opens posteriorly into the cloaca. This tube is about three-quarters the length of the whole worm, but is invariably coiled so as to occupy a position in the hinder half of the parasite only (Figs. 3, 4).

Structurally the tube comprises two distinct parts which are approximately equal in length. The anterior half of the tube is the germinal portion in which the spermatozoa are developed (Fig. 13. A). Here the tube is packed with small rounded cells with compact nuclei. These cells do not appear to be provided with any locomotor apparatus. The hinder portion of the tube shows a distinct lumen bounded by large cells. In paraffin sections the spermatic fluid can not infrequently be found in the lumen of this portion of the tube (Fig. 13. B).

The tube enters the cloaca dorsally to the intestine.* The cloaca has a comparatively narrow outlet but no accurate measurements could be made as some degree of distortion takes place when sections are cut, no matter what method is adopted, and the orifice of the cloaca cannot be seen distinctly except in sections.

The caudal bursa (Figs. 3, 4 & 14), which may be considered as part of the genital apparatus, is peculiar in many respects. It is smaller than is usually found in the parasitic round worms, but is very much thicker and is in fact quite fleshy. Its smallness is, however, compensated for as will be seen later. Its small size, thickness, and the closeness with which it adheres to the female make it difficult to study the pouch in detail. A complete idea of the details of the pouch can only be arrived at as the result of the examination of a number of specimens prepared in different ways, sections cut in paraffin, by freezing and teased preparations.

The pouch may be described as more or less saddle-shaped, the panels of the saddle passing over the sides of the female. The lateral lobes of the pouch are connected anteriorly by a flap which is thicker than any other part. This anterior part is recurved, this serving to anchor it firmly to the anterior margin of the flattened boss on the body of the female in which the vulva opens (Fig. 15. A).

Posteriorly the lateral lobes of the bursa are directly connected by a moderately thin flap. This is to some extent recurved in fresh specimens but not to so marked an extent as the anterior lobe (Fig. 15. B).

This arrangement alone would account for a considerable amount of difficulty in detaching the parasites from each other, but the union

* It is assumed that the ventral surface of the male is directed towards the anterior end of the female.

is rendered far more intimate by the fact that the whole of the inner surface of the pouch, with the possible exception of one small area, is closely beset with small crypts (Fig. 16) into each of which is fitted a small pointed projection developed from a special layer on the surface of the female over the whole area included within the grasp of the pouch (Fig. 17).

Sections of the male worm shew that throughout its extent the pouch is spongy in structure. It comprises an inner and an outer dense layer and between these a loose-textured connective tissue, the main strands of which pass straight from one dense layer to the other (Figs. 12, 17 & 18).

The supporting rays of the pouch are poorly developed and difficult to see in detail in intact parasites (Fig. 3).

The best pictures of them have been obtained in serial sections cut in paraffin. From these it is seen that there are two main trunks. The anterior one gives rise to three broad rays with rounded ends which lie in close contact with each other (Fig. 18). From the posterior trunk two rays of a similar nature take origin.

Other organs. In the anterior part of the body there are two large blind pouches which appear to open by a small orifice common to both through the cuticle on the posterior surface of the body at a point opposite the junction of the anterior and middle thirds of the oesophagus (Fig. 19).

These pouches become wider as they pass backwards and terminate about the middle point of the body. Projecting from the blind end of each there is a little appendix-like prolongation. The nature and function of these has not been determined. Possibly they are the homologues of the cervical glands described by Looss in *Anchylostoma duodenale*.

In the body cavity, and apparently unattached in any way, there are invariably four rounded bodies (Figs. 3 & 4), measuring 100 to 120 microns in diameter, which are largely composed of closely felted filaments each of which shews a close succession of rounded thickenings, thus producing an appearance resembling a string of beads.

In sections of these bodies two distinct zones can be made out. The outer zone is composed of the filaments described, and a central area which stains more intensely, is finely granular, and in which a few nuclei can be detected. The nature and function of these is also unknown.

Female worm. The female worm of which the measurements have already been given, attains its maximum thickness in the neighbourhood of the vulva. It tapers slightly towards the head and tapers continuously towards the tail where it terminates in a subacute point.

What has been said regarding the presence of striations on the cuticle of the male holds good for the female.

The mouth and alimentary tract of the female are, except in the matter of size, the counterpart of the corresponding parts of the male.

The anus in the female is sub-terminal, at a distance of about 300 microns from the tip of the tail, and takes the form of a transverse slit.

If the piece of cuticle containing the vulva be dissected away from the rest of the parasite and spread out flat, a more or less circular area bounded by a distinct line can be seen under a low magnification. This has a slightly granular appearance and is the area covered by the bursa of the male (Fig. 21).

In serial longitudinal sections it is found that this line circumscribes a flattened boss which is slightly undercut to give anchorage to the recurved flaps of the caudal pouch of the male. This undercutting is most marked in worms that have been sectioned while still attached to each other. If the worms be separated before fixing, the boss is scarcely salient at all.

The vulva takes the form of a transverse opening and is not furnished with any protective appendage or prominent lips. It opens somewhat posteriorly to the central point of the boss. As already mentioned, the boss is covered with a specialized layer the surface of which shows immense numbers of little pointed processes for insertion into the crypts on the under-surface of the bursa of the male (Figs. 17 & 22). It appears to be probable that this specialized layer is in reality in the nature of a cement substance which is drawn up into the crypts of the pouch by suction. It is difficult to suppose that actual outgrowths of the cuticle could be fitted so accurately into so many minute crypts of varying size. It is probable that there is one area of cuticle, extending backwards from the vulva, which is not in intimate union with the under-surface of the caudal pouch.

Sections have been examined in which eggs had reached the vagina and even the vulva, and were on the point of being extruded. In view of the facts that the vagina is directed backwards and that the vulva opens posteriorly to the centre of the area covered by the pouch, it seems to be reasonable to suppose that the eggs are passed out under the posterior flap of the pouch. That there must be some channel of this sort is indicated by the fact that there must be some means of escape for eggs and for the waste material passing from the alimentary canal of the male.

The less complete anchorage of the posterior lobe of the pouch also suggests that this may be the case.

It would appear to be a very wasteful procedure on the part of Nature if, as has been suggested, the eggs can only escape as a result of rupture or disintegration of the body of the female. This would be tantamount to the death of the parent worm. A very large proportion of the eggs liberated would in all probability not be viable.

That the view put forward is correct is borne out by the fact that eggs have been observed on a number of occasions in the act of escaping

from beneath the caudal pouch of the male. Living worms were obtained and placed in 0.4 per cent. salt solution. Under a dissecting microscope the eggs were observed to be ejected with some force from under the posterior flap of the caudal pouch, in some cases at intervals of a few seconds and in others at very long intervals.

Genital organs of the female. The ovaries and uteri are twisted round themselves and round each other in so complicated a manner that it has been found impossible to disentangle both branches of the system, for the purpose of measurement, without damage. In many instances it has been found possible to ascertain the length of one branch by sacrificing the other. It has been found that the length varies from two to two and a half times the total length of the worm.

From the examination of serial longitudinal sections it appears that the vagina, which is very short (Fig. 21), opens into a funnel-shaped vulva which is compressed dorso-ventrally. In many paraffin sections the minute cells described as being present in the duct portion of the male genital tube could be found crowded into the funnel-like opening and passing down into the uteri (Figs. 23 & 24).

From the vagina, which is about 150 microns in length and which is provided with very thick walls, two uteri take origin. These are thin-walled tubes which vary greatly in diameter, depending upon the number of eggs contained in them. They measure about 5 millimetres in length in a fully grown parasite. Each branch of the uterus is continued as a long slender ovary measuring 10 to 50 millimetres in length. The ovaries terminate blindly. The blind pouches, described as being present in the anterior part of the male, and the four ball-like structures are present in the female worms, and are proportionately larger.

Eggs. In the distal portions of the ovaries the first evidence of egg formation is the appearance of segmentation in the ovarian contents. In sections stained with hæmatein and eosin the segments are found to be crowded with granules staining intensely with the hæmatein. Further down the tubes, where the eggs have assumed the oval shape, these granules are found disposed at the surface and closely touching each other. In the next stage of development the granules have entirely disappeared and the shells of the eggs have made their appearance (Fig. 25). It appears to be probable that the shells are made from these granules.

The whole process very closely resembles that observed in the stages of development of the oocyst from the macrogamete of *Coccidium*.

The most mature eggs found in the uteri are in the morula stage comprising eight cells, but eggs were found in the mucus on the surface of the membrane of the larynx in which only two cells could be seen (Fig. 26).

The mature eggs measure about 80 microns in length by 40 in width. No evidence of an operculum can be found.

Pathogenic effects. With the exception of the special case cited above no disturbance of health has been noted as being caused by the parasite.

Figures 27 and 28 show respectively longitudinal and transverse sections of the mouth parts of parasites still attached to the mucous membrane.

In Figure 26 it is seen that a "button" of the membrane is drawn into the mouth, and no doubt the chitinous points or lancets set round the opening of the oesophagus puncture the membrane and thus enable the parasite to withdraw blood.

Technique. It has not been found possible to obtain uniformly satisfactory results by any of the methods of preparing sections that have been described, but good results have been obtained at different times with all of them.

It was found to be essential for the penetration of the paraffin to make an opening in the integument as it offered a great resistance. This was generally effected by cutting off a portion of the worm that was not required for examination. It was frequently found to be of great assistance in cutting sections of the worms to adopt the plan described by Looss of painting the surface of the paraffin block with a thin solution of celloidin between each cut.

The chitinous parts of the mouth presented great difficulty when cutting specimens embedded in paraffin, as they shewed a great tendency to crack.

To overcome the difficulty of small parts of the sections becoming detached from the slides while the processes of paraffin extraction and staining were being carried out, the plan was on some occasions adopted of staining the specimens without removing the paraffin. It was found that this could be done successfully provided the paraffin wax was not actually melted when the sections were placed upon the surface of warm water prior to placing them upon the slides. The processes of staining and dehydration were carried out in the usual way and the xylol used for clearing simultaneously removed the paraffin and left the specimens ready for mounting in balsam. The painting of the surface of the block with celloidin did not interfere with this method as the celloidin was removed by the alcohol used for dehydration.

On a large number of occasions, sections, quite satisfactory for some purposes, were cut with the freezing microtome. These sections were washed off the razor either singly or two or three at a time by ejecting a gentle stream of water from a pipette on to the surface of the blade and draining it with the sections either on to a slide or into a watch glass.



FIG. 1. A larynx laid open by cutting through the larynx of the cricoid. Shows a group of worms attached to the aryepiglottic fold on each side.

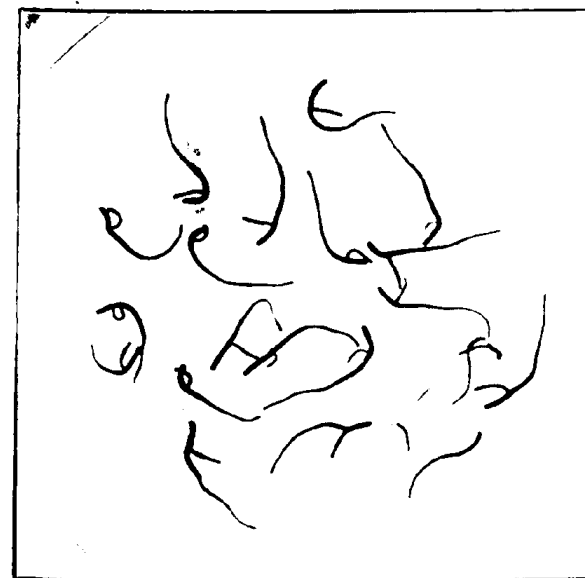


FIG. 2. A number of parasites photographed exactly natural size. In the right hand lower corner, there is a red female with a white male attached to it. The male is scarcely visible against the white background and close to this is a red male attached to a white female.



FIG. 3 ($\times 20$). Detached male parasite showing the straight intestine, single blind seminal tube, the small size of the anal bursa (the rays of which can be seen very indistinctly). Three of the rounded bodies at A.



Fig. 4. The junction of the male and female showing the slight constriction at the junction of the caudal bursa with the body, the single blind seminal tube, the small caudal bursa, two of the rounded bodies.



Fig. 5. Anterior end of the male showing two blunt tubercles on either side of the body.

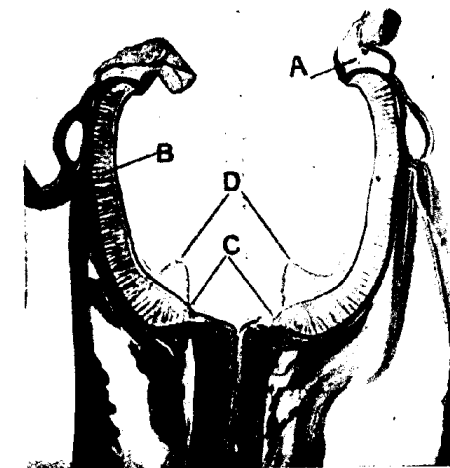


Fig. 6 ($\times 150$). Longitudinal section of the mouth showing (A) the membranous lip containing the canal, (B) the thick chitinous capsule, (C) elliptical holes in longitudinal section, (D) chitinous points.

Note the striated appearance of the chitin. This is due to perforations. (See also Fig. 9.)



Fig. 7 ($\times 10$). A chitinous buccal capsule dissected out and flattened showing—AA the short ribs, also the chitinous points and the ring of elliptical holes shown in Fig. 6.

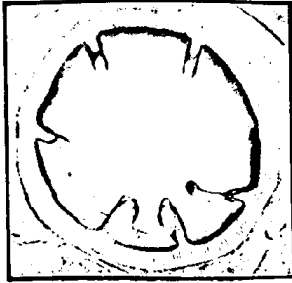


Fig. 8 (x 75). Transverse callost section of buccal cavity cut above the point where one pair of ribs disappears leaving six only.

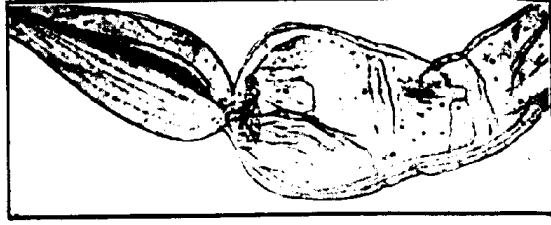


Fig. 10 (x 40). The hinder portion of the oesophagus and the stomach.



Fig. 11 (x 500). A portion of the intestine showing the outer cellular layer, the intermediate homogeneous layer and the inner layer of rods.



Fig. 12 (x 150). Showing cloaca with the intestine entering it on the left side, ventrally in the living specimen and the seminal tube on the right side, dorsally. The terms ventral and dorsal are used assuming that the ventral surface of the male is turned towards the anterior extremity of the female.

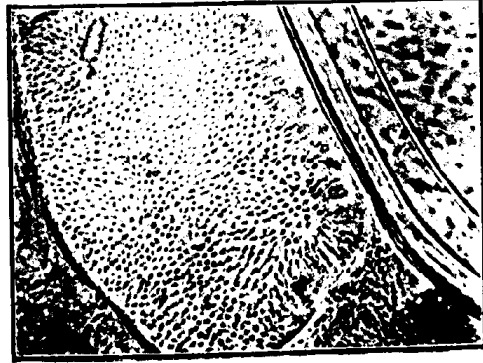


Fig. 9 (x 150). A portion of the buccal capsule seen from the surface. On the left is the membranous lip. The perforations in the chitin are clearly shown.

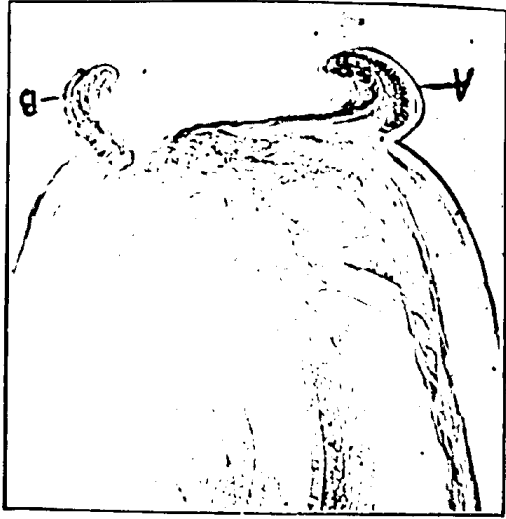


Fig. 15 ($\times 150$). Frozen longitudinal section unstained. Showing at A the recurved anterior flap of the pouch, and at B the less curved posterior flap.



Fig. 16 ($\times 100$). Longitudinal section of posterior extremity of male showing everts on the inner surface of the pouch.



Fig. 13 ($\times 400$). Section of two parts of the scutal tube of the male.



Fig. 14 ($\times 40$). Antero-posterior view of the caudal pouch of a detached male (the right half is slightly damaged) showing the thick fleshy nature and its small size.



Fig. 17 ($\times 460$). Section through the junction of a male and female. Line of junction at A—A' showing the pointed projections fitted into the crypts on the inner surface of the pouch. B, the spongy portion of the pouch.



Fig. 18. Longitudinal section through one of the internal lobes of the pouch showing the anterior trunk giving rise to three rays. A, B, Posterior ray. C, Spongy pouch.



Fig. 19 ($\times 27$). Showing the two blind pouches extending from the common orifice at A to H & B. One is partly concealed by the other.



Fig. 20 ($\times 460$). Section of a rounded body showing the other rhinoceros zone and the inner granular area in which there appear to be some nuclei.

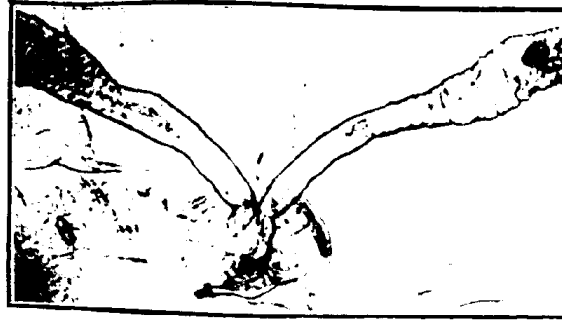


Fig. 21 ($\times 10$). Portion of cuticle of female containing the vulva and showing the area covered by the pouch of the male, the short vagina, and the anterior portions of the uterine tubes.

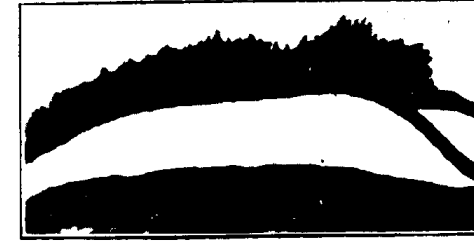


Fig. 22 ($\times 160$). Specialized layer of "boss" of female showing the projections which fit into the crypts of the pouch of the male.



Fig. 23 ($\times 100$). Longitudinal section (dorsio-ventral) of the vulva, short vagina and uterine tubes containing the small cells described in connection with the genital tube of the male.



Fig. 24 ($\times 400$). Oblique section of a portion of the uterus showing the small cells described in connection with the germinal tube of the male.

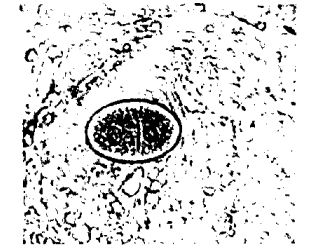


Fig. 26 ($\times 150$). An egg in the mucus from the larynx.



Fig. 25 ($\times 220$). Paraffin section through a female showing eggs in three stages of development.
 A. Eggs crowded with granules.
 B. Granules disposed at the margin.
 C. Granules disappeared and shell formed (these are determined by the process of embedding, etc.).

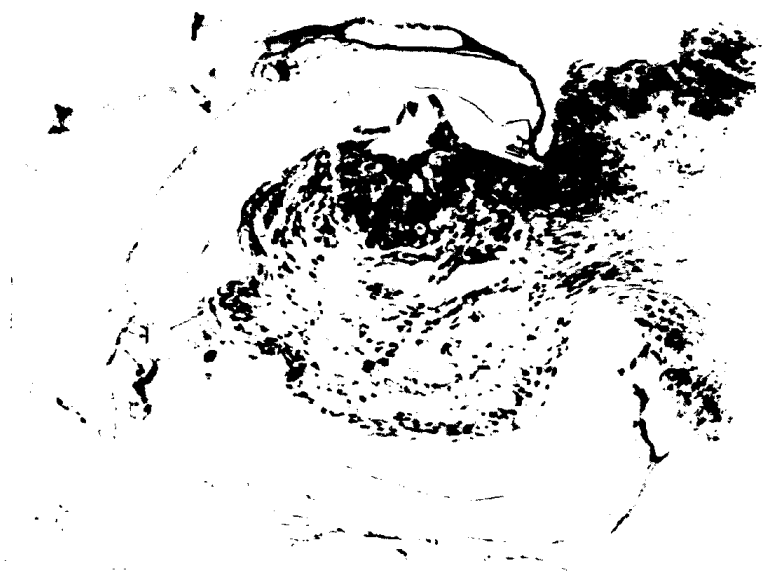


Fig. 27 ($\times 150$). Longitudinal section of the mouth of a worm still attached to the mucous membrane, showing the "bottom" of membrane drawn into the mouth. (In this and the succeeding figure the soft tissues have shrunk somewhat.)

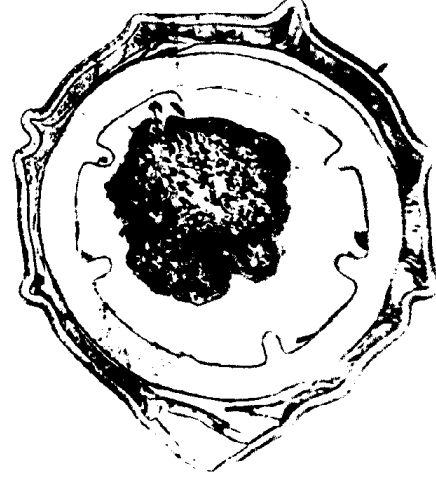


Fig. 28 ($\times 150$). Transverse section of the mouth of a parasite still attached to the mucous membrane.

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**The Orange :
A Trial of Stocks at Peshawar**

BY

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PREFACE

TO ensure in the scions certain desirable qualities, such as long life and hardiness in the tree or the dwarf habit with early and abundant bearing, or superior quality in the fruit, stocks of various kinds are employed.

The influence of the stock on the scion has not yet been fully tested in India for any fruit.

In this Bulletin it is proposed to show, as a result of experiments in the North-West Frontier Province, that success in the cultivation of the orange in North-West India mainly depends on the character of the stock used.

W. R. B.

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The Orange: A Trial of Stocks at Peshawar.

(Received for publication on 23rd August, 1919.)

I. Introduction.

In India, an orange tree, which is properly treated, may be depended on to bear a paying crop at the age of six years, and to yield 300 fruits a year for a period of 15 to 20 years after coming to maturity. After visiting many nurseries and gardens throughout India, the writer estimates that nurserymen sell 400,000 orange plants a year—they have probably distributed 8,000,000 plants at the good sum of Rs. 20,00,000 in the past 20 years. If the trees had been set out at 18 feet apart, on simple calculation, India's groves should now comprise no less than 5,000,000 bearing trees on 60,000 acres. And as the average price of oranges is not less than Rs. 2 per hundred, it might be expected that India's orange crop would be worth Rs. 3,00,00,000 a year.

Unfortunately this is very far from the actual state of affairs. A considerable proportion of the budded trees have declined and died without bearing any crop at all: very few of the trees have yielded 300 oranges even for a year or two: not many of the trees have flourished for 20 years. The area occupied by groves is far short of 60,000 acres: the crop is worth but a small part of the grand sum of Rs. 3,00,00,000.

Nevertheless, some vigorous, bountiful trees that have borne an average crop of 300 fruits for many years and, more rarely, profitable highly fruitful groves are occasionally to be seen in various parts of India. These indicate that the orange can be grown very well in the country. Why then are India's groves so unfruitful compared with similar groves in Europe, America or Australia? What has caused the death of so many of the trees that have been planted?

In India oranges are set out with care on good land and, generally, the groves are protected from drought. The orange is one of the easiest fruit trees to grow—requiring far less pruning, thinning or spraying than peaches and plums—and as a matter of fact the Malta and the Sangtara orange trees receive more care than several other kinds of fruit trees which reach greater perfection from an Indian gardener's hand. Unsuitable soil, unfavourable climatic conditions cannot be the

factors that cause the comparative failure of the orange in India. The orange flourishes on a great variety of soils over the sub-tropical world, and India has plenty of good fruit land and a considerable range of climate. There must be other circumstances which cause the orange groves of India to fail.

Investigations carried out in many gardens and nurseries throughout India, in the years 1905-11, inclined the writer to believe that this failure has been caused by mistakes in the preparation of the plants in the nurseries. In those parts of India that were visited, it was found that nurserymen employed several kinds of stocks for the Malta and the Sangtara, and as the nurserymen were not fruit-growers, they had no assured knowledge of the effects of the stocks they used on the development of trees in the groves. Indeed, the opinions of nurserymen on the merits of stocks were everywhere contradictory and often palpably unreliable: each appeared to use the stock he could most cheaply and conveniently obtain, or which quickly raised nursery plants fit to sell.

In some other matters the failure of the trees was undoubtedly caused by unfavourable conditions that prevailed in the nurseries. The young plants were overcrowded; they struggled for existence with old nursery plants and frequently with tough root-weeds. The areas were so small and congested that suitable rotations could not be followed. In the preparation of the plants careless work was also observed. The orange buds were inserted too high in the stocks. Very often old stocks were used on which buds had failed in several previous years.

In short, the nursery plants were found to be badly grown and unreliable. They were altogether inferior to the plants which nurserymen sell in Europe, America or Australia. No fruit-grower in those countries would set out the poor trees which Indian nurserymen customarily distribute.

These are some circumstances that appeared to the writer to account for the failure of orange groves in India. But despite them all, it yet seemed that the proportion of trees which reach mature age and fruitfulness should be far better than it was found to be.

Outstanding clear above all other probable causes of failure were the facts that several distinct kinds of stocks were used: that great difference of opinion existed amongst growers regarding the merits of the various stocks: that all the stocks could hardly be equally suitable to both the Sangtara and the Malta, and that some of the stocks employed might be unsuitable to either the Malta or the Sangtara.

Accordingly, when orchards at the Peshawar Agricultural Station were being laid out in 1911, the opportunity was taken to include a test of the orange stocks which are commonly used for the Malta and the Sangtara in North-West India.

Budded plants were obtained from a reliable Indian source, good clean cultivation was practised, and irrigation was used with caution. No calamity befell the trees during the trial.

The results shown with the Malta and the Sangtara will be dealt with separately.

II. Climate of the Peshawar Valley.

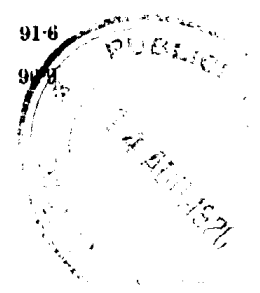
The climate of the Peshawar valley is described in the District Gazetteer as follows:—

Four seasons are recognized at Peshawar: Spring in February, March and April. During the earlier part of this period there are occasional light hail-storms and frequent thunderstorms, and usually rain falls to the extent of three or four inches. Normals of temperature derived from the data of 33 years are as follows:—

Month	Normal maximum temperature	Normal minimum temperature	Normal mean temperature
February	65.7	42.5	54.1
March	75.0	51.7	63.3
April	85.5	60.3	72.9

Summer in May, June and July. Rain rarely falls during this season though thunderstorms sometimes continue well into May which is the hottest of the year. It is frequently hazy, and dust-storms occur in June and July. Normals of temperature are as follows:—

Month	Normal maximum temperature	Normal minimum temperature	Normal mean temperature
May	98.1	69.9	54.0
June	105.9	77.3	91.6
July	102.7	79.2	90.9



Autumn in August, September and October. The season is ushered in by the hot weather rains which do not, however, always reach the valley. October is usually dry. They break over the district in four or five violent storms at intervals of a few days, and two or three inches of rain fall on each occasion. During the first part of this season the sky is more or less uniformly overcast with clouds and the air is steamy and oppressive. Normals of temperature are as follows :—

Month	Normal maximum temperature	Normal minimum temperature	Normal mean temperature
August	99.2	78.0	88.6
September	95.6	70.5	83.1
October	88.2	57.9	73.1

Winter in November, December and January. During this season the weather is variable. The sky is at first hazy, then cloudy, with sometimes slight rain towards the end of December. There is a remarkable absence of wind generally and the air is still and stagnant. The first touch of frost is expected towards the end of November. Normals of temperature are as follows :—

Month	Normal maximum temperature	Normal minimum temperature	Normal mean temperature
November	77.3	46.1	61.7
December	69.0	39.2	53.1
January	63.0	39.6	51.3

The average annual rainfall in the Peshawar valley is 14 inches only. But the experimental groves were irrigated, and never suffered from a deficiency of soil moisture.

III. The Stocks Used.

The trial comprised the following :—

Fifty plants on *Citrus Limonum*, Osbeck, var. This is the “rough lemon” of California and Florida, the “khatti” of the Punjab and North-West Frontier Province, the “kharna” of the United Provinces.

Fifty plants on *Citrus Aurantium*, Linn. This is the “sour” orange of California and Florida, the “khatta” of North-West India, the “narang” of the North-West Frontier Province. It is sometimes called the Seville or marmalade orange.

Fifty plants on *Citrus Limonum*, var. “sweet lime” or “sharbete” or “mitha”. The writer has not seen any accurate botanical description of the “sweet lime”. The fruit is insipid-sweet and is liked by Indians. But it does not appear to be cultivated in Europe, America or Australia.

Fifty plants on *Citrus Medica*, Linn. This is a large coarse citron which is called the “galgal” in North-West India.

IV. The Malta (*Citrus Chinensis*) Grove.

Soil. The following is a report by the Imperial Agricultural Chemist at Pusa on two samples of soils from the Malta grove :—

	0'-1'	1'-3'
Laboratory No.	33-1919	34-1919
	%	%
Moisture (hygroscopic)	0.93	1.02
Combined moisture and organic matter and undetermined	1.38	1.28
Sand and insoluble matters	65.26	64.20
Iron (Fe_2O_3)	4.92	4.78
Alumina (Al_2O_3)	9.61	9.45
Oxide of manganese (Mn_2O_3)	0.02	0.09
Lime (CaO)	9.04	9.92
Magnesia (MgO)	0.68	0.74
Potash (K_2O)	0.94	0.89
Soda (Na_2O)	0.37	0.29
Phosphoric acid (P_2O_5)	0.16	0.14
Carbonic acid (CO_2)	7.58	8.10
Sulphuric acid (SO_3)	0.04	0.03
	100.00	100.00
Available potash (K_2O)	0.017	0.007
„ phosphoric acid (P_2O_5)	0.0038	0.0012
Organic nitrogen	0.05	0.03
Humus	0.80	0.60

REMARKS. The soils are very deficient in available P_2O_5 .

V. The Sangtara (*Citrus nobilis*, Lour.) Grove.

Soil. The following is a report by the Imperial Agricultural Chemist at Pusa on two samples of soil from the Sangtara grove:—

	0"-1'	1"-3'
Laboratory No.	31-1919	32-1919.
	%	%
Moisture (hygroscopic)	1.92	1.62
Combined moisture and organic matter and undetermined	2.65	2.02
Sand and insoluble matters	61.75	62.37
Iron (Fe_2O_3)	5.53	5.29
Alumina (Al_2O_3)	10.88	10.38
Oxide of manganese (Mn_2O_3)	0.03	0.08
Lime (CaO)	9.36	9.64
Magnesia (MgO)	0.87	0.74
Potash (K_2O)	1.12	1.02
Soda (Na_2O)	0.39	0.32
Phosphoric acid (P_2O_5)	0.16	0.16
Carbonic acid (CO_2)	7.21	7.96
Sulphuric acid (SO_3)	0.05	0.02
	100.00	100.00
Available potash (K_2O)	0.015	0.008
„ phosphoric acid (P_2O_5)	0.0016	0.0009
Organic nitrogen	0.05	0.04
Humus	1.35	1.20

REMARKS. The soils are very deficient in available P_2O_5 .



FIG. 1.

Left

Maltas budded on *C. Aurantium*, Linn., the "sour orange" of California and Florida, the "khatta" of North-West India.

Right

Maltas budded on *C. Limonum*, Osbeck, the "rough lemon" of California and Florida, the "khatti" or "kharna" of North-West India.

Age 2 years 3 months from date of planting.

The Maltas on the rough lemon have made an excellent beginning. The Sangtara on this stock did not start very well (Plate VIII, fig. 2).



FIG. 2.

Left

Maltas budded on *C. Limonum*, var. "sharbete," "mitha" or "sweet lime" of North-West India.

Right

Maltas budded on *C. Limonum*, var. "rough lemon" of California and Florida, the "khatti" or "kharna" of North-West India.

Age 2 years 3 months from date of planting.

Here again the "rough lemon" is markedly the better stock.



FIG. 1.

A Malta on *C. Limonum*, var. "rough lemon", "khatti" or "kharna": age 4 years 6 months from date of planting: crop 200 oranges: height 11 ft. 10 in.: breadth at 4 ft. from the ground, 9 ft. 6 in. The "rough lemon" stock certainly appears to give vigour and fruitfulness to the Malta.



FIG. 2.

A Malta on *C. Limonum*, var. "sharbets", "mitha" or "sweet lime": age 4 years 6 months from date of planting: crop 25 fruits: height 5 ft. 9 in.: breadth at 4 ft. from the ground, 5 ft. 4 in. The Malta does not grow at all well on the "sweet lime".

Yet the "sweet lime" proved the best stock for the Sangtara (*C. nobilis*, Lour.) (Plate IX, fig. 1.)



FIG. 1.

A Malta on *C. Aurantium*, Linn., the "sour orange" of California and Florida, the "khatta" of North-West India: age 4 years 6 months from date of planting: crop 10 oranges: height 5 ft. 9 in.: breadth at 4 ft. from the ground, 5 ft.

How exceedingly small and unthrifty the tree is compared with the Malta of similar age which is on the "rough lemon" (Plate II, fig. 1)?

It is extraordinary that this "sour stock", which is perhaps the most popular for the Malta or any sweet orange in America, is so unsuitable for the Malta in North-West India. In discussing stocks for the sweet or Malta orange, Swingle in the "Standard Cyclopædia of Horticulture" says: "No stock is more commonly used in the world's *citrus* regions than the sour orange. Trees propagated on it are long-lived, vigorous and produce fruit of high quality. The stock itself is resistant to mal-di-goma and some other similar diseases which affect other orange stock. Wherever it can be used it should be given preference. It is a congenial stock for all important varieties of oranges, the Satsuma (*C. nobilis*, Lour. var.) alone excepted." Contrary to American experience the sour orange is not a suitable stock for the sweet or Malta orange in North-West India. The Sangtara or Satsuma (*C. nobilis*, Lour.), on the other hand, does well on the sour orange in North-West India.



FIG. 2.

A Malta on *C. Medica*, Linn., the citron or coarse "galgal" of North-West India: age 4 years 6 months from date of planting: crop 16 oranges: height 3 ft. 6 in.: breadth 3 ft. Although it is used by many nurserymen, the citron gives neither vigour nor fruitfulness to the Malta. On the other hand the Sangtara (*C. nobilis*) grows quite well on the citron. But the oranges produced thereby are of very poor quality.



Left

Maltas on *C. Limonum*, var. "rough
lemon," "khatti" or "kharna".
Age 4 years 6 months from date of planting.

Right

Maltas on *C. Limonum*, var. "sharbete"
"mitha" or "sweet lime".



Roots of four distinct *Citrus* stocks, aged 6 years, each of which had a Malta scion or head. Left to right (1) *C. Limonum*, var. "sharbete", "mitha" or "sweet lime" of North-West India. (2) *C. Medica*, Linn., the coarse citron or "galgal" of North-West India. (3) *C. Limonum*, var. "rough lemon" of America, "khatti" or "kharua" of North-West India. (4) *C. Aurantium*, Linn., the sour orange of America, the "khatta" of North-West India.

The sour orange and rough lemon stocks were raised from seed in the spring of 1910. The citron and the sweet lime stocks were propagated from cuttings in the same year. The roots that are shown in the plate are typical of many that were examined. With its great spread of strong well developed roots, the rough lemon could hardly fail to encourage a vigorous, fruitful Malta head. The roots in this picture may be compared with those in Plate XI.

The results of the tests might have been more convincing if all the stocks had been raised from seed. But the sweet lime yields few seeds, which do not germinate well; nor do the young seedlings grow freely. On the other hand, the sweet lime and the citron are easily raised from cuttings and they grow with great vigour and fruit very heavily when they are not budded. It is noteworthy that the Sangara grows and fruits well on the sweet lime stock which has been propagated from a cutting. (Plate IX, fig. 1; and Plate XI, fig. 1.)

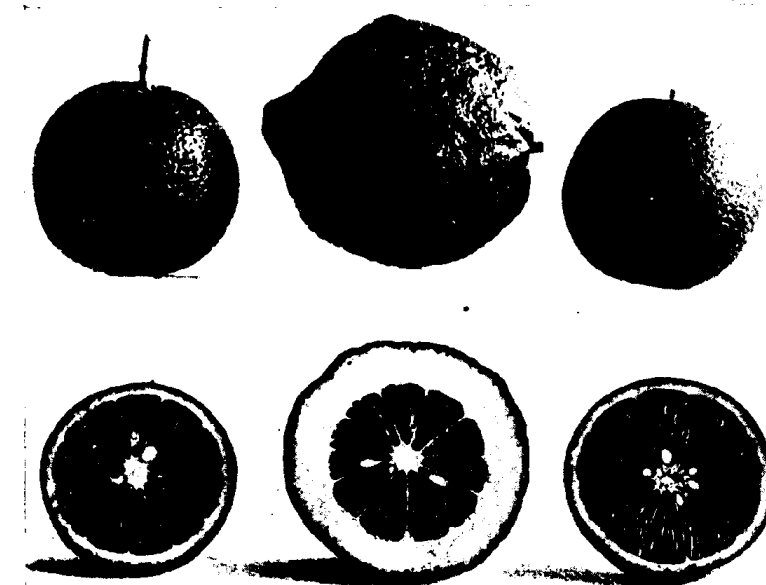


FIG. 1.

In the centre, fruits of *C. Limonum*, the "rough lemon," "khatti" or "kharna"; on the right and left, Malta fruits that were grown on the "rough lemon" stock.

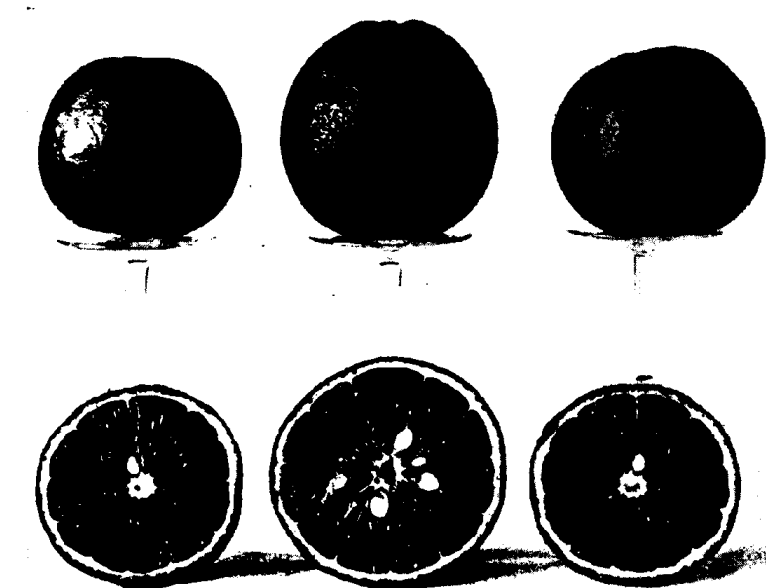


FIG. 2.

On the right and left, *C. Limonum*, var. "sharbete," "mitha" or "sweet lime"; in the centre, Malta that were grown on the "sweet lime". The "sweet lime" has thin, clear, pale lemon-yellow, smooth skin and few seeds. The Malta in the picture has a hollow heart, but this was probably caused by the fruit having been in store for nearly two months.

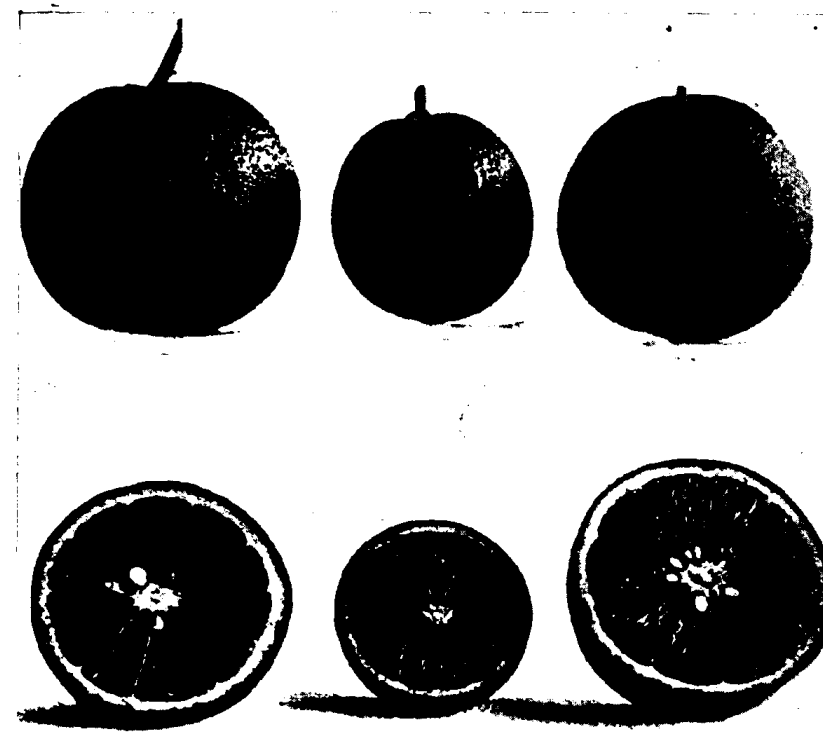


FIG. 1.

On the right and left are Maltas that were grown on *C. Limonum*, var. "rough lemon", "khatti" or "kharna"; in the centre, Maltas that were grown on *C. Limonum*, var. "sharbete", "mitha" or "sweet lime".

On the "sweet lime" stock, Malta fruits from trees which are over six years of age are generally small and, invariably, they contain few seeds.

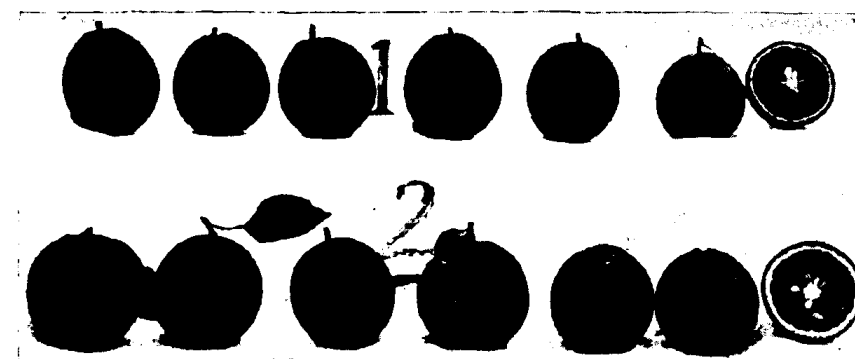


FIG. 2.

Top row. Malta oranges which were grown on the "sweet lime", "mitha" or "sharbete" (*C. Limonum*). On this stock the fruits are smaller and have much thinner skin than Maltas which are grown on any other stock in North-West India. The oranges are distinctly oval in shape, and pale unattractive lemon-yellow in colour. The seeds average about seven in number. The juice is moderately abundant, sweet, and in flavour better than that of oranges on any of the other stocks which were used in the trial.

Bottom row. Malta oranges that were grown on the "rough lemon", "khatti" or "kharna". On this stock the Maltas are large and rather coarse, perfectly globular, rich attractive orange in colour and inclined to be thick-skinned. The juice is very abundant, sparkling and, on young trees especially, somewhat too acid. The seeds are numerous and large, usually numbering about sixteen or seventeen.



FIG. 1.

<i>Left</i> Sangtaras budded on "sour orange." "khatta" (<i>C. Aurantium</i>, Linn.) Age 2 years 3 months from date of planting. Unlike the Sangtara, the Malta entirely fails on the citron. (Plate III, fig. 2.)	<i>Right</i> Sangtaras budded on citron, "galgal" (<i>C. Medica</i>, Linn.).
---	---



FIG. 2.

<i>Left</i> Sangtaras on "sweet lime", "mitha", or "sharbete" (<i>C. Limonum</i>). Age 2 years 3 months from date of planting. The Malta unlike the Sangtara is more vigorous on the "rough lemon" than on the "sweet lime". (Plate I, fig. 2, and Plate IV.)	<i>Right</i> Sangtaras on "rough lemon", "khatti" or "kharna" (<i>C. Limonum</i>).
--	---



FIG. 1.

A Sangtara on the "sweet lime", "sharbete," or "mitha" (*C. Limonum*); age 7 years from date of planting. On the "sweet lime" the Sangtara is tall, and its branches, lacking strength, are easily broken by the wind or weight of fruit. At 6 years of age the crop was 500 good oranges per tree. It is unfortunate that the "sweet lime", which gives vigour with abundant fruit of high quality to the Sangtara, only produces a weak Malta tree with, however, fruit of very high quality. (Plate I, fig. 2; Plate II, fig. 2; and Plate IV.)



FIG. 2.

A Sangtara on the "sour lime" or "khatta" (*C. Aurantium*, Linn.); age 7 years from date of planting. The picture very well shows the vigorous compact habit which the Sangtara assumes when it is budded on the "sour orange". Yet the Sangtara (*C. nobilis*, Lour.) is not satisfactory on the "sour orange" in California and Florida. The Malta, on the other hand, does well on the "sour orange" in the orange States of America, but fails entirely on this stock at Peshawar. (Plate III, fig. 1.)



FIG. 1.

A Sangtara on the "rough lemon", "khatti" or "kharna" (*C. Limonum*, Osbeck). At the age of 7 years all of the trees in the trial were dying or dead. They began to decline after fruiting heavily in their sixth year, when the average crop per tree was 321 fruits.

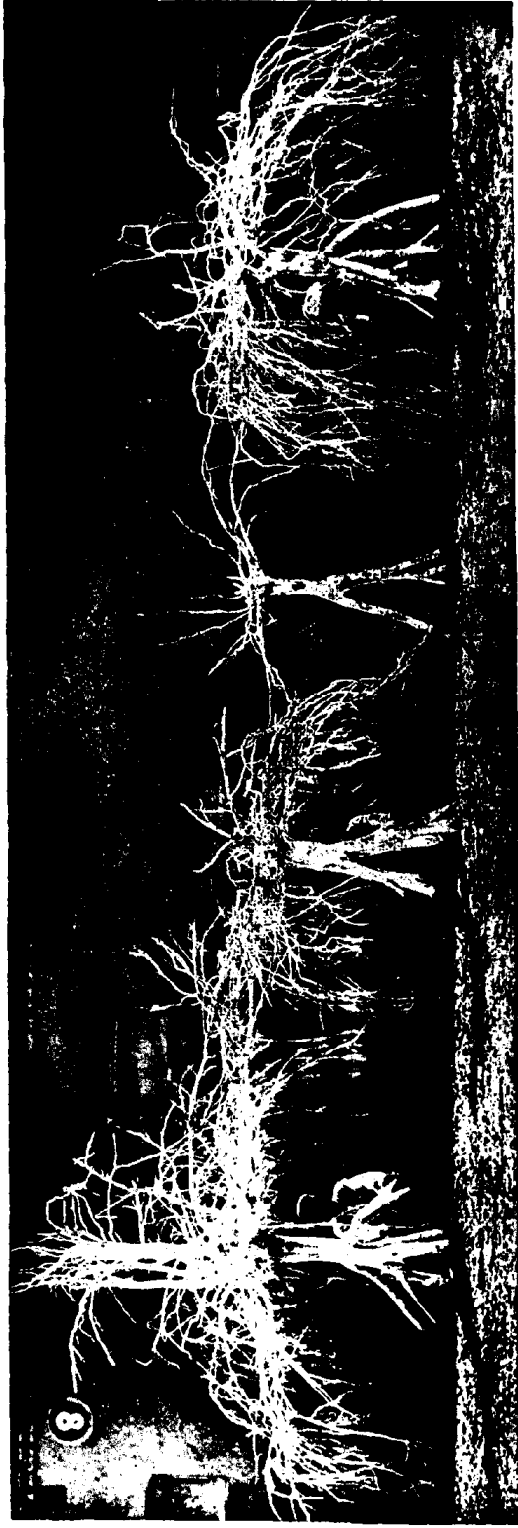
It is truly extraordinary that the "rough lemon" which gives great vigour with fruitfulness to the Malta is totally unsuitable for the Sangtara. (Plate I; Plate II, fig. 1.)



FIG. 2.

A Sangtara budded on the citron or "galgal" (*C. Medica*, Linn.); age 7 years from date of planting. On this stock the Sangtaras were vigorous and healthy until they attained 6 years of age. Then some of the branches began to die. Very few oranges were produced until the sixth year. The average crop per tree was then 440 fruits, but these were dry, flavourless and unsaleable.

It is noteworthy that the Malta hardly grows at all when it is budded on the citron. (Plate III, fig. 2.)



Roots aged 7 years which had Sangtara (*C. nobilis*, Lour.) heads.

4

3

2

1



Roots aged 6 years which had Malta (*C. chinensis*, Osbeck) heads.

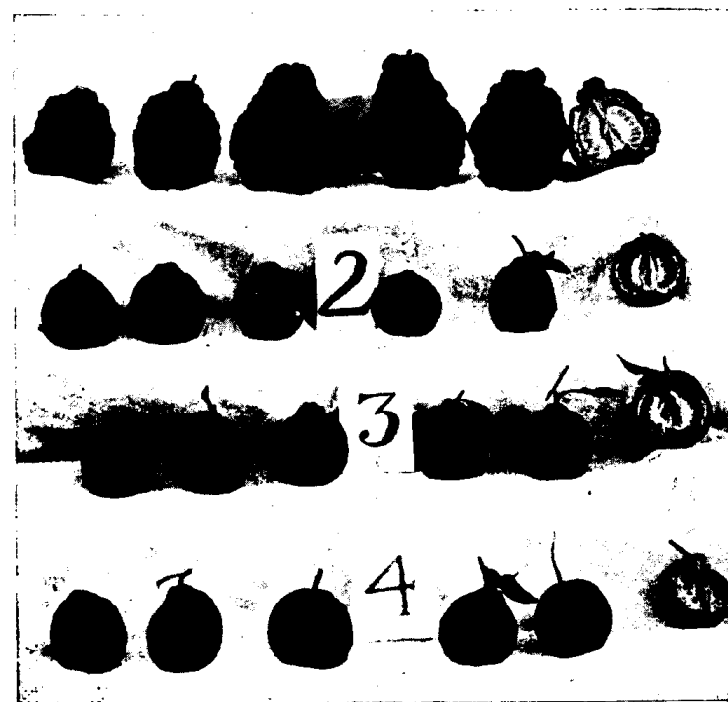
4

3

2

1

Reading from left to right, (1) "sour orange" or "khatta" (*C. Aurantium*, Linn.), (2) citron or "galgal" (*C. Medica*, Linn.), (3) "rough lemon" "khatti" or "kharna" (*C. Limonum*, Osbeck), (4) "sweet lime" "mitha" or "sharbete" (*C. Limonum*). It seems incredible that the roots numbered 1, 2, 3 and 4 in the upper and lower pictures are the same stocks, altered completely in vigour and much in habit by the scions they respectively supported. The reciprocal effects of the stock on the scion has perhaps never been more clearly shown than in these two pictures.



Top row. Sangtara oranges from a tree budded on the citron or "galgal" (*C. Medica*, Linn.). The fruits were exceedingly coarse in appearance and, as they had very little juice, they were unsaleable. The average number of seeds per fruit was eight.

Second row. Sangtara oranges from a tree budded on the "sour" orange or "khatta" (*C. Aurantium*, Linn.). The fruits were fairly juicy and the skin thin and tight for this class of fruit. The flavour was quite good. The average number of seeds per fruit was nine.

Third row. Sangtara oranges from a tree budded on the "rough lemon", "khatti" or "kharna" (*C. Limonum*). Oranges on this stock closely resembled those produced by the "sour orange" stock. The average number of seeds per fruit was ten.

Fourth row. Oranges from a tree budded on the "sweet lime", "mitha" or "sharbete" (*C. Limonum*). On this stock the fruits produced were larger and better in flavour than those on any other stock. The oranges were inclined to be too loose in skin and somewhat coarse in appearance.

VI. Summary of Conclusions.

THE MALTA.

Of all the orange stocks which are used by nurserymen in North-West India, the "rough lemon," "khatti" or "kharna" (*C. Limonum*, Osbeck, var.) is the one which gives greatest vigour and fruitfulness to the Malta.

The "sweet lime," "mitha" or "sharbete" (*C. Limonum*, var.), is suitable for the Malta in the small private garden only, where a dwarf tree with a few oranges of high quality are desired: the stock is unsuitable for the commercial Malta grove.

The citron or "galgal" (*C. Medica*, Linn.) and the "sour orange" or "khatta" (*C. Aurantium*, Linn.) are not suitable stocks for the Malta in North-West India.

THE SANGTARA.

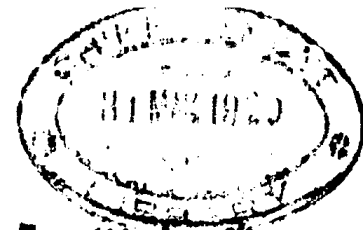
In almost all respects the "sweet lime", "sharbete" or "mitha" (*C. Limonum*, var.) is the best stock for the Sangtara.

The "rough lemon," "khatti" or "kharna" (*C. Limonum*, Osbeck, var.) and the citron or "galgal" (*C. Medica*, Linn.) are not suitable stocks for the Sangtara.

The stock and scion influence each other profoundly in producing vigour and fruitfulness in the orange tree, and in developing colour, shape, size, quality, flavour, beauty and seedlessness in the fruit.

Tests of stocks should be made wherever the orange is grown in India.

Bulletin No. 94



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Agricultural Research Institute, Pusa

**A Preliminary Note on the Behaviour in North
India of the First Batch of Sugarcane Seedlings
distributed from the Sugarcane-breeding
Station, Coimbatore**

BY

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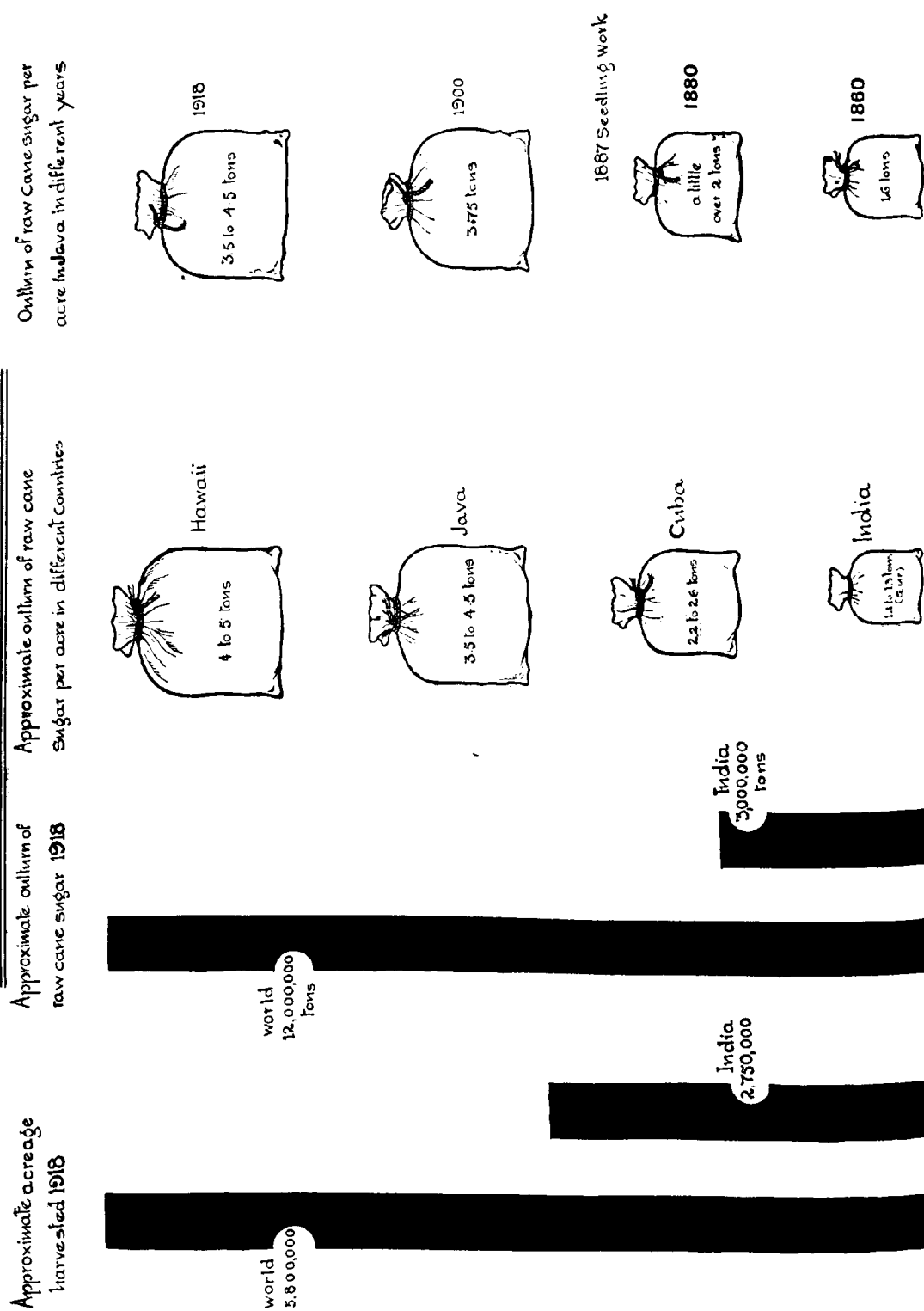
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A FEW SUGARCANE FIGURES



A Preliminary Note on the Behaviour in North India of the First Batch of Sugarcane Seedlings distributed from the Sugarcane-breeding Station, Coimbatore.

(Received for publication on 9th October 1919.)

Introduction.

THE steady increase in the quantity of white sugar imported into India, together with the depressing effect which such importations, combined with their low prices, was having on the indigenous Gur (crude sugar) industry, made the Government of India, in the year 1911, direct their attention to this important industry with a view to try to put it on a satisfactory basis. The discussions on the subject, at the meeting of the Board of Agriculture in 1911, showed that the problem will have to be tackled in at least two directions, viz., (1) the manufacturing or the mechanical aspect, with a view to improve the present wrong or wasteful methods; and (2) the agricultural, including the botanical aspect, with a view to improve the varieties at present grown and carry out other improvements in the methods of culture.

That the sugar industry in India is, at present, in a bad state, is evident from the figures given in the chart opposite. It is seen that, though India can boast of nearly half the world's acreage under cane, her output is only a fourth. It further contrasts the yield per acre in India with those obtained in the other cane countries, a contrast which gets all the more emphasized to India's disadvantage, when we remember that, whereas in the other countries the figures represent the quantity of refined sugar, the Indian figures are those for *gur* or *jaggery*, a more impure product. But we take heart from the fact that Java, which in the year 1860 was able to produce only about as much sugar per acre as India at the present day, has since been able to force up production in such a manner that in the year 1918 that country ranked second only to Hawaii in the matter of production per acre. In the case of India, it is doubtful, if we shall ever be able to rise to the level of the other tropical countries owing to insuperable difficulties of climate, but let us remember, that even a small increase in production will go a great way to ameliorate the position of India as a sugar-producer.

From the map of India opposite it is further evident that, to improve the Indian industry, attention will have to be concentrated on North India, chiefly the United Provinces, because (1) that province contains nearly half of India's acreage under cane, and (2) it is a vital industry in that province and sugarcane is the chief rent-paying crop, a crop "which could not easily find an equivalent in any other crop grown there." The Punjab and Bengal would come next with their one-third to half million acres under cane.

The purely botanical work, viz., that of breeding a better cane for North India, was entrusted to a breeding station which in November 1912 was started at Coimbatore in the Madras Presidency under Dr. C. A. Barber, C.I.E., who was appointed Government Sugarcane Expert for all-India but with headquarters at Coimbatore. This was sought to be attained by raising canes from seed, instead of from cuttings as is ordinarily done by the ryot, a method which had already proved its utility in the other sugarcane countries of the world. The difficulties experienced in previous trials at raising cane seedlings were soon overcome—in fact even before the land intended for the station was taken possession of—and we soon had a very large number of seedlings, some of them the much-desired crosses between the thin indigenous North Indian and the thick tropical kinds.¹ But it was not until the February of 1918 that the station was able to send out the first batch of selected seedlings for trial to North Indian farms.

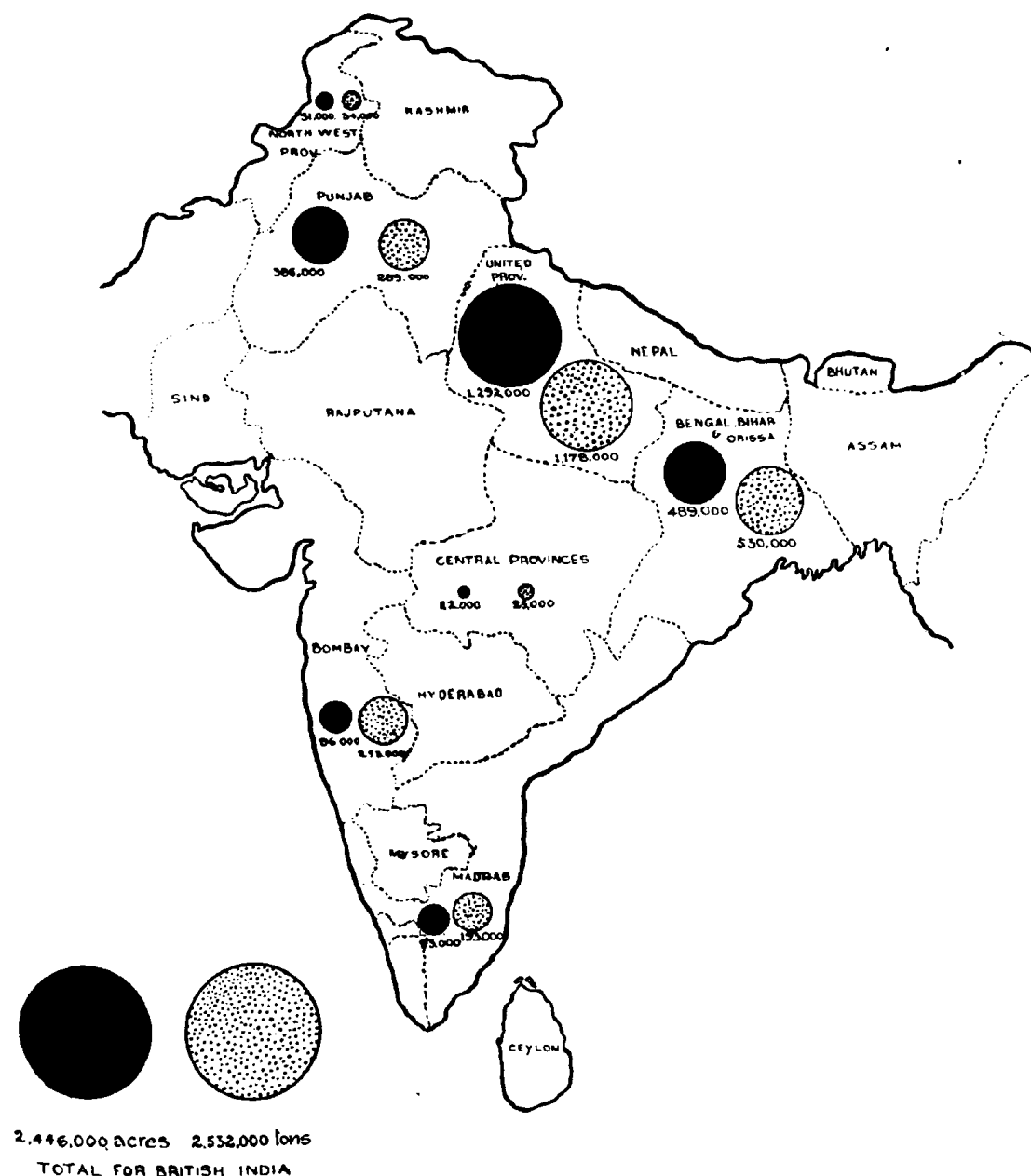
In this bulletin are presented the results of this first year's trials. The subsequent behaviour of the Coimbatore productions, when introduced into North India, has always been a matter of anxious consideration for the station; but it is fortunate that the first year's results appear to be, on the whole, encouraging. It is thought that the results thus published will not only enable the farms to take a more intelligent interest in the growing of these seedlings, but also to offer valuable suggestions for the future work of the station, which, of necessity, had to be located far away from the area for which the seedlings are intended. The station has now reached a stage when a closer connection with the North Indian farms is needed, and constant reports on the progress of the distributed seedlings will greatly help to shape the future lines of work at the station. A few photographs are included to illustrate the growth of the seedlings in the different North Indian farms.

Selection of Coimbatore as the site for the all-India Sugarcane-breeding Station.

Though the main object of the work at the Sugarcane-breeding Station, Coimbatore, was to produce for North India a cane better than

¹ The details of this work are fully described in a Memoir by Dr. C. A. Barber, C.I.E., *Mems. of the Dept. of Agri. in India, Bot. Series*, Vol. VIII, No. 3.

Map of India showing the acreage under cane & outturn of Gur or Jaggery in the different provinces.



The shaded circles represent the acreages under cane in the different provinces and those with dots the total yield for the province in tons. The figures are for the quinquennium ending 1916-17.

the type now grown in that locality, the station itself had to be located at Coimbatore because the sugarcane rarely flowers in North India, and, even if it does, does not generally set seed. The selection of Coimbatore as a site for the station was amply justified soon after its foundation by the very large number of seedlings that it was found possible to raise there.

A minor disadvantage.

This selection—which as shown above was inevitable—carried with it one disadvantage, viz., we had no knowledge as to how the seedlings bred and grown at Coimbatore might behave later when introduced into North India. This was fully recognized even at the outset, and, to gain some knowledge on this point, a set of seedlings—six in number—was introduced into North Indian farms even as early as 1914, i.e., as soon as ever material was available for distribution.

The first batch of seedlings was in no way selected and consequently the various farms were requested to reject them from cultivation as soon as the first set of selected seedlings was available for distribution in February 1918. One of these, however, M.2, a Kaludai Boothan seedling raised in 1911-12, is still grown at Shahjahanpur as a wind-break on account of its good growth and habit (Plate V).

The first seedlings raised at the Station were mostly thick and hence unsuitable for North India.

During the early years of the station the varieties that flowered were mostly thick canes and we had but little control over the parents. The seedlings produced were consequently mostly thick and so unsuitable for introduction into North India. Later on, however, it was found possible to induce many of the thin canes also to flower at the station. This, together with the steadily increasing knowledge of the different parents¹ gained in the meanwhile, enabled the station to plant out, for the season 1917-18, a crop of seedlings more than 50 per cent. of which were of a type suitable to be grown in North India.²

The first distribution to North India was made in February 1918.

This enabled the station to send out its first batch of selected seedlings in February 1918. But a new difficulty presented itself. The final

¹ Venkatraman, T. S. "Study of arrowing in the sugarcane." *Agri. Journal of India*, Special Indian Science Congress Number, 1917.

² It is perhaps worth mentioning here that though it has been possible to effect crosses, between thick canes and most of the groups that occur in North India, the two classes represented by (1) Nargori, Kewali, Sararoo, etc., and (2) Mungo, Hemja, Rheora, Burli Kuswar, etc., offer special difficulties because these do not flower under Coimbatore conditions and, even if they do, produce only unhealthy flowers. These are at the same time very desirable parents, and any information on the arrowing (flowering) of these varieties in any locality will be welcome.

chemical analyses figures for the 1917-18 crop would be available only in March-April, while the North Indian farms wanted the seedlings at least in February—the general planting season in North India. At this stage the accumulated analytical experience was called in for aid. It was found that the final analyses figures varied correspondingly with the results obtained in February when the crop is on the whole immature. This justified the distribution of the seedlings on a comparative basis and saved a whole year for the work.

A statement is appended giving the distribution as made in February 1918. In response to individual requests from the different farms a certain amount of information about the parentages of the different seedlings is also included. Besides the thin seedlings and thin canes mentioned in this statement, certain thick seedlings and varieties were distributed to certain Madras farms, to Hebbal and to Manjri, but their growth in this, the first year, does not justify their inclusion in this report.

Statement showing the distribution of thin seedlings and varieties in February 1918.

(A cross mark placed against a locality indicates that the cane was distributed to that locality.)

Name of seedling or variety	PLACES TO WHICH DISTRIBUTED.								Notes on parentage, origin, etc.	
	Bangalore	Manjri	Gwalior	Gurdaspur	Shajahanpore	Cawnpore	Pusa	Sepaya		Tharsa
Co. 201	x	x	x	x	x		x	x	x	Panahi seedling. General collection. Selfed or possible cross with M. 2 or M. 1017, two vigorous Madras seedlings of rather low sucrose.
Co. 202	x	x	x	x	x		x	x	x	Chittan seedling. General collection. "Rogue" type. Chittan is a thick striped cane occurring round about Coimbatore.
Co. 203	x	x	x	x	x		x	x	x	Saretha seedling. General collection. Very likely selfed.
Co. 204	x	x	x	x	x		x	x	x	Chittan seedling. General collection. Some vigorous Naanal seedlings, which possess an abundance of healthy pollen, were flowering on the windward side; and cross-pollination with these is highly probable. Arrows of Chittan, collected under conditions, where selfing was the most likely, gave a different type of seedlings.
Co. 205	x	x	x	x	x		x	x	x	Vellai x Saccharum spontaneum. Bagged cross. The mother arrow possessed very few (2 per cent.) slightly open anthers, and as other stray pollen was kept out by enclosing the mother arrow in a muslin bag it may be taken to be a cross between the parents indicated.
Co. 206	x	x	x	x	x		x	x	x	Ashy Mauritius seedling. General collection. "Rogue" type.

Panahi seedling. General collection.
 Selfed or possible cross with M. 2 or M. 1017, two vigorous Madras seedlings of rather low sucrose.
 Chittan seedling. General collection.
 "Rogue" type. Chittan is a thick striped cane occurring round about Coimbatore.
 Saretha seedling. General collection.
 Very likely selfed.
 Chittan seedling. General collection.
 Some vigorous Naanal seedlings, which possess an abundance of healthy pollen, were flowering on the windward side; and cross-pollination with these is highly probable. Arrows of Chittan, collected under conditions, where selfing was the most likely, gave a different type of seedlings.
 Vellai x Saccharum spontaneum. Bagged cross. The mother arrow possessed very few (2 per cent.) slightly open anthers, and as other stray pollen was kept out by enclosing the mother arrow in a muslin bag it may be taken to be a cross between the parents indicated.
 Ashy Mauritius seedling. General collection. "Rogue" type.

Statement showing the distribution of thin seedlings and varieties in February 1918—cont'd.

Name of seedling or variety	PLACES TO WHICH DISTRIBUTED.							Notes on parentage, origin, etc.
	Bangalore	Manjri	Gwalior	Gurdaspur	Shajehanpore	Cawn-pore	Pusa	
Co. 207			X		X		X	J.213 X Saretha. Unbagged cross. The mother arrow had practically no healthy pollen, therefore not selfed. Saretha pollen was constantly dusted over the stigmas when they were receptive, so Saretha is the likeliest male parent. The mother arrow was not protected by muslin bag, so remote chances of cross-pollination with other varieties, chiefly M.2.
Co. 208		X	X		X	X	X	J.213 seedling. General collection. This variety has no healthy pollen, therefore not selfed. Likely crosses with M.2 or M.1017, two vigorous Madras seedlings of rather low sucrose which were flowering freely in the neighbourhood. Khelia seedling. General collection. Very likely selfed. This variety possesses abundant fertile pollen and no others were flowering in the vicinity at the time.
Co. 209			X		X		X	J.213 seedling. General collection. This variety has no healthy pollen, therefore not selfed. Likely crosses with M.2 or M.1017, two vigorous Madras seedlings of rather low sucrose which were flowering freely in the neighbourhood.
Co. 210		X	X		X	X	X	Green Sport of Striped Mauritius X Saretha. Unbagged cross. The mother variety has a fair quantity of its own pollen, so may be a selfed seedling. The stigmas were constantly dusted with Saretha pollen, so Saretha is a likely male parent. With such an abundance of fertile pollen, possibility of cross-pollination with other varieties flowering in the vicinity is very remote.
Co. 211					X		X	

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Co. 212	X	X	X	X	X	X	X	J.213 X M.2. Unbagged cross. The mother variety has no fertile pollen, so not selfed. Probably a cross with M. 2 which was the only variety flowering in the neighbourhood at the time.
Co. 213			X	X	X	X	X	J.213 X Kansar. Unbagged cross. The mother variety has no fertile pollen, so not selfed. May be a cross with Kansar whose pollen was artificially dusted over the stigmas, or with M.2 which was flowering freely near by.
Co. 214				X	X		X	Striped Mauritius X } Unbagged cross. (Saretha X Sacch. } Notes on parentage similar to those of Co. 211.
Co. 215				X	X	X	X	Green Sport of Striped Mauritius X Saretha
Co. 216				X	X	X	X	Chittan seedling. General collection. This variety possesses an abundance of fertile pollen, so very likely selfed. Possibility of cross-pollination with Karun or Kaludai
Co. 1	X	X	X	X	X	X	X	Boothan which were flowering freely in the neighbourhood. This is a medium thick cane of high sucrose content (over 20 per cent. in the juice in a field test).
Kassoer	X	X	X	X	X	X	X	Two indigenous canes of Java. Kassoer possesses an excellent habit and is now being used as a female parent owing to the absence of fertile pollen of its own.
Taboe								These Java seedlings have been growing at the station from the commencement. These were distributed, partly because a few of them were reported to be doing well in North India and partly for comparison with the distributed Co. seedlings.
Monjet.								
J. 3a	X	X	X	X	X	X	X	
J. 36	X	X	X	X	X	X	X	
J. 139	X	X	X	X	X	X	X	
J. 213	X	X	X	X	X	X	X	
J. 247								

COIMBATORE SUGARCANE SEEDLINGS IN NORTH INDIA.

NOTE 1. "General collection" indicates that the arrows were collected in the field without any control over the male parent.

NOTE 2. "Rogue" is the term applied to a seedling of thick parentage in a "General collection", which shows a remarkable resemblance to the North Indian thin cane, being much thinner and more vigorous than the parent. (Vide Bateson and Pilew, "Journal of Genetics", July 1915, page 13).

NOTE 3. In the above statement wherever crosses are involved the two parents are separated by a cross mark; the first named represents the female parent and the second the male parent.

NOTE 4. For explanation of "Bagged" and "Unbagged" crosses see the text.

Explanation of the terms "Bagged" and "Unbagged" crosses with a short note on the methods of crossing in sugarcane current at the Cane-breeding Station.

These two terms require a certain amount of explanation for their being properly understood. Crossing in the sugarcane presents peculiar difficulties, as emasculation is practically entirely ruled out owing to the extreme delicacy of the floral structures; even a prolonged bending of the main axis has been known to result in the complete drying up of the arrow. Fortunately, however, we have in the cane, certain varieties which are male sterile in different degrees. If this male sterility is absolute, we can, by enclosing such flowers in muslin bag and introducing into it some known pollen, obtain a cross, about the male and female parentages of which we can assume a high degree of certainty. Such a one is Co. 205. If, however, the mother shows a certain degree of male fertility and we introduce some other known pollen—keeping the arrow under bag—the resultant seedlings will either be selfed or cross-pollinated with a known father. Both these are referred to as "bagged crosses" in the above statement.

It was found, however, that bagging an arrow frequently exerted an adverse influence on its seed-setting¹; and therefore in later years crossing was frequently done by merely marking the mother arrows in the field and keeping them constantly dusted with some known pollen till the stigmas were found to wither. These are called "unbagged crosses." In these the male parents are only probable as there is an ever-present possibility of any stray wind-borne pollen getting access to the stigmas. The parentage becomes yet more uncertain, when, as in the cases of Cos. 214, 215, and 216, the mother arrow possesses fertile pollen of its own, for there then arises three different distinct possibilities as to the parentage of the resultant seedlings.

- (a) Selfed,
- (b) Cross with the pollinated father,
- (c) Cross with some unknown parent through some stray wind-borne pollen.

The above remarks may perhaps convey to the reader an impression as to the futility of parentage notes in cases like those of Cos. 214, 215 and 216, but against it the following considerations are advanced:—

- (1) In the absence of more accurate information, it is an advantage to know at least the most likely parents, in following the behaviour of such seedlings in future years.

¹ Venkatraman, T. S. "Study of arrowing in the sugarcane." *Agri. Journal of India*, Special Indian Science Congress Number, 1917.

- (2) In the character of the resultant seedlings, we occasionally get some indications by which it is possible to guess the male parents with a certain degree of certainty.
- (3) With the Breeding Station sanctioned only for a limited period, the purely utilitarian aspect had to be prominently kept in view, and, so far, the results would appear to justify the means employed.

Selection of types for each locality.

In the distribution an attempt was made to pick out the seedling with an eye to the cane now successfully grown in each locality, but it is felt that it will be sometime before much specialisation is possible in this direction. The annual visits by the staff of this office and the periodic reports from the different farms will, it is hoped, soon yield valuable data on this question.

A method to minimise "personal equation" in the selection work at the Cane breeding Station.

One very important qualification for a breeder is the ability to quickly compare with one another different plants or strains with a view to selection and propagation. Such a valuation has often to be made on a large number of characters and this is a matter in which "personal equation" is likely to play not an insignificant part. That this work of comparing and selecting is not a light one at the Cane-breeding Station, will be readily conceded, when it is realized that each year the station has as many as 5,000 new seedlings and 600 already selected ones, in different stages of filtration, from which to pick material for further trial and propagation.

The method described.

To systematize this work as far as possible and to guarantee that each character gets its due recognition in the final estimate a system of marking was introduced. A list was prepared of the characters considered important in forming the estimate and each allotted a maximum of ten marks. All the seedlings were then examined for some particular character at a time and marks noted against each in proportion to its merits. This process was then repeated for each of the other characters on the list and the totals made up for each seedling. A large number of marks, in the totals thus arrived at, will indicate the satisfactory nature of the seedling in most or all the characters and it is therefore safe to make the selections on this basis.

The behaviour of the distributed seedlings in the different North Indian farms during the first year of trial.

This method, having proved itself useful at the Cane-breeding Station for some time, was adopted in a tour to North India (in December 1918 to January 1919) undertaken with the special object of studying the behaviour of the distributed seedlings in that locality. Besides notes on health, height, arrowing, length of formed cane, thickness of canes, etc., marks were given for four important field characters, viz. :—

- (1) Stand or germinating capacity.
- (2) Vigour or weight of harvest.
- (3) Habit, i.e., whether the canes in the clump stand upright, or are slanting, or fall about in all directions seriously interfering with subsequent cultural operations. Further the straightness of canes is a character of considerable importance in (1) the transport to the factory in carts, and (2) the packing on the hoppers at the mill.
- (4) Tillering, i.e., the number of canes per stool at harvest. This is included in No. 2, but was thought of sufficient importance to be separately considered.

The table hereunder gives the marks obtained by each distributed seedling for the above four characters in each of the farms visited. In the remarks column will be found some tentative notes on the parentages considered likely to be useful in the different tracts.

Statement of marks obtained by the distributed seedlings in the different farms with notes on the parentages likely to be useful in the different tracts. (See Plates I, II, III, IV, V, VI for comparison of growth).

Co. Nos.	Sugarcane Breeding Station, Coimbatore	Bangalore	Maulri	Thara	Pusa	Sepaya	Cawnpore	Shahjhanpur	Gurdaspur	REMARKS
Co. 201	32 8, 10, 8, 8.	30 8, 7, 8, 7.	36 10, 9, 10, 7.	32 9, 7, 9, 7.	28 6, 7, 8, 7.	32 9, 8, 9, 6.	..	35 8, 9, 9.	23 6, 6, 6, 5.	(1) The top figure against each seedling represents the aggregate marks obtained by the seedling for all the four characters. The bottom figures represent the marks for each character, for (1) Stand, (2) Vigour, (3) Habit and (4) Tillering. The maximum for each character was fixed at ten.
Co. 202	39 10, 10, 9, 10.	23 6, 6, 4, 7.	35 10, 9, 8, 8.	20 7, 9, 5, 8.	24 7, 8, 6.	33 9, 8, 9, 7.	..	35 10, 8, 7, 10.	33 8, 9, 10, 6.	(2) Data placed against a locality indicates that the seedling was not available for examination generally because of not having been distributed to that locality.
Co. 203	25 6, 7, 8, 4.	25 6, 7, 4, 8.	28 8, 6, 6, 8.	17 3, 4, 4, 6.	13 3, 4, 3, 3.	..	..	16 6, 4, 3, 3.	12 4, 1, 5, 2.	(3) The distributed seedlings included two "Rogues"—Co. 202 and Co. 206—and their satisfactory behaviour in most of the farms justified the hopes placed in them on their first appearance.
Co. 204	34 8, 10, 9, 7.	25 7, 6, 6, 6.	36 10, 8, 9, 9.	25 4, 6, 6, 9.	15 3, 6, 3, 3.	29 7, 7, 8, 7.	..	32 8, 8, 10, 6.	29 7, 7, 10, 5.	(4) "Rogues" and Crosses with Sacch. spontaneum (Co. 206) are apparently the most promising lines for the Punjab as that tract requires the hardest kinds.
Co. 205	29 6, 7, 9, 7.	26 7, 6, 6, 7.	38 10, 10, 10, 8.	29 7, 8, 5, 9.	13 3, 4, 3, 3.	31 9, 9, 6, 7.	..	25 6, 7, 6, 6.	34 8, 9, 10, 7.	(5) For the United Provinces J. 213 crosses deserve a full trial.
Co. 206	34 7, 9, 10, 8.	32 8, 8, 8, 8.	39 10, 9, 10, 10.	33 8, 8, 9, 8.	29 7, 6, 9, 7.	33 8, 7, 10, 8.	..	31 6, 7, 9, 7.	33 8, 9, 9, 8.	(6) But for the unfortunate tendency to smut shown by J. 213 seedlings (vide notes elsewhere in this bulletin) this would appear to be a useful parent for Sepaya, Maulri and Thara.
Co. 207	31 7, 9, 8, 7.	..	..	27 7, 9, 5, 6.	15 4, 5, 3, 3.	24 8, 6, 5, 5.	..	22 6, 5, 5, 8.	..	(7) The seedlings showed very poor growth at Gwalior and no notes were recorded for that locality.
Co. 208	31 9, 8, 8, 6.	..	37 10, 9, 8, 10.	35 8, 9, 9, 9.	24 7, 9, 4, 4.	30 8, 6, 9, 6.	31 9, 7, 7, 8.	40 10, 10, 10, 10.	..	
Co. 209	31 8, 9, 7, 7.	..	..	29 7, 9, 5, 8.	21 6, 7, 3, 5.	..	..	23 8, 7, 5, 8.	..	
Co. 210	32 8, 10, 7, 7.	..	36 10, 10, 10, 6.	36 9, 10, 8, 9.	28 9, 9, 3, 7.	34 9, 9, 8, 8.	31 3, 10, 8, 10.	28 6, 8, 6, 8.	..	
Co. 211	36 8, 9, 5, 4.	..	..	..	7 4, 5, 4, 4.	23 6, 7, 5, 5.	..	17 5, 4, 4.	..	
Co. 212	31 9, 8, 8, 6.	..	34 10, 8, 8, 8.	..	17 4, 5, 4, 4.	32 8, 8, 9, 7.	20 4, 4, 5, 7.	23 7, 6, 8, 7.	..	
Co. 213	30 8, 9, 7, 6.	..	..	..	30 7, 8, 7, 8.	28 8, 8, 6, 6.	..	30 6, 8, 10, 6.	24 6, 5, 8, 5.	
Co. 214	30 7, 9, 7, 7.	..	..	..	20 9, 5, 3, 3.	30 10, 7, 7, 6.	..	24 7, 5, 7.	20 7, 0, 8, 5.	
Co. 215	31 9, 9, 7, 6.	..	..	..	18 6, 5, 2.	22 9, 5, 4, 4.	..	21 6, 6, 5, 4.	25 7, 4, 7, 7.	
Co. 216	27 5, 10, 4, 5.	..	..	..	23 5, 8, 4, 5.	29 8, 10, 5, 9.	..	19 4, 6, 8, 6.	23 6, 4, 7, 6.	

"Arrowing" and "smutting" of the distributed seedlings in the different farms.

Tendency to arrow and liability to smut are serious drawbacks in any distributed seedling and the statement below gives the record for the seedlings in respect of these two characters at the time of examination. The upper figure gives the note on "arrowing" and the lower one on "smutting."

Distributed Co. seedlings	Character studied	Cane-breeding Station, Coimbatore	Bangalore	Manjeri	Gwalior	Tharua	Pusa	Sepaya	Cannopore	Shahjahanpur	Gurdaspur	REMARKS
Co. 201	Ar.	Nil	Few	Prof.		Nil	Nil	Nil	..	Nil	Nil	(1) Note the special liability to smut in the Saretha seedling—Co. 203, and Khelia seedling—Co. 209. (2) Seedlings with J. 213 or Saretha as either of the parents show a similar liability to smut. The above parents will, therefore, have to be used with very great caution in breeding cane for a locality where smut is a serious consideration.
Co. 202	Sm.	Nil	Nil	Nil		1 sht.	Nil	Nil	..	Nil	Nil	
Co. 203	Ar.	Few	Prof.	Prof.		Prof.	Mod.	1 Ar	..	Nil	Nil	
Co. 204	Sm.	Nil	Nil	Nil		1 sht.	Mod.	.. ¹	..	Nil	Nil	
Co. 205	Ar.	Few	1 sht.	Nil		Nil	1 sht.	Bad	..	Bad	Nil	
Co. 206	Sm.	Prof.	Prof.	Prof.		Prof.	Nil	Nil	..	Nil	Nil	
Co. 207	Ar.	Nil	Nil	Nil		Nil	Nil	Prof.	..	Nil	Nil	
	Sm.	Nil	Prof.	Prof.		Prof.	Prof.	Nil	..	Nil	Nil	
	Ar.	Nil	Nil	Nil		Nil	Nil	Nil	..	Nil	Nil	
	Sm.	Prof.	Prof.	Prof.		Prof.	Prof.	Prof.	..	Nil	Nil	
	Ar.	Nil	Nil	Nil		Nil	Nil	Nil	..	Nil	Nil	
	Sm.	Nil	Nil	Nil		Nil	Nil	Nil	..	Nil	Nil	

conditions and no notes could be recorded.

Co. 208	Ar.	Nil	..	Few	The seedlings showed poor growth because of abnormal weather												Nil	..
Co. 209	Sm.	Nil	..	Nil													1 sht. ?	..
Co. 210	Ar.	Nil	..	..													Nil	..
Co. 211	Sm.	Nil	..	..													Bad	..
Co. 212	Ar.	Few	..	Few													Nil	..
Co. 213	Sm.	Nil	..	Nil													Nil	..
Co. 214	Ar.	Few	..	..													Nil	..
Co. 215	Sm.	Nil	..	..													1 sht. ?	..
Co. 216	Ar.	Few	..	..													Nil	..
	Sm.	Nil	..	..													Nil	..
	Ar.	Few	..	..													Nil	..
	Sm.	Few	..	..													Nil	..
	Ar.	Few	..	..													Nil	..
	Sm.	Few	..	..													Nil	..
	Ar.	Few	..	..													Nil	..
	Sm.	Nil	..	..													Nil	..

¹ These seedlings were destroyed at this farm owing to the appearance of smut.

Prof. = Profuse.

Mod. = Moderate in number or quantity.

Sht. = Shoot

.. = The seedling was not available for observation generally because of not having been distributed.

Similarly, tendency to smut in a seedling is not apparently a matter for serious consideration in the Punjab. It is a very serious drawback in a seedling intended to be distributed to the United Provinces, Sepaya—where the Farm Superintendent entirely destroys the crop on the first appearance of smut in the field—and Pusa. In places like Manjri, Hebbal and Tharsa it is apparently not of much account. In some of these localities the late-formed lateral shoots often regularly show smut and the crop does not appear to suffer much in consequence.

Chemical analyses of the distributed seedlings.

Lastly the sucrose contents of the seedlings is a character of great importance and the present distributions have accordingly been analysed in the different farms. It is to be remembered, however, that the analyses figures are not strictly comparable, because, (1) of the smallness of the samples analysed, (2) of the possibility that at the time of analyses the seedlings may not have been equally ripe in all the places, (3) of differences in the methods of analyses followed at the various stations. The various officers have very kindly forwarded the analyses figures for comparison and these are published in the statement herewith appended.

Character of the juice of the Coimbatore seedlings in different localities.

[illegible]

Character of the juice of the Coimbatore seedlings in different localities—contd.

Locality	Co. 207.				Co. 208.				Co. 209.			
	Brix	Sucrose	Glucose	Co-eff. of purity	Brix	Sucrose	Glucose	Co-eff. of purity	Brix	Sucrose	Glucose	Co-eff. of purity
Sugarcane-breeding Station, Coimbatore												
Manjri	16.24	12.91	0.31	78.9	14.27	9.97	1.28	80.9	14.59	11.08	..	80.1
Tharsa	19.36	17.08	0.15	91.1	17.01	12.86	..	75.7	18.72	15.34	0.18	88.4
Pusa	19.34	15.34	0.23	86.3	17.50	14.51	0.63	82.8	17.10	14.19	0.37	83.0
Maneria, 12-07 per cent. Su. in juice, Kuswar 15-41 and Rheora 13-19.	..	15.28	0.23	93.6	..	16.33	0.51	80.4	..	11.57	1.42	..
Sepaya	..	12.48	0.92	..	..	11.67	1.53	..	..	..	..	..
Shahjahanpur	..	..	..	..	..	..	..	..	..	..	..	..
Highest sucrose in selected varieties under field conditions 13-0, average 11-0.	..	..	..	..	..	..	..	..	..	..	..	..
Gurdaspur	..	..	..	..	..	..	..	..	..	..	..	..
The average of a number of analyses of Dhaulti was 14.60 per cent. sucrose in juice.	..	..	..	..	..	..	..	..	..	..	..	..
Locality	Co. 210				Co. 211				Co. 212			
	Brix	Sucrose	Glucose	Co-eff. of purity	Brix	Sucrose	Glucose	Co-eff. of purity	Brix	Sucrose	Glucose	Co-eff. of purity
Sugarcane-breeding Station, Coimbatore												
Manjri	16.57	13.33	..	80.5	14.93	11.74	..	79.7	17.34	14.31	..	82.5
Tharsa	18.34	14.93	0.14	86.9	..	..	..	..	17.04	13.53	..	79.3
Pusa	17.94	15.31	0.50	85.5	15.97	13.15	1.15	82.5	18.40	16.13	0.53	87.5
Maneria, 12-07 per cent. Su. in juice, Kuswar 15-41 and Rheora 13-19.	..	17.06	0.39	88.9	..	16.04	0.32	88.6	..	15.42	0.20	90.2
Sepaya	..	8.17	2.32	..	11.37	1.94	..	..	..	9.32	2.32	..
Shahjahanpur	..	..	..	..	..	..	..	..	..	..	..	..
Highest sucrose in selected varieties under field conditions 13-0, average 11-0.	..	..	..	..	..	..	..	..	..	..	..	..
Gurdaspur	..	..	..	..	..	..	..	..	..	..	..	..
The average of a number of analyses of Dhaulti was 14.60 per cent. sucrose in juice.	..	..	..	..	..	..	..	..	..	..	..	..

Character of the Juice of the Coimbatore seedlings in different localities.

Locality	Co. 213				Co. 214				Co. 215				Co. 216			
	Brix	Sucrose	Glucose	Co-eff. of purity	Brix	Sucrose	Glucose	Co-eff. of purity	Brix	Sucrose	Glucose	Co-eff. of purity	Brix	Sucrose	Glucose	Co-eff. of purity
Sugarcane-breeding Station, Coimbatore																
Manjri	15.80	12.13	..	76.1	10.46	16.22	..	83.4	17.04	13.71	0.82	80.5	15.60	12.24	..	78.1
Tharsa	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Pusa	18.34	15.69	1.01	85.6	16.88	16.56	0.48	87.9	17.50	14.45	0.85	82.5	14.09	11.68	1.07	78.0
Maneria, 12-07 per cent. Su. in juice, Kuswar 15-41 and Rheora 13-19.	..	15.25	0.34	85.2	..	18.67	0.28	93.0	..	16.24	0.29	88.0	..	18.09	0.40	95.3
Sepaya	..	8.73	2.61	..	..	12.56	1.35	..	..	11.02	1.71	..	..	11.14	1.97	..
Shahjahanpur	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Highest sucrose in selected varieties under field conditions 13-0, average 11-0.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Gurdaspur	13.11	1.02	80.7	..	17.98	0.37	97.3	..	12.74	0.96	78.1	..	15.10	1.22	83.8	..
The average of a number of analyses of Dhaulti was 14.60 per cent. sucrose in juice.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

NOTE 1. All available analyses figures are given in this statement.

NOTE 2. Data indicate that the figures are not available generally because of the seedling not having been distributed.

NOTE 3. At the cane-breeding station the seedlings were analysed three times and the highest figures are here recorded. Some of the analyses did not include glucose determinations and hence the absence of these figures in a few cases.

PLATE I



Co. 202

Co. 201



Co. 204

Co. 203



Co. 206

Co. 205

Coimbatore seedlings at the Gurdaspur Farm. The variety seen behind is Dhanlu, a dwarf local cane. Note the comparative better growth of the Coimbatore seedlings. The gauge seen in the picture has alternate foot spaces marked black and white and is placed to enable comparison of height of growth.



Co. 210 Co. 209 Co. 208
Coimbatore seedlings at the Tharsa Farm. The growth was so good that some of them had to be heavily supported with bamboos.



J. 247 Khari and Sunnabile (at the Tharsa Farm.)
Some of the promising canes grown by the local Agricultural Department.
The gauge seen in the pictures has alternate foot spaces marked black and white and is placed to enable comparison of height of growth.



Co. 215

Co. 208

Co. 202



Co. 202

Co. 201

Coinbatore seedlings at the Cattle-breeding Station, Sepaya.

Note the free growth and satisfactory habit.

The gauge seen in the pictures has alternate foot spaces marked black and white and is placed to enable comparison of height of growth.



The tall row of reeds seen in the picture is that of Co. 210 grown at the Cawnpore Farm. The growth is very promising.



The bulk crop seen in the picture is of J. 33a grown at Cawnpore for seed. To the left are seen a few rows of Ashy Mauritius. The gauge seen in the pictures has alternate foot spaces marked black and white and is placed to enable comparison of height of growth.

PLATE V



A cane plot at the Shahjahanpur Sugarcane Research Station. The two rows to the right are of M. 2, a Madras seedling raised in 1911-12. This seedling has a low sucrose but is grown as a wind-break because of its good growth and excellent habit.



Coimbatore seedlings at the Pusa sugarcane area. From left to right: Karun, Cos. 207, 206, 205, 204, 203, 202, 201, and Kuswar. Karun is a thick cane introduced from Coimbatore, and Kuswar a thin dwarf North Indian cane. Note the comparative better growth of the Coimbatore seedlings. Some of these have arrowed freely here. The gauge seen in the pictures has alternate foot spaces marked black and white and is placed to enable comparison of height of growth.



Arrowing of the distributed seedlings at Manjri Farm.



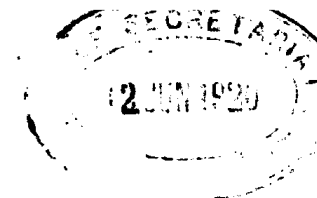
Co. 204

Co. 203

Co. 202

Arrowing of the distributed seedlings at Tharsa Farm.
The gauge seen in the pictures has alternate foot spaces marked black and white and is placed to enable comparison of height of growth.

Bulletin No. 95



1920

Agricultural Research Institute, Pusa

**A Note on the Treatment of Surra in Camels
by Intravenous Injections of Tartar Emetic**

BY

H. E. CROSS, M.R.C.V.S., D.V.H., A.Sc.,
Camel Specialist, Sohawa, Punjab.



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A Note on the Treatment of Surra in Camels by Intravenous Injections of Tartar Emetic.

(Received for publication on 3rd December, 1919.)

In the early part of 1917, I carried out experiments with tartar emetic in connection with the treatment of surra in camels. Six camels were finally submitted to treatment, and the results obtained may be of interest to those at present working on surra in camels and other animals.

From the 27th August, 1917, to the 22nd July, 1919, these camels were kept under observation by Captain Pool, I.A.R.O., who during this period was in charge of the laboratory. I am indebted to him for the daily blood examination and the care of these camels during this time.

Camel No. 1. Obtained from the 53rd Silladar Camel Corps, Sargoda. Aged 8 years. Condition poor.

Received the following treatment:—

1917		
June 2nd .	200 c.c. of a 1 per cent. solution of tartar emetic intravenously.	Fed well.
June 3rd .	Do.	Fed well.
June 4th .	250 c.c. of a 1 per cent. solution of tartar emetic intravenously.	Fed well.
June 5th .	Do.	Fed well.
June 6th .	Do.	Fed well.
June 7th .	Do.	Fed well.

After the last dose the camel went off feed and did not feed normally for two days.

The camel never did well and died on 14th October in an emaciated condition 129 days after treatment finished but no trypanosomes re-appeared in the blood.

Camel No. 2. Obtained from the 53rd Silladar Camel Corps, Sargoda. Condition poor. Aged 9 years.

Received the following treatment:—

1917		
May 26th .	600 c.c. of a 1 per cent. solution of tartar emetic intravenously.	Shortly after injection respiration became very rapid. Off feed.
May 27th .		Off feed.
May 28th .		Off feed.
May 29th .		Off feed.
May 30th .		Fed fairly.
May 31st .		Fed fairly.
June 1st .		Fed well.

This camel continued to feed well but never improved in condition. An injury to the leg necessitated an operation on November 21st, from which he did not recover.

No trypanosomes reappeared in the blood since treatment finished (179 days).

Camel No. 3. Obtained from the 52nd Silladar Camel Corps, Jhelum. Condition poor. Aged 7 years.

Received the following treatment :—

1917		
May 23rd .	250 c. c. of a 1 per cent. solution of tartar emetic intravenously.	Fed well.
May 24th .	Do.	Fed well.
May 25th .	Do.	Fed well.

On the morning of 26th the camel was off feed and did not feed well for 4 days ; after this he fed well and improved greatly in condition. Died on July 14th, 1919, as result of falling down a Khud in the grazing ground.

This camel worked constantly from 15th January, 1919, to 1st May, 1919, carrying a load of 5 maunds 24 miles one day and 14 the next, or an average of 19 miles a day.

Two hundred and forty-one days after treatment finished one guinea pig and one rabbit were inoculated with blood from this camel but remained healthy.

No trypanosomes reappeared in the blood since treatment finished (780 days).

Camel No. 4. Obtained from the 54th Silladar Camel Corps, Lahore. Condition fair. Aged 7 years.

Received the following treatment :—

1917		
May 23rd .	200 c. c. of a 1 per cent. solution of tartar emetic intravenously.	Fed well.
May 24th .	Do.	Fed well.
May 25th .	250 c. c. of a 1 per cent. solution of tartar emetic intravenously.	Fed well.
May 26th .	Do.	Fed well.
May 27th .	Do.	Fed well.
May 28th .	Do.	Fed fairly.

For three days after the last dose the camel did not feed well, but after this he fed well and improved in condition.

Two hundred and thirty-eight days after treatment finished one guinea pig and one rabbit were inoculated with blood from this camel, but remained healthy.

Died on 23rd October, 1919, whilst being castrated.

No trypanosomes reappeared in the blood since treatment finished (513 days).

Camel No. 5. Obtained from the 65th Government Camel Corps, Campbellpur. Condition poor. Aged 9 years.

Received the following treatment :—

1917		
May 18th .	200 c. c. of a 1 per cent. solution of tartar emetic intravenously.	Fed well.
May 20th .	250 c. c. of a 1 per cent. solution of tartar emetic intravenously.	Fed well.
May 22nd .	Do.	Fed well.
May 24th .	Do.	Fed well.
May 26th .	Do.	Fed well.
May 28th .	Do.	Fed well.
May 30th .	Do.	Fed well.
June 1st .	Do.	Fed fairly.
June 3rd .	Do.	Fed fairly.
June 5th .	Do.	Fed fairly.

For five days after the last dose the camel fed only fairly but after this he fed well and improved in condition.

Two hundred and thirty days after treatment finished one guinea pig and one rabbit were inoculated with blood from this camel, but remained healthy.

From 15th January, 1919, to 1st May, 1919, this camel worked constantly, carrying a load of 5 maunds 24 miles one day and 14 next, or an average of 19 miles a day.

No reappearance of trypanosomes for 887 days since treatment finished (November 8th, 1919).

Condition (November 8th, 1919) good.

Camel No. 6. Obtained from the 52nd Silladar Camel Corps, Jhelum. Condition fair. Aged 8 years.

Received the following treatment :—

1917		
March 20th .	60 c. c. of a 1 per cent. solution of tartar emetic intravenously.	Fed well.
March 22nd .	Do.	Fed well.
March 24th .	Do.	Fed well.
March 26th .	Do.	Fed well.
March 28th .	Do.	Fed well.
March 30th .	Do.	Fed well.
April 1st .	Do.	Fed well.
April 3rd .	Do.	Fed well.
April 5th .	Do.	Fed well.
April 7th .	Do.	Fed well.

This camel fed well during the whole of the treatment.

Two hundred and eighty-nine days after treatment finished one guinea pig and one rabbit were inoculated with blood from this camel, but remained healthy.

This camel worked continuously from 15th January, 1919, to 1st May, 1919, carrying a load of 5 maunds 24 miles one day and 14 miles the next, or an average of 19 miles a day.

No reappearance of trypanosomes for 945 days since treatment finished (November 8th, 1919).

Condition at present time (November 8th, 1919) good.

Summary.

	Number of days trypanosomes absent since treatment finished	Condition
	Days	
Camel 1.—Died from debility	129	Very poor.
Camel 2.—Died as result of operation	179	Poor.
Camel 3.—Died as result of fall in grazing ground	780	Very good.
Camel 4.—Died whilst undergoing castration	513	Good.
Camel 5.—Alive	887	Alive, good condition.
Camel 6.—Alive	945	Alive, good condition.

Remarks.

(1) From these experiments one may justly conclude that camels Nos. 3, 4, 5 and 6 were cured and that tartar emetic gives promise of success in the treatment of surra; but before tartar emetic can be definitely stated to be a cure for surra, a large number of animals must be submitted to treatment, so that definite conclusions can be arrived at.

(2) Great care has to be exercised when injecting tartar emetic, owing to the fact that if any of the solution, instead of being injected into the vein, is injected subcutaneously, sloughing results.

(3) Injection of tartar emetic is liable to cause fainting; it must be injected slowly at blood heat.

I have found that—

- (a) fainting is not so liable to occur if the injection is given during the intervals between the paroxysms, i.e., when the temperature is not high,
- (b) large doses, say 600 c.c. of a 1 per cent. solution, can be safely given in one day to fully grown camels if the amount is given in 3 injections with 2-3 hours' interval between the injections; whereas in the majority of cases if 600 c.c. of a 1 per cent. solution is given in one injection death results.

Agricultural Research Institute, Pusa

A Summary of the Experiments on Rice in Bihar and Orissa from 1912 to 1919

BY

G. C. SHERRARD, B.A.

Deputy Director of Agriculture, Patna Circle, Bihar and Orissa



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A Summary of the Experiments on Rice in Bihar and Orissa from 1912 to 1919

(Received for publication on 19th January, 1920.)

THE various experiments which are summarised in this paper were carried out in order to discover the best methods of cultivating rice in Bihar and Orissa both from the point of view of outturn and of profit. They were mostly undertaken on land which could be irrigated at least occasionally and are concerned with questions of ploughing, seed selection, sowing, transplanting and manuring. As is usually the case with a summary of experiments which has to be given at a specified date, some of the questions investigated have not yet been sufficiently examined, in others the results are indefinite; nevertheless various conclusions may be drawn.

For the sake of clearness I have divided the paper into four parts.

- A. Introduction.
- B. A summary of the experiments in cultivation.
- C. A summary of the experiments in the use of manures.
- D. Conclusions that, I think, may be drawn.

A. Introduction.

Although experiments were carried out before 1912-13, I have thought it preferable to commence with that date because up to that time there was only one Deputy Director in charge of all the farms in the province (which is roughly the size of France), and it was impossible for him to give the experiments close personal supervision. The consequence was that as the farm staffs were for the most part untrained in experimental work and lacking in the spirit of impartial scientific enquiry many of the results were inaccurate.

I arranged the experiments on the Bankipore and Dumraon Farms up to 1916-17 inclusive, after which they were designed by Mr. Robinson, Assistant Director of Agriculture; on the Cuttack Farm up to 1915-16, after which they were designed by Mr. Sethi, Deputy Director of Agriculture; on the Sabour Farm in 1912-13, after which Mr. McGowan, the Professor of Agriculture, was responsible, though the majority of the rice experiments there were actually carried out by Mr. Sil, the Assistant Professor of Agriculture. In certain experiments I have recorded the results in a different form to that in which they were given in the yearly farm reports, and have sometimes drawn different conclusions from them.

1. EXPLANATION OF THE TABLES.

In the following tables the outturns are given in pounds per acre, the profits in rupees and annas per acre.

A deficit, or loss is shown by prefixing a *minus* sign (—).

A *maund* is 82 lb., a *seer* (one-fortieth of a *maund*) is taken as 2 lb.

In all cases where the outturn is entered without the name of the crop, the crop is rice. Unless otherwise stated the rice was some variety of the main crop harvested in December, and was transplanted.

It is important that an experiment should be tested on a variety of plots and for several seasons. In those tables which show the average results, therefore, I have recorded the number of trials (*i.e.*, the total number of plots), the area (*i.e.*, the sum of the area of all the plots) and the number of years during which the trials were carried out. In the same tables the average outturn in pounds per acre produced by each treatment was arrived at as follows:—The records available were usually the average results for each year reduced, for the sake of conformity, to pounds per acre, with a note as to the number and size of the plots; but the number and size of the plots varied from year to year. I have multiplied these recorded results by the area of the plots in their respective years, added the products together and divided by the total area in acres.

When the average results are given in the body of the report the results of each year will be found in the appendix.

In certain cases the profits resulting from an experiment are given, but these should not be regarded as more than an indication of what may be expected. Naturally the results will vary in different circumstances. The figures given were obtained from the farm books and include the cost of the seed, manures, labour (both of men and animals) and so forth on the one side, and on the other the value of the outturn at the then market rates. No allowance has been made for rent, purchase and depreciation of implements, or the wages of the Superintendent or superior farm staff other than the mates (foremen actually in charge of the coolies). For practical purposes these figures seem sufficient. They show that as a result of actual experiments a field, which unmanured or untreated brought in A rupees, after the addition of a manure or special treatment brought in A *plus* or *minus* X rupees when all extra expenses had been deducted. Questions of rent, depreciation *etcetera* do not arise as they are common to the treated and untreated field: the important point is the *plus* or *minus* X rupees. It should however, be remembered that a ryot almost invariably pays less in cultivation charges than a Government farm in the same district and any profit obtained is therefore likely to be larger. And further, at the present

moment (the end of 1919) the value of the crops has increased since the first experiments recorded much more than the price of labour.

2. THE *paira* CROP.

Although the main object of these experiments is to discover their effect upon the rice yet whenever the rice was followed by a *paira* crop, the details of the latter have been included, except in those cases (such as when varying numbers of seedlings were transplanted) in which the treatment applied to the rice could not appreciably influence the *paira*.

The *paira* is a cold weather crop broadcast in the mud amongst the standing paddy in October on the heavier rice lands of most parts of Bihar. No extra cultivation beyond sowing is required and the crop, which owing to the fact that it is then low, is unharmed when the rice is harvested in December is gathered in due course in March. Several crops are grown in this manner but they are nearly always leguminous—perhaps the most common being *khesari*, lentils, small peas, gram and linseed or some mixture of these.

The average profit from 16 unmanured fields during four years on the Bankipore Farm was, from the rice Rs. 22-10 per acre, from the *paira* Rs. 20-1. So that, on suitable land, the *paira* is of almost equal value to the rice. In obtaining this average the whole cost of the cultivation, such as ploughing, puddling and so forth has been charged to the rice, only the cost of the seed, broadcasting and harvesting the *paira* being charged to that crop. But as the ploughing and puddling would have been necessary for the rice in any case, the *paira* can be looked upon as a very valuable bye-product.

As the *paira* is nearly as valuable as the rice, the effects on it of manures applied to the rice ought to be considered, and the *paira* outturns have been included for that reason.

And further, the possibility of introducing a *paira* crop on lands on which it is not at present grown should be carefully considered, for it follows that if by the addition of some simple manurial prescription a good *paira* crop can be grown on such lands the value of the outturn will be nearly doubled at once. Unfortunately up to the present very little attention has been paid to this point. The problem was attacked at Dumraon (see table 33 and the following remarks) and was apparently solved, but the experiments were not completed. It would, I think, be advisable to put down a complete manurial series on every farm containing rice lands on which a *paira* is not grown, and sow a *paira* in each plot with careful notes of the results. If the addition of certain elements enabled the *paira* to grow, it might

be found possible to obtain them in a cheap form. For example, at Dumraon it seems almost certain that potash is required; possibly the same is true as regards Cuttack Farm where the chemical analysis shows that the percentage of potash is low. If it is found that the addition of potash enables a good *paira* crop to be grown in these districts the discovery of potassic salts in Orissa should render the manure available at a comparatively low cost if it prove impossible to supply it cheaply as ashes.

Too much reliance, however, cannot be placed on manurial results as shown in a *paira* crop until the experiments have been made on a large number of plots, as they are subject to more than the usual number of factors likely to mask the effect of the manures; for example, small inequalities in the surface of the rice field made at the time of puddling or otherwise will cause the water to stand longer in certain parts and render the germination of the *paira* uneven.

3. THE FARMS.

Four farms are dealt with in this report, Bankipore, Cuttack, Dumraon and Sabour.

Bankipore Farm. This farm was situated immediately south of Patna Junction Station in Bihar on heavy dark soil typical of a large part of the Patna District and particularly of the low lying area south of the Ganges Bank on which the East Indian Railway main line is built. It was almost entirely rice land.

The following chemical analysis of the soil was made by Mr. Taylor, the Agricultural Chemist to the Government of Bihar and Orissa:—

Particulars.	NORTH OF THE DIS- TRIBUTARY		SOUTH OF THE DIS- TRIBUTARY	
	Surface soil per cent.	Sub-soil per cent.	Surface soil per cent.	Sub-soil per cent.
Insoluble matter	76.96	73.84	75.60	73.85
Potash	0.82	0.82	0.80	0.83
Soda	0.82	0.82	0.50	0.52
Lime	1.89	1.65	0.82	1.32
Magnesia	1.38	1.96	0.73	1.17
Iron aluminium	14.46	17.06	17.24	18.32
Phosphorous pentoxide	0.25	0.30	0.17	0.13
Sulphur trioxide	trace	trace	trace	trace
Carbon dioxide	trace	trace	trace	trace
Combined moisture and organic matter*	3.42	3.55	4.23	3.36
TOTAL	100.00	100.00	100.00	100.00
* Containing nitrogen	0.07	0.055	0.065	0.043

Cuttack Farm. This farm is situated about 6 miles from Cuttack in Orissa on the Taldana Road. The soil is a sandy loam and typical of much of the land in the Cuttack delta. The greater part of the area is rice land.

The following table gives the chemical analysis of the soil.

Particulars.	Surface soil (first 9 inches), per cent.	Sub-soil (second 9 inches), per cent.
Insoluble silicates and sand	86.66	84.33
Ferric oxide	3.74	4.83
Alumina	5.52	6.37
Lime	0.30	0.39
Magnesia	0.59	0.41
Potash	0.24	0.33
Soda	0.03	0.17
Phosphoric acid	0.03	0.03
Sulphuric acid	0.01	0.007
Carbonic acid	0.05	0.06
Organic matter and combined water *	2.83	3.07
TOTAL	100.00	100.00
* Containing nitrogen	0.004	0.004

Dumraon Farm. This farm is situated in Bihar on land lying either side of the East Indian Railway main line just east of Dumraon Station. The soil is a sandy loam. There is very little rice land.

Sabour Farm. This farm is at Sabour about 4 miles east of Bhagalpur in Bihar. The soil of the rice lands on the farm is fairly heavy, the following details are given by Mr. Taylor, the Agricultural Chemist to the Government of Bihar and Orissa and were deduced from 70 samples of soil.

	Per cent.
Nitrogen in its organic form	0.07
Available P ₂ O ₅	0.011
Available K ₂ O	0.011

B. Cultivation experiments

The experiments have tested to a greater or lesser extent a number of common practices and, speaking broadly, the general result has been to show that the cultivator is right in his methods. This is what one would expect, for, on the face of it, changes in the way of cultivating the crop which increase the yield without adding to the cost or requiring new implements, would almost certainly have been discovered by the cultivators themselves in the course of the many generations during which they have been growing rice. It is not usually wise therefore, to devote too much time or space to this class of enquiry if the first few results show the present practice to be sound. Conversely, it is absolutely necessary to proceed cautiously should it appear that a mere change in the method results in a distinct improvement. The new process should be studied under varying conditions and particularly over a number of seasons, for an initial success may be due simply to the fact that the test was carried out under the best conditions and in a good year.

Of course these remarks do not apply to the introduction of obvious improvements, in vogue in well cultivated areas, to ignorant and backward cultivators such as jungle tribes. In such cases the Agricultural Department has the opportunity of carrying out at once what under modern conditions would take place of itself in a comparatively short space of time historically speaking; but opportunities of this kind are unlikely to occur in the rice tracts of Bihar.

Besides dealing with experiments which tested the value of existing practices, this part also includes experiments designed to compare the results of ordinary methods of cultivation with other methods depending upon facts or implements beyond the knowledge of the cultivator. For example, the use of seed grain that sinks in a saturated salt solution and the case of an improved plough. The average cultivator is not likely to discover for himself that a salt solution will float heavier grain than pure water, and would not willingly incur the expense of an improved plough unless he was sure it would be to his advantage in the end.

1. HOT WEATHER CULTIVATION.

Taking the province as a whole the rice lands are not as a rule cultivated during the hot weather. North of the Ganges they are usually ploughed, and the cultivators there say that this reduces the weeds and improves the yield. South of the river, on the other hand, the ryots more commonly leave them uncultivated from harvest

time until they are puddled preparatory to transplanting, as they maintain that the weeds which grow up during the interval rot, when turned under water, before the rice is transplanted and thus benefit the crop, that is, they prefer to keep the weeds and utilise them as a green manure. On some of the low-lying heavy lands, however, there are certain weeds which do not die when the land is puddled, and these are occasionally checked by ploughing the surface during the hot weather.

TABLE I.

(Bankipore.)

NUMBER OF		Total area in acres	Ploughed in the hot weather with a	AVERAGE INCREASE OVER THE UNPLOWED PLOTS			
Trials	Years			RICE		GRAM	
				Grain	Straw	Grain	Straw
13	4	2.4	Punjab plough . .	113	99	183	161
5	3	0.8	Hindustan plough . .	89	11	219	188
9	4	1.6	Local plough . .	29	43	85	108

TABLE II.

(Cuttack.)

NUMBER OF		Total area in acres	Treatment	AVERAGE	
Trials	Years			Grain	Straw
4	2	0.8	Ploughed in the hot weather.	1,219	1,883
4	2	0.8	Unploughed . .	1,066	1,414

The Bankipore table above shows that hot weather cultivation on land south of the river in Patna distinctly increases the yield of the rice and still more of the *paira* when carried out with a plough having a share and mould board (such as the Punjab or, to a less extent, the Hindustan) though there is only a little extra yield of rice from cultivation with the local plough. It is probable that this last fact explains the ryot's neglect of the practice, especially if the increase in his *paira* was not associated with the hot weather ploughing, as is quite possible.

At Cuttack, in Orissa, hot weather cultivation has increased the yield.

Definite figures from land north of the river would be useful for comparison; while a series is required to show whether the increased yield is maintained over a number of years at the same figure or whether, as is more probable, there is a fall in the proportional increase when the same land is ploughed every year, though not back to the original out-turn from unploughed land.

Still we may say that it certainly pays, and is better farming, in Patna, Cuttack, and probably elsewhere, to invest in a plough such as the Punjab or some similar make and to plough the land at least once with it during the hot weather to aerate the soil and kill the weeds, rather than to leave it unploughed.

2. SEED SELECTION.

TABLE III.

(Cuttack.)

Seed sown	AVERAGE OF DUPLICATE TRIALS IN TWO YEARS	
	Grain	Straw
Seed that did not pass through sieve	1,754	2,583
Corresponding unselected seed	1,743	2,413
Seed that sank in a saturated salt solution	2,011	2,531
Corresponding unselected seed	1,799	2,480

Two simple methods of seed selection were tried, in one case the seed was rubbed over a sieve of such a size that it let through about half the sample—the larger seeds which did not pass through were sown, in the other case the seed was thrown into a saturated solution of salt in water and the seeds which floated were rejected.

It will be seen that seed selected in the former way gave an increased outturn of 0.6 per cent. of grain only, but seed selected by the salt solution produced an increase of 11.8 per cent.; that is selection by weight is much better than selection by size.

Selecting seed in this way is simple and inexpensive and will well repay the cultivator, the rejected seed that floats can be sold and the salt from the brine given to the cattle.

3. TRANSPLANTED AND BROADCAST RICE COMPARED.

It is a well known fact that transplanted rice gives a larger out-turn and is more profitable than broadcast, and the following trials bear this out.

TABLE IV.

(Sabour.)

Cultivation	1915-16	
	Grain	Straw
Transplanted	939	3,466
Broadcast	475	2,388

The experiments were carried out in triplicate on 0.1 acre plots, the figures are the average of the three plots.

TABLE V.

(Cuttack.)

NUMBER OF		Total area in acres	Cultivation	AVERAGE			
Trials	Years			Grain	Straw	Cost	Profit
8	4	1.6	Transplanted	1,545	2,013	R s. 22 5	R s. 27 11
8	4	1.6	Broadcast	1,237	2,004	23 6	16 7

It will be noticed that the expenditure at Cuttack on broadcast rice was Rs. 1-1-0 per acre more than on transplanted. In Bihar the reverse is the case, transplanting costing considerably more than broadcasting. The following examples from non-experimental fields on the Bankipore Farm give definite figures (they were selected by opening the farm books at random).

	Cultivation charges per acre	Grain per acre	Straw per acre
1915-16.			
6.1 acres transplanted	R s. p. 25 0 4	629	672
8.7 acres broadcast	19 1 5	511	907
1916-17.			
5.8 acres transplanted	18 12 3	1,430	1,905
7.4 acres broadcast	14 11 5	562	735

This shows that the cultivation cost in Bihar is Rs. 5 per acre more when the rice is transplanted. The fact that the difference between the yield is less and the cost of broadcasting more in proportion at Cuttack than in Bihar is probably due to the system of cultivating broadcast lands in Orissa, referred to in the next section.

The Bankipore figures given above cannot be considered so reliable as the others when comparing the yields (though as a comparison of the cost of the two methods they are perfectly fair) because the fields were selected by chance from the books instead of being selected as of equal value on the land, and the operations were not necessarily carried out at the same time, nevertheless they have the advantage of being actual figures of comparatively large areas of similar land under field conditions on one farm, and may therefore be taken as approximately correct. With the above proviso, the following is the additional yield from transplanted rice on the three farms.

At Bankipore, Bihar ; 92 per cent. of grain and 57 per cent. of straw.

At Sabour, Bihar ; 98 per cent. of grain and 45 per cent. of straw.

At Cuttack, Orissa ; 25 per cent. of grain and 4 per cent. of straw.

Another point worth considering is the yield in each case from a given weight of seed. The seed rate per acre of broadcast land in Bihar is about 30 lb., in Orissa about 80 lb. The seed rate per acre of seed bed is about 500 lb., and, as one acre of seed bed transplants ten acres of land, the seed rate per acre of land transplanted is about 50 lb. Therefore, from the tables given above it follows that from 1 lb. of seed is obtained—

16 lb. when broadcast, or 19 lb. when transplanted at Sabour.

18 lb. when broadcast, or 21 lb. when transplanted at Bankipore.

15 lb. when broadcast, or 31 lb. when transplanted at Cuttack.

The greater difference between the two at Cuttack is due to the method of growing broadcast rice in Orissa where many seedlings are uprooted. But considering the results in Bihar alone, where no seedlings are destroyed, it appears that although there may be rather better germination in the seed bed than in the field this does not account for the difference, and it follows that the plants benefit from the check of uprooting and transplanting them.

But, it may be asked, if the money return and the yield from transplanted rice is greater, why then do the ryots who, of course, are quite aware of this, broadcast any land at all. They do so for a mixture of reasons. Some lands while too low for dry crops are too high for transplanted rice, which requires more water, and are therefore put down under broadcast rice. Others again are too low, and are liable to be flooded too deep by the heavy rains shortly after transplanting so a rice

is broadcast which has more chance of keeping above water. Also, and more important in the rice tracts, it is usually impossible to transplant the whole area owing to lack of labour. The seed beds are sown at the commencement of the rains and the sowing period cannot be extended for long (see section 5) while if the seedlings are not transplanted within a fairly definite time after they are sown the yield falls off considerably (see section 8), but transplanting is slow and laborious work, about ten labourers being required to transplant an acre in one day, and everyone wants to transplant at nearly the same time. Thus the area that can be commanded is restricted. The cultivators usually transplant as much as they can.

4. BROADCAST RICE IN ORISSA.

(In this section and this section only, the figures of yields refer to broadcast rice.)

The cultivation of broadcast rice is not uniform throughout the Province. In Bihar the land is prepared as for any other crop and sown at the rate of 15 *seers* (30 lb.) of seed per acre, the after cultivation consisting of weeding when necessary. Throughout Orissa and the greater part of Chota Nagpur, on the other hand, the seed rate is very much higher, never less than 30 *seers* (60 lb.) usually 40 *seers* (80 lb.) and even as much as 60 *seers* (120 lb.). The land is not prepared so well, but when the crop is about a month old it is ploughed through with the local plough. The cultivators state that this checks the weeds, thins the crop and loosens the soil; and this is correct as there is a great improvement in the rice after it has been ploughed through. But (as we have seen in section 3) though the yield of broadcast rice in Orissa more nearly approaches that of transplanted rice than it does in Bihar it costs more and the method is proportionally less economical.

The merits of the two systems require careful investigation. Some enquiry has already been made, but not sufficient.

TABLE VI.

(Cuttack)

NUMBER OF		Total area in acres	Seed rate per acre	AVERAGE	
Trials	Years			Grain	Straw
14	6	2.8	40 <i>seers</i> (80 lb.) . .	1,795	2,767
14	6	2.8	30 <i>seers</i> (60 lb.) . .	1,810	2,569
14	6	2.8	20 <i>seers</i> (40 lb.) . .	1,905	2,785

In these experiments the crop was ploughed through according to the local practice, and the results show clearly that the seed rate can be reduced with advantage, thereby effecting a considerable saving in seed grain and also increasing the yield. It occurred to me, however, that this was due to the better preparatory cultivation of the land on the government farm compared to that of the local cultivators, and that the ploughing through could be omitted in the former case. This was tested in the series given below.

TABLE VII.

(Cuttack.)

NUMBER OF		Total area in acres	Seed rate per acre	After treatment	AVERAGE	
Trials	Years				Grain	Straw
4	2	0.8	40 seers (80 lb.)	Ploughed through	1,518	2,157
4	2	0.8	30 seers (60 lb.)	Do.	1,420	1,898
4	2	0.8	20 seers (40 lb.)	Do.	1,551	2,580
4	2	0.8	15 seers (30 lb.)	Not ploughed	1,637	2,777

These experiments as far as they go, show that it would be better to follow the Bihar custom in Cuttack. A further trial was made later.

TABLE VIII.

(Cuttack.)

Seed rate per acre	Preparation before sowing	Treatment after sowing	1917-18			
			Grain	Straw	Cost of cultivation	Profit
35 seers (70 lb.)	Ploughed 5 times.	Ploughed through.	1,650	4,047	R a. 24 13	R a. 24 0
35 seers (70 lb.)	Do.	Not ploughed	1,455	4,406	30 9	14 15
25 seers (50 lb.)	Do.	Do.	1,537	3,946	28 2	17 14
25 seers (50 lb.)	Ploughed 10 times.	Do.	1,778	5,227	31 9	23 11

The experiments were in duplicate on 0.8 acre plots, the figures are the average of the two plots.

On this occasion a larger yield was obtained with a comparatively low seed rate on the better cultivated land, but the higher seed rate and the local cultivation proved slightly more profitable. It would,

however, have been better as a test of the two methods had the seed rate been reduced, if not to the 15 seers of Bihar, at least to the 20 seers that have so far proved the best on this farm.

On the whole the evidence available up to date appears to me to be in favour of not ploughing through. But there is another advantage in the Orissa custom, though it is one quite unknown to the local cultivators; that is to utilise the system to apply a green manure to the broadcast rice.

TABLE IX.

(Cuttack.)

NUMBER OF		Total area in acres	Treatment	AVERAGE		
Trials	Years			Grain	Straw	Profit
6	3	1.2	Green manure (dhaincha)	1,710	2,481	R a. 23 10
6	3	1.2	Unmanured	1,456	2,327	22 3

In these experiments 10 lb. of *dhaincha* (*Sesbania aculeata*) per acre were mixed with the rice seed before sowing, and the whole sown together. When the crop was ploughed through a month later most of the *dhaincha* plants were uprooted and those that were not were pulled up and forced into the mud, as are other upstanding weeds, by the gang that goes through the fields after the ploughing through. This proved beneficial and profitable.

The two questions have not yet been examined in conjunction to find out whether it pays better to prepare the land well, reduce the seed rate and not plough through, or to retain the high seed rate, mix in *dhaincha* and plough through. The evidence, though insufficient as yet, is in favour of the latter as it has given a larger increase per cent.

5. LOSS FROM LATE RAINS AND LATE SOWING.

Every one knows that if the rains are late the rice crop is poor, but any information as to the relation between the time of sowing and the decrease of the crop should be of use to those interested in the gross output. Probably the best way of arriving at correct figures would be to transplant the same area for a number of years with seedlings of the same variety sown at the first favourable rainfall, recording the date and the yield. But this would involve other questions, such as the nature of the rainfall each year, and, possibly, variations in the soil, while in any case it would take a long time to arrive at satisfactory figures.

In order to obtain some idea of the loss due to late transplanting only, I arranged a series at Bankipore and Sabour in 1912, in which the seed was sown and the seedlings transplanted at intervals of half a month, thus artificially approximating later and later rains, while the land used could be irrigated when necessary, thus eliminating any difficulties due to breaks in the rains. I have only recorded the dates of transplanting, but the seeds were sown about 5 weeks earlier in each case.

TABLE X.

Transplanted on	BANKIFORE		SABOUR		AVERAGE		LOSS PER CENT	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
July 10th 1912 . . .	1,579	2,793	1,708	3,999	1,543	4,896	0	0
July 25th 1912 . . .	1,107	2,298	1,767	4,046	1,437	3,173	6.87	35.19
August 10th 1912 . . .	1,066	2,246	1,517	3,196	1,291	2,721	16.33	44.42
August 25th 1912 . . .	954	2,052	1,353	3,182	1,153	2,607	25.28	46.75
September 10th 1912 .	724	1,537	1,116	2,650	920	2,093	40.38	57.25

Each transplanting was on 6 plots of 0.2 acre each, the figures are the average of 6 plots; the figures in the column of averages are thus based on 2.4 acres each.

These trials show that a delay of a fortnight beyond the usual time (in this case the first sowing was about June 5th) means a loss of nearly 7 per cent. of grain, a delay of a month 16 per cent. loss, while if the rains are delayed until the first week in August the loss is over 40 per cent. The loss of straw is larger in each case.

These figures, of course, can only be taken as approximate.

6. WET AND DRY SEED-BEDS.

Two kinds of seed-beds are sown. In one the seed-bed is puddled under water before sowing and kept wet, in the other the seed is sown in moist land in the same way as other crops.

TABLE XI.

Cultivation	SABOUR			CUTTACK			SABOUR		CUTTACK	
	NUMBER OF			NUMBER OF			AVERAGE		AVERAGE	
	Trials	Years	Total area in acres	Trials	Years	Total area in acres	Grain	Straw	Grain	Straw
Wet seed-bed	16	3	0.4	6	3	1.2	1,372	...	1,778	3,155
Dry seed-bed	16	3	0.4	6	3	1.2	1,325	...	1,647	2,955

The above trials show an increased yield in favour of a wet and puddled seed-bed of 3.5 per cent. of grain at Sabour and 7.9 per cent. at Cuttack. The cost of cultivation in each case is about the same, the average for the two years 1916-17 and 1917-18 at Cuttack being Rs. 25.5 per acre for a dry and Rs. 25.6 per acre for a wet seed-bed. Therefore a wet seed-bed is more profitable.

The cultivator prefers a wet seed-bed, but he is dependant to a great extent upon the weather. The seed is sown at the commencement of the rains and any undue delay in sowing decreases the outturn very much more than the difference between the two types of seed-bed (section 5). The cultivator, therefore, sows his seed in a dry seed-bed if he cannot obtain sufficient water at sowing time to enable him to puddle it. He can, of course, influence this to some extent by his choice of the position of his seed-beds.

7. SEED RATE IN THE SEED-BED.

TABLE XII.

(Sabour.)

Seed rate per acre of seed-bed	1913-14 Grain
1 maund (82 lb.)	1,120
4 maunds (328 lb.)	1,625
8 maunds (656 lb.)	2,110
16 maunds (1,312 lb.)	1,670

On single 0.1 acre plots.

TABLE XIII.

(Sabour.)

NUMBER OF		Total area in acres	Seed rate per acre of seed- bed	AVERAGE Grain
Trials	Years			
3	3	0.3	2 maunds (164 lb.) . .	1,195
3	3	0.3	4 maunds (328 lb.) . .	1,159
3	3	0.3	10 maunds (820 lb.) . .	1,166

TABLE XIV.

(Bankipore.)

NUMBER OF		Total area in acres	Seed rate per acre of seed-bed	AVERAGE	
Trials	Years			Grain	Straw
12	3	2.7	5 maunds (410 lb.)	747	980
12	3	2.7	7.5 maunds (615 lb.)	636	964

TABLE XV.

(Cuttack.)

NUMBER OF		Total area in acres	Seed rate per acre of seed-bed	AVERAGE	
Trials	Years			Grain	Straw
9	3	1.8	3 maunds (246 lb.) .	1,301	1,846
9	3	1.8	4 maunds (328 lb.) .	1,484	2,028
9	3	1.8	5 maunds (410 lb.) .	1,543	1,879

In every series, while the different plots were transplanted from seed-beds sown with varying quantities of seed, the same number of seedlings were transplanted in each plot.

In the first year's trials at Sabour (table 12) 1 maund gave by far the lowest outturn, 4 and 16 maunds each gave about the same and 8 maunds higher than either; therefore the best weight must be between 4 and 16.

Table 13 shows that the results from 2, 4 and 10 maunds are all about the same. At first sight, from this table alone, it might appear that it would therefore pay best to sow 2 maunds, but the results may equally mean that the optimum rate lies between 4 and 10 maunds, and taking the other tables into consideration this is the correct interpretation.

The Bankipore series (table 14) shows that the best seed rate is below 7.5 maunds.

The Cuttack experiments (table 15) clearly show that 4 *maunds* give a larger yield than 3, and 5 than 4.

Taking the 4 tables together therefore, we find that the best seed rate lies between 5 and 7.5 *maunds*. As a matter of fact the cultivator's usual seed rate is about 5 to 7 *maunds* per acre of seed-bed depending on the soil and local conditions. The experiments show that this is correct and should not be either reduced or increased.

This might have been expected, because the cultivators must have experimented in innumerable trials in past years.

From one point of view, however, the results are surprising. An officer, commenting on the Cuttack series, when he heard that while different seed rates were sown in the seed-beds the same number of seedlings were transplanted in each plot said, "If this is so, it is almost inconceivable that the thinner sown and presumably stouter seedlings would give much the smallest yield per acre." It is curious. Nevertheless the cultivator transplants approximately the same number of seedlings in a given area on each occasion, and it is nearly inconceivable to suppose that if by the simple and economical process of sowing less seed he could increase his yield, he would not do so. It would appear, therefore, that just as we have seen that the yield is increased by the check of transplanting so it is necessary to crowd the seedlings to some extent in the seed-bed probably to check root development before transplanting.

8. TIME AT WHICH TO TRANSPLANT THE SEEDLINGS.

TABLE XVI.

(Cuttack.)

Age of seedlings	1916-17		1917-18		1918-19		AVERAGE	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
20 days old . . .	994	2,121	979	1,845	1,296	2,203	1,090	2,056
30 days old . . .	920	1,588	1,817	2,306	1,397	2,149	1,211	2,014
40 days old . . .	1,045	2,121	1,465	2,716	1,579	2,536	1,363	2,458

Each year the experiments were carried out in duplicate on 0.1 acre plots, the figures are the average of the two plots.

The cultivator usually transplants his seedlings when they are five to six weeks old. The above table shows that at any rate it is unwise to transplant them when they are younger than this.

9. THE NUMBER OF SEEDLINGS TO TRANSPLANT IN EACH HOLE.

TABLE XVII.

(Bankipore.)

NUMBER OF		Total area in acres	Number of seedlings	AVERAGE	
Trials	Years			Grain	Straw
10	3	2.1	1 in each hole . .	746	1,209
46	7	9.8	2 in each hole . .	994	1,824
46	7	9.8	4 in each hole . .	1,070	1,916
46	7	9.8	8 in each hole . .	1,187	2,161

TABLE XVIII.

(Cuttack.)

NUMBER OF		Total area in acres	Number of seedlings	AVERAGE	
Trials	Years			Grain	Straw
10	5	2	1 in each hole . .	1,873	3,189
10	5	2	2 in each hole . .	1,964	3,156
10	5	2	4 in each hole . .	2,003	3,501
10	5	2	8 in each hole . .	1,913	3,706

TABLE XIX.

(Sabour.)

NUMBER OF		Total area in acres	Number of seedlings	AVERAGE	
Trials	Years			Grain	Straw
161	5	4.1	1 to 2 in each hole .	1,414	...
161	5	4.1	4 to 6 in each hole .	1,577	...

In certain parts of India, particularly Madras, a large saving has been effected by transplanting single seedlings instead of bunches as was the local practice, and a number of experiments have been carried out at Bankipore, Cuttack and Sabour to ascertain whether a similar saving was possible in this province. From the results recorded above it is obvious that it is not possible in Bihar. The fact that two seedlings have given a slightly better result than eight, and four than both at Cuttack show that a small number of seedlings may possibly succeed in Orissa, but further investigation is advisable as the number of trials and the total area of the experiments at Cuttack were less than on the other farms.

At Sabour, where Mr. Sil, the Assistant Professor of Agriculture, carried out many series, and to a less extent at Bankipore, the possibility of succeeding with one or two seedlings under special conditions was carefully examined. Trials were made with early and late sowings, with thickly and thinly sown seed-beds, from wet and dry seed-beds, in heavily manured and unmanured land, etc., but I have not burdened this report by recording all these experiments in detail as they led to no definite results, the total outturn varied as might be expected but the largest number of seedlings gave the highest yield.

On the other hand the average cultivator can probably effect a certain saving if he takes the trouble to plant bunches more regular in number, at present though he hardly ever puts less than eight into a hole frequently bunches of over 20 can be found. No experiments, however, have been made as yet to ascertain the number at which the yield begins to fall off again.

10. THE DISTANCE APART AT WHICH TO TRANSPLANT THE SEEDLINGS.

TABLE XX.

(Sabour.)

NUMBER OF		Total area in acres	Distance apart	AVERAGE	
Trials	Years			Grain	Straw
3	3	0.15	6 inches . . .	1,146	4,162
3	3	0.15	9 inches . . .	1,186	3,595
3	3	0.15	12 inches . . .	919	2,768
3	3	0.15	18 inches . . .	454	2,125

The cultivator usually transplants his seedlings from six to nine inches apart, and the above table shows that this is correct.

11. NIGAR.

Nigar means literally "putting off." It is used by the cultivators in Bihar in connection with running water off the fields; e.g., the process of running the water out of the *ahars* to dry them preparatory to *rabi* cultivation, or the draining of the rice fields.

The water is usually run out of the rice fields twice, shortly after transplanting and again in the *utra nichchatra* which usually falls between the 12th and 24th of September. This section is concerned with this last *nigar* which is of importance on the area irrigated by the Sone Canals.

If the fields are dried shortly after transplanting no particular strain falls on the canal for two reasons, firstly because the fields are not all

drained at the same time but more or less in rotation as they are transplanted, secondly because less water is generally required to fill them up again as the time is usually one of heavy rainfall. The *utra nigar*, however, is different. It is done by rule at the beginning of the *utra* and is applied to all rice, transplanted and broadcast, early and late. The land is left to dry throughout the *nichchatra*, and at the commencement of the next *nichchatra*, the *hathia*, every field is filled up again. It is this that throws a strain on the canal. As the canal authorities point out, if the practice could be done away with, or even if it could be modified, the use of the canal would not be limited by the necessity of delivering a maximum supply on a given date and it could, therefore, irrigate a larger area of the country.

After discussions with various Public Works Officers, a series of experiments were drawn up to commence in 1916 and to be carried out on canal lands under the supervision of the Irrigation and Agricultural Departments, officers of both departments being present at and reporting on each operation. Before describing these I will recapitulate the questions involved as they appeared to me.

It may be assumed that *nigar* is beneficial for at least four reasons. (1) Theoretically it is probably advantageous to dry and aerate the soil. (2) It is the custom, not only on the canal irrigated lands, but also in those parts of Gaya and Patna irrigated by the indigenous system of pines and *ahars*,* except when there is so little reserve water that there is a danger that the fields cannot be refilled. (3) Even on the canal lands, where water is assured, the practice involves a certain amount of work in opening and closing the fields, and no one does unnecessary work. (4) Both the Irrigation and the Agricultural Departments had carried out experiments previously which showed that *nigar* was beneficial.

On the other hand it is probably not necessary to *nigar* on a given date. The cultivator has no doubt found that the *utra* is about the best time for the majority of his rice, the main crop harvested in December, but besides this his rice includes varieties such as *sirhanti* harvested in October and *kartika* harvested in November. If nigarring them at this time did harm they would be nigarred earlier, and conversely if it did them good the nigarring time of the main crop could be varied without doing much damage.

Thus the series should at least include main crop varieties nigarred at different times and *kartika* nigarred a month earlier than the usual time. (I find that unfortunately in the experiments the *kartika*

* See the author's paper "Indigenous Irrigation Works in Bihar and their improvement" in the *Agricultural Journal of India*, Vol. XI, Part II.

was nigarred a month later than usual instead of a month earlier, and as this is tantamount to no nigarring, I have excluded the result. The mistake was possibly due to my giving insufficient instructions as I was unaware at the time that I should be unable to supervise the experiments personally.

If it could be proved that small variations in the time of nigarring caused no appreciable loss, the canal authorities would be justified in insisting on different blocks of the canal irrigated land being nigarred and filled up again on different dates, and they would then have extra water to supply further areas.

Definite knowledge could not be obtained in one year even if the experiments were carried out over a large area, for variations in the rainfall must influence the result. It was necessary, therefore, to continue the experiments for a sufficient number of years to represent a fair average.

This has not yet been done, but the results of three seasons given below are very encouraging.

TABLE XXI.

NUMBER OF		Total area in acres (about)	Kind of rice	Treatment	AVERAGE	
Trials	Years.				Grain	Straw
16	3	3	Main crop harvested in Decem- ber	Nigarred at the usual time	1,422	1,950
				Not nigarred	1,373	1,901
				Nigarred at the usual time <i>khari</i> salt	1,460	1,884
				Not nigarred <i>khari</i> salt	1,519	2,080
				Nigarred at the usual time but not allowed to dry enough to crack the soil.	1,325	1,679
				Nigarred on September 1st	1,308	1,739
				Nigarred on September 15th	1,181	1,612
				Nigarred on October 1st	1,119	1,599
				Nigarred on October 15th	1,268	1,909
				Nigarred at any time the weather permits from September 1st to October 15th.	1,275	1,773
10	3	1.8	<i>Kartika</i> harvested in Novem- ber.	Nigarred at any time the weather permits from September 1st to October 15th but not allowed to dry enough to crack the soil.	1,310	1,897
				Nigarred at the usual time	1,353	1,646
				Not nigarred	1,341	1,768

There was a heavy fall of rain during the nigarring period of 1917 and the plots did not dry. This has a considerable effect on the figures which are the average of three years only. Of course, such years should be included, but they should not form one-third of the whole.

The first two experiments show that *nigar* is beneficial, though the increase is only 3.6 per cent. It will probably be found to be larger when the average of a number of years is taken.

In the last two nigarring is shown to benefit *kartika* rice also but to a less extent. The increase in this case is almost negligible being only .9 per cent. Here again the percentage of gain should be larger after a longer trial including a smaller proportion of unfavourable years, but it is improbable that *kartika* when nigarred at the same time as the main crop varieties will derive as much benefit from the process as they do.

The third and fourth experiments were included to test the action of *khari* salt, which was added to both just after the water was run out of the niggared plot. From table 21 it appears that the addition of this salt has more than made good the loss due to not nigarring but a reference to table P in the appendix shows that this is due to the extraordinary (and probably incorrect) figures of the first series at Ageon in 1918. If these are omitted *khari* salt is found to have no effect.

Comparing number five with number one it appears, as would be expected, that it is better to dry the soil completely; but this result is contradicted in numbers ten and eleven. This would, naturally, take longer to decide than the other points, as it is more dependent on the weather.

The most important plots in the series are numbers six to nine, where the period of *nigar* is varied from September 1st to October 15th. Of these September 15th is practically the customary time. Up to the present they show that no harm results if the water is run off at any time between these dates and run in again after the usual interval. In other words they justify the canal authorities in dividing up the area into blocks to be nigarred on varying days between these dates, and thereby conserving water for irrigating land at present outside the canals.

C. Manurial experiments.

I have divided this part into chemical manures and simple manures for convenience in reference. But, while as a rule the section on chemical manures contains those manures which are relatively expensive and difficult to obtain, and that on simple manures describes those which are usually cheaper and more easily available, no definite line can be drawn between the two. The value of the manures in each case depends upon their power of supplying the plants with the same elements, and some manures (for example, saltpetre and bonemeal) though included among the chemical manures are easily obtained in certain tracts.

1. CHEMICAL MANURES

TABLE XXII.

(Bankipore.)

SUMMARY OF EXPERIMENTS ON RICE IN

Manure applied per acre	RESIDUAL RESULTS IN 1915-16						RESIDUAL RESULTS IN 1916-17					
	RICE			GRAM			RICE			KERAO		
	Grain	Straw	Profit	Grain	Straw	Profit	Grain	Straw	Profit	Grain	Straw	Profit
160 lb. of ammonium sulphate	1,648	2,788	Rs. A. 17 8	331	276	Rs. A. 8 14	1,497	1,905	Rs. A. 28 1	795	758	Rs. A. 28 1
220 lb. of superphosphate	1,585	2,808	31 0	433	322	12 11	817	1,280	5 4	894	751	30 7
100 lb. of muriate of potash.	1,374	2,019	13 1	464	350	15 6	295	627	12 0	575	430	17 6
160 lb. of ammonium sulphate + 100 lb. of muriate of potash.	1,876	3,024	12 11	633	491	22 5	1,372	1,652	21 10	972	793	33 1
160 lb. of ammonium sulphate + 120 lb. of superphosphate	1,886	3,372	23 2	402	308	11 4	1,687	2,080	34 2	1,001	892	35 6
120 lb. of superphosphate + 100 lb. of muriate of potash.	1,420	2,422	10 11	482	360	15 4	792	1,082	5 5	754	638	25 9
Unmanured	1,028	1,545	12 5	413	336	12 3	205	435	16 4	682	587	21 14
												5 10

The experiments were in duplicate on 0.2 acre plots, the figures are the average of the two plots.

BIHAR AND ORISSA FROM 1912 TO 1919

TABLE XXIII.

(Bankipore.)

Manures applied per acre	1918-19		
	RICE		
	Grain	Straw	Profit
164 lb. of superphosphate	1,165	2,120	Rs. A. 28 3
410 lb. of bonemeal	1,360	2,485	29 10
Unmanured	1,330	2,965	51 11

The experiments were in duplicate on 0.2 acre plots, the figures are the average of the two plots.

Table 22 is interesting in that all the manures paid for themselves in the year of their application, if both crops are taken into account, notwithstanding their relatively high price in 1915.

While the series was only carried out in duplicate and for one year and is therefore not so reliable as would be a number of trials spread over several years, yet certain deductions can be made as to the value of the three classes of manures on this soil, and these deductions have much more weight if borne out not only by a comparison of two plots with two plots but by combining the results of the whole series of 14 plots into two groups for each manure.

Ammonia is clearly shown to be a valuable manure for rice. The two plots treated with ammonium sulphate have given a large increase over the unmanured plots. Again, when the six plots that received ammonium sulphate are compared with the eight plots that did not, the manure is shown to have given an increase of 33 per cent. of grain and 39 per cent. of straw. A small part of this increase is due to the sulphur as we shall see when discussing *khari* salt in the next section.

At first sight its residual effects on the rice (in 1916-17) appear extraordinary, the plots manured with ammonia the previous year giving an increase over the others of 187 per cent. of grain and 121 per cent. of straw. But, while this manure has a considerable residual effect, this enormous increase is only indirectly due to it. The plots were

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N20

flooded for a short time in 1916 and the impetus given to the plants by the nitrogenous dressing, besides making them stronger, made them slightly taller, so that they were both able to stand the immersion better and were under water for a shorter time. Nevertheless, although the actual increase in this case is largely a matter of luck, there is the other side of the question, had the plants not been given this extra help they would not have been taller and stouter and would not have received less damage than the rest—while short floods are frequent in this low-lying rice tract.

The *paira*, a leguminous crop, is not likely to be affected by a nitrogenous manure, and the outturn of the gram on the six plots manured with ammonium sulphate was the same as that on the eight plots that were not; the average figures are 455 lb. of grain per acre in the former case and 453 lb. in the latter.

Superphosphate has given good results, its application producing a large increase of rice over the unmanured plots. A comparison of the six plots treated with superphosphate with the eight plots not so treated shows an increase due to this manure of 10 per cent. of grain and 22 per cent. of straw.

Its residual results are also considerable. The six plots to which superphosphate was added in the previous year giving an average increase over the eight to which it was not added of 30 per cent. of grain and 28 per cent. of straw. Here again, as in the case of the ammonium sulphate described above, the effect may have been exaggerated by the unfortunate year, nevertheless the residual value in the second year, must be considerable.

(In the 1918-19 series given in table 23 the addition of phosphate manures would seem to have given a negative result, but it appears certain that the unmanured plots were in some way better than the others.)

Superphosphate has apparently had no effect on the *paira* in the first year, the figures obtained by a comparison of all the plots showing a slight decrease; but similar figures for the second year show an increase from this manure of 16 per cent. of grain and 21 per cent. of straw in the *kerao*. In view of the warning already given (in the introduction) against too hasty a judgment of the effects of a manure on the *paira* crop I am inclined to think that the results must have been masked in some way the first year, even if it is equally likely that they have been somewhat exaggerated the second year.

The figures obtained by a comparison of the plots manured with potash with those not so manured show an average increase of 20 lb.

per acre of rice grain the first year, which is negligible, and a loss of 22 per cent. the second, which is of course only the compliment of the lucky gain made by the ammonium sulphate plots explained above, and is therefore of no consequence. It appears then that this manure has no effect on the rice in this soil.

Its influence on the *paira* crop is not definite. A comparison as above of all the plots of the first year shows an increase due to potash of 35 per cent. of grain and 29 per cent. of straw, but the residual results are *nil*.

TABLE XXIV.

(Cutlack.)

NUMBER OF		Total area in acres	Manure applied per acre	Grain	AVERAGE Straw
Trials	Years				
6	3	1.2	160 lb. of sulphate of ammonia + 120 lb. of superphosphate + 100 lb. of muriate of potash.	2,273	4,600
6	3	1.2	160 lb. of sulphate of ammonia + 120 lb. of superphosphate.	2,286	4,757
6	3	1.2	160 lb. of sulphate of ammonia + 100 lb. of muriate of potash.	2,318	4,733
6	3	1.2	120 lb. of superphosphate + 100 lb. of muriate of potash.	1,946	3,321
6	3	1.2	Unmanured	1,782	3,145

None of these manures paid for their application in any of the three years, and the series was discontinued owing to the steady rise in their price. Nevertheless, while bearing this in mind, the results are of value in that they show the class of manures that will benefit the rice on this soil.

Ammonia is obviously beneficial. Comparing the 18 plots which received ammonium sulphate with the 12 which did not we arrive at an increase due to this manure of 23 per cent. of grain and 45 per cent. of straw.

Phosphatic manures gave a small increase, a comparison in the same way of the plots manured with superphosphate with those that were not showing an increase in the former of 6 per cent. of grain and 7 per cent. of straw.

Potash also gave an average increase of 7 per cent. each of grain and straw.

TABLE XXV.

(Sabour.)

Manure applied per acre	1913-14		1914-15		1915-16		1916-17	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Unmanured	786	1,778	625	1,230	1,240	2,540	1,365	2,108
5 maunds (410 lb.) of bonemeal in 1913-14.	890	1,640	1,120	2,000	1,195	2,755	1,330	3,121
3 maunds (246 lb.) of bonemeal in 1913-14 and 1915-16.	685	1,460	1,190	2,402	870	1,525	1,665	2,455
1 maund (82 lb.) of bonemeal + $\frac{1}{2}$ maund (41 lb.) of saltpetre each year.	910	1,675	840	1,649	1,115	3,085	1,625	2,730

The experiments were in duplicate on 0.1 acre plots, the plots being the same each year; the figures are the average of the two plots.

Deductions from this series must be somewhat indeterminate, particularly as all the manures have given a negative result in 1915-16, when it would seem that something must have happened to increase the relative yield of the unmanured plot.

The bonemeal and saltpetre has given an average increase of 118 lb. of grain per acre per annum during the four years.

It is noteworthy that in each case the addition of bonemeal has given a substantial increase, not in the year of its application but in the succeeding year. Thus the bonemeal applied in 1913-14 has given no definite results that year, the gain in one case being counterbalanced by the loss in the other, but in the next year the 5 maunds have produced an increase of 79 per cent. of grain over the unmanured plot, and the 3 maunds an increase of 90 per cent. Again the addition of 3 maunds in 1915-16 has produced no result in that year but has resulted in an increase of 22 per cent. of grain the next year.

The single application of 5 maunds of bonemeal in the first year has produced slightly more during the four years than have the two applications of 3 maunds each.

TABLE XXVI.

(Sabour.)

Manure applied per acre	1914-15		1915-16		1916-17		1917-18	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Green manure (<i>sannai</i>) each year.	1,120	1,919	1,947	6,570	935	6,072	665	5,547
Green manure (<i>sannai</i>) + 5 maunds (410 lb.) of bonemeal each year.	1,080	2,007	2,300	6,620	1,050	6,320	1,075	6,490
Green manure (<i>sannai</i>) + 5 maunds (410 lb.) of bonemeal in 1915-16 and 1917-18.	785	1,543	1,982	6,048	822	6,690	505	6,840
Green manure (<i>sannai</i>) + 10 maunds (820 lb.) of bonemeal in 1915-16 and 1917-18.	995	2,030	1,980	5,915	620	6,780	635	6,962

The experiments were in duplicate on 0.05 acre plots, the plots being the same each year, the figures are the average of the two plots.

The results in this series are not definite.

Comparing the plots which received green manure and bonemeal each year with those that received green manure alone, it appears that the bonemeal had no effect the first year (the yields being practically the same) but produced an increase of 23 per cent. the next year, followed by increases of 12 per cent. and 62 per cent. in the two following years. That is, the bonemeal acted as in the previous table.

In the next two cases, however, the effect of the bonemeal is by no means clear. In 1915-16 we may conclude that the green-manure caused the increase, as the outturns are the same as that of the plots manured with green manure alone, but the bonemeal seems to have had no effect in the next year either. It is possible that the whole series has been upset by an uneven growth of the *sannai*, always a danger when the results are dependent upon a green-manure as a constant factor.

TABLE XXVII.
(Bankipore.)

NUMBER OF Trials	Years	Total area in acres	Manure applied per acre	RICE		GRAM		Year's Profit
				Grain	Straw	Grain	Straw	
4	2	0.8	300 lb. of basic slag	1,501	2,254	421	361	Rs. A. 16 1 24 14
4	2	0.8	1,640 lb. of lime	1,533	2,402	480	454	18 7 15 3
4	2	0.8	Unmanured	1,497	2,198	553	454	21 8 53 9

TABLE XXVIII.
(Sabour.)

Manure applied per acre	1914-15		1915-16		1916-17		1917-18		AVERAGE	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Green manure (sesame) + 820 lb. of lime	1,165	2,400	2,315	7,785	820	5,745	840	5,885	1,285	5,454
Green manure (sesame)	1,130	1,919	1,947	6,570	935	0,072	665	5,547	1,167	5,027

The experiments were in duplicate on 0.08 acre plots, the same plots receiving the manure each year, the figures are the average of the two plots.

TABLE XXIX.

(Cutlack.)

Manure applied per acre	1913-14		
	Grain	Straw	Profit
350 lb. of basic slag	1,855	2,742	Rs. A. 31 4
1,640 lb. of lime	1,722	2,691	34 14
Unmanured	1,495	2,511	42 0

The experiments were in duplicate on 0.2 acre plots, the figures are the average of the two plots.

TABLE XXX.

(Cutlack.)

Manure applied per acre	1913-14		
	Grain	Straw	Profit
200 lb. of basic slag	1,978	2,870	Rs. A. 33 6
1,640 lb. of lime	2,258	3,280	43 3
Unmanured	1,906	3,068	42 11

The experiments were on 0.2 acre plots on broadcast rice.

TABLE XXXI.

(Cutlack.)

Manure applied per acre	1912-13	
	Grain	Straw
Green manure + 246 lb. of lime	2,367	3,777
Green manure (dhaincha)	2,434	3,938

The experiments were on four plots of 0.2 acre each, the figures are the average of the four plots.

(Cutlack.)

NUMBER OF		Total area in acres	Manure applied per acre	AVERAGE	
Trials	Years			Grain	Straw
6	3	1.2	Green manure + 1,230 lb. of lime.	2,134	3,177
6	3	1.2	Green manure (<i>dhaincha</i>)	2,131	3,417

Time, therefore, is not a profitable manure for Bankipore or Cuttack and, though it appears more likely to do good at Sabour, this is not yet certain for the comparison (table 28) was a green-manured with a green-manured and limed area, and, depending as it does upon the growth of a crop, green manure is not necessarily a constant factor.

2. SIMPLE MANURES.

By simple manures are meant manures which the ryot can obtain without much difficulty.

TABLE XXXIII.
(Dumraon.)

Manure applied per acre	1908-09		1909-10		1910-11		1911-12			1912-13		
	Rice		Rice		Rice		Rice			Rice		
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Profit	Grain	Straw	Profit
50 maunds of cowdung .	2,024	4,920	2,972	9,020	2,613	6,713	2,665	4,715	Rs. A' 41 8	1,906	3,044	Rs. A. 24 14
100 maunds of cowdung	2,152	3,654	2,972	8,610	2,044	4,428	1,896	3,792	19 11	1,688	3,382	11 6
84 maunds of cowdung + 3.75 maunds of castor cake.	3,075	2,665	3,321	9,840	2,572	4,920	2,665	4,920	32 7	2,295	5,032	35 8
Green manure (amarai) .	2,373	4,715	2,603	9,020	2,142	3,587	1,640	2,972	15 5	1,168	2,480	9 1
Green manure (dhaincha)	2,050	3,936	2,788	10,250	2,972	5,863	2,337	5,380	81 4	1,127	2,562	6 12
3 maunds of bonemeal + 1 maund of salt-petre.	2,255	4,612	2,929	7,980	2,767	5,227	2,347	3,997	25 7	1,691	3,761	6 11
Unmanured . . .	1,845	2,542	1,742	5,330	1,610	3,772	1,271	2,306	10 8	789	1,804	0 9

Manure applied per acre	1912-13						1913-14					
	GRAM			RICE			GRAM			RICE		
	Grain	Straw	Profit	Year's profit	Grain	Straw	Profit	Grain	Straw	Profit	Year's profit	Year's profit
50 maunds of cowdung	887	1,209	Rs. A. 26 14	Rs. A. 51 12	1,886	4,869	Rs. A. 48 15	656	594	Rs. A. 21 0	Rs. A. 69 15	Rs. A. 69 15
100 maunds of cowdung	461	491	10 0	21 6	1,722	3,844	39 8	676	574	21 10	61 0	61 0
34 maunds of cowdung + 3.75 maunds of castor cake	615	635	15 11	51 3	2,132	4,397	51 4	451	410	13 0	4 4	4 4
Green manure (sennai)	615	512	14 8	23 9	1,578	3,382	30 11	533	471	16 7	47 2	47 2
Green manure (dhaincha)	512	779	13 9	20 5	1,865	4,264	44 3	828	284	6 8	50 11	50 11
3 maunds of bonemeal + 1 maund of salt-petre.	471	594	11 1	17 12	1,322	2,972	8 8	848	225	8 3	16 11	16 11
Unmanured	287	348	3 8	4 1	1,250	2,665	24 9	154	123	1 3	25 12	25 12

Manure applied per acre.	1914-15.						1915-16.					
	RICE.			GRAM.			RICE.			GRAM.		
	Grain.	Straw.	Profit.	Grain.	Straw.	Year's profit.	Grain.	Straw.	Profit.	Grain.	Straw.	Year's profit.
50 maunds of cowdung	1,619	3,936	54 12	205	205	Rs. A. 57 10	2,132	3,690	47 9	2,132	3,690	47 9
100 maunds of cowdung	1,650	3,118	50 7	154	154	50 13	1,998	3,484	28 12	1,998	3,484	28 12
34 maunds of cowdung + 3.75 maunds of castor cake.	2,081	3,408	58 10	102	123	56 11	2,095	3,740	28 6	2,095	3,740	28 6
Green manure (sennai)	2,152	3,639	66 7	143	154	66 7	1,931	4,202	41 0	1,931	4,202	41 0
Green manure (dhaincha)	1,127	3,649	16 13	82	102	13 14	1,449	3,484	28 10	1,449	3,484	28 10
3 maunds of bonemeal + 1 maund of salt-petre	1,250	2,378	5 3	113	102	3 9	1,586	2,510	10 11	1,586	2,510	10 11
Unmanured	635	1,640	8 3	82	102	5 4	1,009	2,356	8 4	1,009	2,356	8 4

The experiments were on 0.2 acre plots, each plot receiving the same manure yearly.

This interesting series was started by my predecessor before the formation of the province. Unfortunately it could not be laid out in duplicate as there are not sufficient suitable rice plots at Dumraon. After a careful study of the plots (which I was better able to make after my transfer to Bankipore when this became my nearest outlying farm as opposed to his furthest from Calcutta), I found that the plot manured with 34 *maunds* of cowdung and 3.75 *maunds* of castor cake was lower, and therefore usually better, than the rest, which discounts to some extent the comparatively large yields from this manure. The plot manured with 50 *maunds* of cowdung was just lower than the others. Thus, as is generally the case with a single series, certain reservations are necessary when comparing the outturns plot with plot.

Nevertheless the accumulated benefit derived by applying these manures yearly and the profit that would accrue where such a practice common is most plain, and, if necessary, leaves a large margin for any error that might be due to variations in the plots. Thus if we omit the suspect plot manured with 34 *maunds* of cowdung and 3.75 of cake and, further, reduce the outturns from the plot manured with 50 *maunds* of cowdung to the same as those from the plot manured with 100 *maunds* (which would more or less agree with the experience on other farms, as is shown later), we find that had a man owning 5 acres of similar rice land manured each acre yearly with one of these five manures for eight years he would have increased his rice grain receipts by an additional 29,693 lb. Thus :—

From his acre manured with—	lb.
50 <i>maunds</i> of cowdung	6,441
100 <i>maunds</i> of cowdung	6,441
Sennai green manure	5,411
Dhaincha green manure	5,534
3 <i>maunds</i> bonemeal + 1 <i>maund</i> saltpetre	5,866
TOTAL	29,693

His extra receipts in money during the last five years alone, and only counting the rice, would have been, according to the farm accounts which naturally show less profit than a cultivator would make, Rs. 442. (As a matter of fact, they would have been more, for an Indian cultivator wise enough to apply such a series of manures would not only save over labour and incidental expenses, but would notice when his bonemeal and saltpetre plot was being run at a loss owing to the rise in price of these manures, and would have abandoned this dressing.)

But there is another way of examining the results which is not open to the same objections due to the series being on a single line of plots, that is a comparison of the relative returns of the plots. Whatever the initial difference between the outturn of the plots, any increase or decrease of this difference must be due to the treatment of the plot, and a steady advance must be due to the accumulated effect of the manure. In practice, of course, dealing with living plants and a complicated soil one cannot expect an arithmetical progression, but only an indication.

If the increase over the unmanured plot in the first year in each case is taken as 1 and the increase in the other years reduced proportionally, we get the following figures :—

TABLE XXXIV.

Manures per acre.	1908-9	1909-10	1910-11	1911-12	1912-13	1913-14	1914-15	1915-16
50 maunds of cowdung .	1	1.579	1.249	1.789	1.434	0.816	1.263	1.442
100 maunds of cowdung .	1	4.007	3.27	2.036	2.603	1.537	3.306	3.223
34 maunds of cowdung + 3.75 maunds of castor cake.	1	1.234	0.758	1.15	1.216	0.717	1.173	0.883
Green manure (<i>sannai</i>) .	1	1.615	0.942	0.692	0.711	0.615	2.646	1.73
Green manure (<i>dhaincha</i>) .	1	5.102	6.498	5.2	1.649	3	2.4	2.148
3 maunds of bonemeal + 1 maund of saltpetre.	1	2.651	2.749	2.624	2.2	0.176	1.5	1.407

Several deductions can be made from this table. In the first place none of the manures has proved harmful after a number of years, all have given an increase over the unmanured plot in the first year, and added to this in most of the succeeding years. Had the accumulated effects been harmful, the figures would have shown a gradual or rapid decline. These particular manures are not likely to cause harm, but I mention the fact because I have occasionally heard the opinion expressed that continuous green-manuring causes a decrease. That the *dhaincha* (*Sesbania aculeata*) has not done this is obvious. At first sight the case for *sannai* (*Crotalaria juncea*) may not seem so certain but applying a green manure is not the same thing as adding a definite quantity of manurial matter. The amount is dependent upon the growth of the plants to be ploughed in and these, like all plants, will vary from season to season, and therefore the fall to less than the original increase during three years is only due to faulty growth of the crop. Were it due

to any harmful action of the manure it would not have been followed by a rise to nearly three times in the seventh and over one and a half times in the eighth year.

From an examination of table 34 up to and including the year 1912-13, where it is divided by a vertical line, it appears that both the plot manured with 100 maunds of cowdung and that manured with 3 maunds of bonemeal and 1 maund of saltpetre have reached a level. That is to say the accumulated effect in both these manures does not seem to be raising the outturn any further. This implies that in each case the quantity applied yearly could have been reduced in future without lowering the outturn had the series been carried on as before, but at this point I introduced a *paira* crop.

This *paira* crop raised questions which have not yet been solved though perhaps the solution can be indicated. The cultivators of the neighbourhood do not grow a *paira* on light soils of this nature as a rule, and the wisdom of this is shown in these experiments where though the unmanured plot gave a small return the first year this fell to little more than half in the second, less than a third in the third (when the outturn did not even pay the small expenses incurred) and failed entirely in the fourth year. This looks as if some essential plant food was lacking in the soil. It is not nitrogen, firstly because a leguminous crop like gram would certainly obtain enough of this element on a soil that supported rice, secondly because in that case the *paira* crop on the bonemeal and saltpetre plot would stand out from the rest. It could hardly be phosphorous, for then also the bonemeal plot should have beaten the others. Therefore it is probably potash, and this is further borne out by a comparison of the plots; the best returns on the whole in each year were obtained from the plots manured with farm-yard manure, which contains a certain amount of potash but did not supply enough. (In the fourth year when the *paira* was not harvested, there was probably enough on the cowdung plots to produce a small profit though, owing to a misunderstanding, this was discarded with the rest.

Now, if a good *paira* crop could be grown on these lands it would almost double the yearly returns, as shown in the introduction to this paper when discussing the *paira* at Bankipore, and it would seem as if this might be obtained, and the yield of rice increased as well, by a simple and cheap manurial dressing containing potash. Before it can be recommended definitely, however, trials should be made on the Dumraon Farm; I was unable to do so as I had to wait for suitable plots and left before these could be obtained.

TABLE XXXV.

Dumraon.

Manure applied per acre	1916-17		
	Grain	Straw	Profit
50 maunds of cowdung	1,742	2,435	Rs. A. 20 10
Green manure (<i>dhaincha</i>)	1,886	2,502	22 4
5 maunds of castor cake	1,993	2,914	13 5
Unmanured	1,698	2,726	20 10

The experiments were carried out on 0.2 acre plots.

This series, though of little value by itself, shows nothing to contradict the deductions made above. *Dhaincha*, though it has not given the largest yield, has proved the most profitable. Castor cake which has produced the largest outturn, has not paid for itself.

TABLE XXXVI.
(Bankipore.)

(Dumfries.)

NUMBER OF		Total area in acres	Manure applied per acre	RICE			GRAM			Year's profit
				Grain	Straw	Profit	Grain	Straw	Profit	
4	2	0.8	100 maunds of cowdung	340	574	Rs. 4. —0 12	70	17	Rs. 4. 4 8	Rs. 4. 3 12
4	2	0.8	50 maunds of cowdung	240	291	0 6	81	90	4 12	5 2
6	3	1.2	5 maunds of castor cake	150	137	—11 3	—90	—85	—4 11	—15 14
2	1	0.4	5 maunds of mustard cake	—45	—570	—13 14	..	..	..	..
14	5	3	2 maunds of Eleri salt	270	112	6 13	44	32	1 2	7 15
4	2	0.8	2 maunds of sulphate of magnesia . .	224	334	—7 10	—137	—126	—6 14	—14 8
3	4	1.8	Green manure (<i>dhaincha</i>)	—25	—97	—3 1	18	12	1 9	—1 8
4	3	0.8	Green manure (<i>sesuai</i>)	163	154	1 5	18	23	1 1	2 6

(Bankipore.)

The experiments were in duplicate on 0.2 acre plots, the figures are the average of the two plots.

Well-preserved farm-yard manure, as might be expected, has given an increase, a dressing of 100 *maunds* per acre showing a higher additional yield of rice than any other of the manures considered. This extra yield, however, has not paid the cost at farm rates of the manure (valued at 2 annas a maund) and of carting and spreading it though when the additional yield of the *paira* crop is included a profit is shown. Manuring with 50 *maunds* of cowdung resulted in less rice but a larger profit. But the residual value must also be considered. There are figures for one year only on the rice alone in table 37. Taking the average yields of four trials in two years from table 36 and combining them with the residual results of two of these trials in one year from table 37, we find that after three crops the additional profits per acre are, from 100 *maunds* of cowdung Rs. 20-14, from 50 *maunds* Rs. 3-3 or Rs. 17-11 in favour of the larger amount.

A further series was laid down to compare the value of 100 *maunds* of cowdung with 50 *maunds*, the results of which are shown in the following table.

TABLE XXXVIII.
(*Banckipore.*)

The experiments were in duplicate on 0.2 acre plots, the figures are the average of the two plots.

In this case the larger dressing proved as usual less profitable on the rice than the smaller in the first year but at the end of two years had given an extra yield per acre of 138 lb. of grain and 810 lb. of straw of rice with an increased profit of Rs. 2-6 and 305 lb. of grain and 156 lb. of straw of gram with an increased profit of Rs. 16-10, or a total additional profit of Rs. 19.

It may be concluded therefore, that when a single dressing is given at intervals it is better to apply 100 rather than 50 *maunds* of cowdung.

Returning to table 36; oil-seed cakes, though usually raising the yield, have not proved profitable manures at Bankipore.

Khari salt (hide salt) has given the highest average yield of rice grain of any of these manures except one, and the largest money return while its residual value is also considerable in the one year shown in table 37. Sulphur and chlorine are both deficient in this soil. Magnesium sulphate produces nearly as great an effect as *khari* salt, and the figures have been included for comparison, but its greater cost puts it out of the running as a rival. Common salt also increases the yield of rice, the addition of 2 *maunds* (164 lb.) per acre to broadcast rice in 1917-18 resulted in an increase of 229 lb. of grain, but the manure did not pay for itself. *Khari* salt is an impure sodium sulphate containing chloride and owing to its very impurities, provides both sulphur and chlorine at a lower cost in each case than if they were added separately.

Green-manuring with *sannai* has shown a profit. The negative results with *dhaincha* are surprising and contrary to the experience on other farms, but a reference to tables T and U in the appendix show that this manure gave a profit over the unmanured plots in three years out of the four and it is probable that there was some unrecorded adverse factor in the fourth. This view is strengthened by the fact that the average increase of the *paira* is the same for both the manures.

TABLE XXXIX.

(Cuttack).

NUMBER OF		Total area in acres	Manure applied per acre	AVERAGE INCREASE OVER THE UNMANURED PLOTS		
Trials	Year			Grain	Straw	Profit
14	10	2-77	Green manure (<i>dhaincha</i>)	327	495	Rs. A. 8 2
9	5	1-73	50 <i>maunds</i> of cowdung	166	112	2 3
7	4	1-4	50 <i>maunds</i> of village <i>khatto</i>	34	4	-0 14
2	1	0-33	5 <i>maunds</i> of gingelly cake	2	-192	-11 8

The profit of the green manure is based on ten trials only.

Green-manuring with *dhaincha* (*Sesbania aculeata*) has given the best results of the manures tried on the Cuttack Farm. The advantage of green-manuring is its low cost, and it is well worth recommending in the neighbourhood.

Fifty *maunds* of cowdung, although so far not producing so much increase in the yield of rice on this soil as at Bankipore, has proved a profitable manure.

The comparison of cowdung with an equal quantity of village *khatto* shown in this table emphasises two useful points. *Khatto* is a dry mixture of cowdung and ashes used as a manure by the local cultivators, and may be taken as their farm-yard manure. But farm-yard manure of the ordinary type preserved under cover on the farm is shown to be nearly five times as effective. Again the use of *khatto* resulted in a small loss on the farm (14 annas per acre) the slight extra yield not paying for the extra labour and cost of the manure. This helps to prove the contention several times repeated in this report that any manures which pay on the farms will pay the cultivators still more as his expenses are lower; for in this instance *khatto* manure must pay the cultivators or they would not apply it.

The trials of cake are too few for certainty in themselves, but here again this type of manure has not been found profitable.

TABLE XL.

(Sabour.)

Manure applied per acre	1912-13	
	Grain	Straw
Green manure (<i>dhaincha</i>)	1,687	3,276
Unmanured	1,499	3,227

The experiments were in triplicate in 0-1 acre plots, the figures are the average of the three plots.

Green-manuring with *dhaincha* has given an increase of 188 lb. per acre in this case, or 12-5 per cent.

D. Conclusions.

Various details of rice cultivation in Bihar have been examined in part B, and the results so far obtained appear to me to warrant the following conclusions.

It pays to plough those rice lands of Patna and Cuttack which are not at present cultivated during the hot weather, if a Punjab or some similar plough is used—and it would probably pay to do so elsewhere. (Section 1.)

Seed selection by the simple salt water method pays, and should be adopted by the cultivators. (Section 2.)

Transplanted rice produces more grain and pays better than broadcast rice. (Section 3.)

The method of cultivating broadcast rice in vogue in Orissa and Chota Nagpur, while probably in itself inferior to that of Bihar, is capable of a simple combination with green manure that has given an increase of 17 per cent. of grain. (Section 4.)

Sowings should take place as early as possible, as a delay results in a considerable loss that increases rapidly the longer the sowing is put off. (Section 5.)

A wet seed-bed pays better than a dry seed-bed. (Section 6.)

The usual seed rate is correct under present conditions. (Section 7.)

The time the seedlings are kept in the seed-bed before transplantation is probably correct, at any rate it cannot be reduced. (Section 8.)

The number of seedlings transplanted in each bunch cannot with safety be reduced below eight in Bihar. (Section 9.)

The distance apart at which the seedlings are transplanted is probably correct, at any rate it cannot be increased. (Section 10.)

The results of three years' experiments support the contention that the authorities of the Sone Canals would be justified in insisting on different blocks of the canal-irrigated lands being nigarred on varying dates between September 1st and October 15th, as this would not lower the yield of rice and would enable the canal to supply a larger area. During these three years no harm has resulted through varying the *nigar* between these dates, and, while there is no harm in continuing the experiments up to the five to seven years I originally suggested, it is unlikely, from every point of view, that so small a variation in the time of *nigar* would cause a loss, certainly not one equal to the gain that would result from the larger crops, and greater insurance of crops, on the extra land that could be irrigated. (Section 11.)

The examination of manures in part C cannot be summarised so easily. The primary object of the experiments with chemical manures (section 1) is to ascertain what class of manure is required, and of those in section 2 to find cheap manures that will pay: naturally the enquiries overlap. The answer in each case depends chiefly upon the nature of the soil and varies from place to place; general deductions, therefore, are not of much value.

Expensive chemical manures are not likely to pay under existing conditions on rice alone, although they may more than pay their way where a good *paira* crop can be grown in addition, as we have seen at Bankipore. A possible exception is ammonium sulphate for, as might be expected with a gramineous crop such as rice, this manure has given a large increase, 23 per cent. of grain at Cuttack and 33 per cent. at Bankipore. (The difference in favour of Bankipore is probably due to the sulphur in the manure, an element that is deficient on that farm.)

On the other hand special cases may occur where it will pay to import manures for a definite purpose; a case in point is Dumraon, and possibly Cuttack, where it seems likely that potash may enable a good *paira* to be grown and thus nearly double the proceeds from the land. (Introduction and part C, section 2, table 33.) The possibility of introducing a *paira* crop should be carefully considered on all rice lands on which it is not now grown.

Several local manures have been proved to pay.

Of these the most important under present conditions is green manure, because of its low cost and the ease with which it can be applied. Green manure is obtained by sowing 30 lb. per acre of *dhaincha* (*Sesbania aculeata*) or 60 lb. of *sannai* (*Crotalaria juncea*) on the rice fields at the first rain and ploughing it in when the land is puddled before transplanting. The cultivator can grow the seed on any unused land, and its application only requires a little extra work, a rough ploughing or two at sowing time and one or two extra when puddling.

A reference to the tables shows that *dhaincha* gave an increase of 19.8 per cent. of grain and Rs. 8.2 per acre of profit at Cuttack, 11 per cent. of grain and Rs. 1.10 per acre of profit at Dumraon, 12 per cent. of grain at Sabour. The average result at Bankipore was a decrease, but the manure resulted in an increase of grain and profit in three out of the four years and was probably masked in the fourth by some unexplained error; more particularly as the average increase in the *paira* was the same as that from *sannai*. *Sannai* gave an increase of 14 per cent. of grain and Rs. 1.5 per acre of profit at Bankipore, the only farm on which it was tried. (I have not included table 33 at Dumraon, where both did well, as the series is single and accumulative.)

Well-preserved farm-yard manure is also profitable. The average increase at Bankipore from a dressing of 100 maunds was 29.2 per cent. of rice and 13.6 per cent. of *paira* grain. The addition of 50 maunds produced an increase of 20.6 per cent. of rice and 15.9 per cent. of *paira* grain at Bankipore, 8.8 per cent. of rice grain at Cuttack and 2.6 per cent. at Dumraon (again ignoring table 33). When a single application is made at intervals 100 maunds are more profitable than half that amount. Well-preserved farm-yard manure proved five times as valuable as the local substitute at Cuttack.

**Khari* salt is a profitable manure on soils, such as that at Bankipore which are deficient in sulphur and chlorine. It gave an average increase of 19 per cent. of rice grain, 9 per cent. of *paira* grain, and Rs. 7.15 per acre of profit. When tried at Cuttack, where the chemical analysis shows there is more sulphur, it did not pay for itself. (Table W in the appendix.)

APPENDIX

B.—CULTIVATION EXPERIMENTS.

(1) Hot weather cultivation.

TABLE A.

(Bankipore.)

	1914-15		1915-16				1916-17			
	RICE		RICE		GRAM		RICE		GRAM	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Ploughed in the hot weather with a										
Punjab Plough . .	489	642	1,322	1,985	747	538	470	1,230	1,000	800
Hindustan Plough . .	478	560	...	...	...	...	1,210	1,880	1,310	1,230
Local Plough . .	365	543	1,159	1,833	677	506	230	700	840	780
Unploughed . .	489	632	961	1,568	619	426	720	1,430	840	750

TABLE A—contd.

(Bankipore.)—contd.

	1916-17				1917-18				1917-18			
	RICE		GRAM		RICE		GRAM		RICE		GRAM	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Ploughed in the hot weather with a												
Punjab Plough . .	1,485	2,082	1,097	1,037	1,461	1,656	597	411	1,646	1,993	946	825
Hindustan Plough . .	...	...	...	...	1,337	1,615	781	514	...	...	...	...
Local Plough . .	...	...	...	...	1,162	1,368	1,193	1,029	...	...	...	...
Unploughed . .	1,312	2,090	760	737	1,049	1,543	802	617	1,905	2,216	704	586

In 1914-15 each experiment was in triplicate on 0.2 acre plots, in 1915-16 on four 0.2 acre plots, in 1916-17 and 1917-18 the first series was on 0.1 acre plots, the second in duplicate on 0.2 acre plots. Where they were on more than one plot the figures are the average of the plots.

TABLE B.

(Cuttack.)

Treatment	1915-16		1916-17	
	Grain	Straw	Grain	Straw
Ploughed in the hot weather	1,353	1,706	1,086	2,060
Unploughed	1,107	1,537	1,025	1,291

Each year the experiments were in duplicate on 0.2 acre plots. The figures are the average of the two plots.

(2) Seed Selection.

TABLE C.

(Cuttack.)

Seed sown	1914-15		1915-16	
	Grain	Straw	Grain	Straw
Seed that did not pass through sieve	1,871	2,870	1,638	2,296
Corresponding unselected seed	1,842	2,767	1,645	2,060
Seed that sank in a saturated salt solution.	1,826	2,829	2,196	2,234
Corresponding unselected seed	1,771	2,562	1,827	2,398

Each year the experiments were in duplicate on 0.2 acre plots, the figures are the average of the two plots.

(3) Transplanted and broadcast rice compared.

TABLE D.

(Cuttack.)

Cultivation	1915-16		1916-17		1917-18		1918-19	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Transplanted	1,927	2,362	1,491	1,588	1,571	2,255	1,189	1,845
Broadcast	1,684	1,942	1,247	1,435	1,368	2,023	650	1,614

Each year the experiments were in duplicate on 0.2 acre plots, the figures are the average of the two plots.

(4) Broadcast rice in Orissa.

TABLE E.

(Cuttack.)

Seed rate per acre	1912-13		1913-14		1914-15		1914-15		1915-16		1916-17		1917-18	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
40 seeds (80 lb.)	2,213	4,125	2,094	2,624	1,604	3,101	1,461	2,470	1,555	1,845	1,578	2,203	2,039	2,998
30 seeds (60 lb.)	2,554	4,258	2,149	2,709	1,174	1,994	1,317	2,255	1,524	1,538	1,720	2,562	2,234	2,665
20 seeds (40 lb.)	2,580	4,458	2,156	2,672	5,140	2,896	1,532	3,270	1,570	1,891	1,920	2,229	2,167	2,076

Each series was in duplicate on 0.2 acre plots; the figures are the average of the two plots.

TABLE F.
(Cuttack.)

Seed rate per acre	After treatment	1914-15		1915-16	
		Grain	Straw	Grain	Straw
40 seers (80 lb.)	Ploughed through	1,481	2,470	1,555	1,845
30 seers (60 lb.)	Do. . .	1,317	2,255	1,524	1,538
20 seers (40 lb.)	Do. . .	1,532	3,270	1,570	1,891
15 seers (30 lb.)	Not ploughed	1,783	3,198	1,491	2,357

Each year the experiments were in duplicate on 0.2 acre plots, the figures are the average of the two plots.

TABLE G.
(Cuttack.)

Treatment	1915-16			1916-17			1917-18		
	Grain	Straw	Profit	Grain	Straw	Profit	Grain	Straw	Profit
			R s.			R s.			R s.
Green manure (dhaincha)	2,328	3,088	50 8	1,214	1,740	17 3	1,589	2,614	18 8
Unmanured	2,182	2,702	45 6	850	1,563	8 9	1,335	2,716	12 10

Each year the experiments were in duplicate on 0.2 acre plots, the figures are the average of the two plots.

(6) Wet and dry seed beds.

TABLE H.

Cultivation	SABOUR						CUTTACK					
	1913-14		1914-15		1916-17		1916-17		1917-18		1918-19	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Wet seed-bed	2,260	..	762	..	205	497	1,711	3,162	1,835	3,357	1,768	2,947
Dry seed-bed	2,100	..	686	..	295	1,030	1,701	3,049	1,507	3,230	1,733	2,528

At Sabour the first year each experiment was on 8 plots of 0.025 acre, and in the two following years on 4 plots of 0.025 acre; at Cuttack each year the experiments were in duplicate on 0.2 acre plots; in all cases the figures are the average of the plots.

(7) Seed rate in seed bed.

TABLE I.
(Sabour.)

Seed sown per acre of seed bed	1914-15	1915-16	1916-17
	Grain	Grain	Grain
2 maunds (164 lb.)	1,351	1,096	1,137
4 maunds (328 lb.)	1,359	1,058	1,061
10 maunds (820 lb.)	1,149	1,163	1,186

Each year the experiments were on 0.1 acre plots.

TABLE J.
(Bankipore.)

Seed sown per acre of seed bed	1914-15		1915-16		1916-17	
	Grain	Straw	Grain	Straw	Grain	Straw
5 maunds (410 lb.)	815	981	887	1,244	499	713
7.5 maunds (615 lb.)	697	946	541	1,107	635	848

Each experiment was on 6 plots of 0.2 acres in 1914-15 and on 3 plots of 0.25 acre in each of the two following years ; the figures are the averages of the plots.

TABLE K.
(Cuttack.)

Seed sown per acre of seed bed	1916-17		1917-18		1918-19	
	Grain	Straw	Grain	Straw	Grain	Straw
3 maunds (246 lb.)	1,547	1,947	1,300	2,532	1,055	1,058
4 maunds (328 lb.)	1,886	2,306	1,300	2,460	1,257	1,319
5 maunds (410 lb.)	1,845	1,742	1,555	2,460	1,230	1,435

Each year the experiments were in triplicate on 0.2 acre plots ; the figures are the average of the three plots.

(9) The number of seedlings to transplant in each hole.

TABLE L.

(Bankipore.)

Number of seedlings	1912-13		1913-14		1914-15		1915-16		1917-18.		1918-19.	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
1 in each hole	..	..	788	1,276	919	1,297	401	960	..	..	..	..
2 in each hole	1,126	2,371	1,005	1,325	785	1,102	365	854	912	574	415	980
4 in each hole	1,205	2,429	979	1,450	867	1,350	407	865	894	711	505	985
8 in each hole	1,316	2,663	1,150	1,709	1,081	1,630	574	1,107	1,085	859	875	1,680

Each experiment was on 20 plots of 0.2 acre each in 1912-13 ; on 4 plots of 0.2 acre each in 1913-14 and 1914-15 (both series) ; on 2 plots of 0.25 acre each in 1915-16 (both series) ; the first series on three and the second on 2 plots of 0.25 acre each in 1916-17 ; on 3 plots of 0.25 acre each in 1917-18 ; on 2 plots of 0.2 acre each in 1918-19. The figures are the average of the various plots.

TABLE M.
(Cuttack.)

Number of seedlings	1912-13		1913-14		1914-15		1915-16		1916-17	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
1 in each hole . . .	2,097	3,895	2,296	2,970	2,976	3,546	1,660	2,678	1,238	2,853
2 in each hole . . .	2,189	4,147	2,852	2,716	1,932	3,290	1,545	2,644	1,300	2,985
4 in each hole . . .	2,261	4,702	2,665	3,280	2,132	3,921	1,746	2,572	1,210	2,972
8 in each hole . . .	2,132	4,946	2,465	3,408	2,199	4,095	1,727	3,080	1,040	2,998

Each year the experiments were in duplicate on 0.2 acre plots; the figures are the average of the two plots.

TABLE N.
(Sabour.)

Number of seedlings	1912-13		1913-14	1914-15		1915-16	1916-17	
	Grain	Straw	Grain	Grain	Grain	Straw	Grain	Straw
1 to 2 in each hole . . .	2,005	4,261	2,601	992	976	2,776	1,028	2,091
4 to 6 in each hole . . .	2,469	4,580	2,678	1,152	1,192	3,309	1,195	2,415

The first year the experiments were on single plots of 0.1 acre each, and in the following years on 40 plots of 0.025 acres each, the figures are the average of the 40 plots.

(10) The distance apart at which to transplant the seedlings.

TABLE O.
(Sabour.)

Distance apart	1914-15		1915-16		1916-17	
	Grain	Straw	Grain	Straw	Grain	Straw
6 inches . . .	1,252	...	1,615	4,787	1,470	3,537
9 inches . . .	912	...	1,160	4,200	1,485	2,990
12 inches . . .	667	...	877	3,282	1,212	2,255
18 inches . . .	142	...	660	2,605	560	1,645

Each year the experiments were on 0.05 acre plots.

(II) Nigar.
TABLE P.

Kind of rice	Treatment	SOHARA.						AGEON.					
		1916		1917		1918		1916		1917		1918	
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Main crop, harvested in December.	Nigarrd at the usual time . . .	1,570	1,578	1,701	3,063	1,912	2,273	1,365	2,209	662	1,377	1,956	1,912
	Not nigarrd . . .	1,306	1,399	1,672	2,437	1,860	1,897	1,356	2,236	808	1,770	1,804	2,383
	Nigarrd at the usual time + <i>khari</i> salt.	1,797	2,026	1,638	1,662	1,872	2,062	1,424	2,290	1,027	1,512	1,797	2,061
	Not nigarrd + <i>khari</i> salt . . .	1,463	1,505	1,743	2,753	1,994	2,019	1,556	2,432	1,038	1,815	1,610	2,147
	Nigarrd at the usual time but not allowed to dry enough to crack the soil.	1,760	1,645	1,843	2,326	1,865	1,533	1,481	2,465	841	1,512	1,073	1,355
	Nigarrd on September 1st . . .	1,046	1,018	1,859	2,213	1,759	2,158	1,207	2,066	980	1,328	1,584	1,928
	Nigarrd on September 15th . . .	1,153	1,069	1,422	2,098	1,866	2,160	821	1,776	768	1,045	1,547	1,903
	Nigarrd on October 1st . . .	1,452	1,474	1,459	2,342	1,640	1,854	703	1,570	546	966	1,520	1,808
	Nigarrd on October 15th . . .	1,325	1,377	1,768	2,361	1,700	2,232	1,443	2,687	907	1,500	1,325	1,762
	Nigarrd at any time the weather permits from September 1st to October 15th	1,301	1,302	1,508	2,294	1,867	2,178	1,501	2,459	861	1,607	1,141	1,507
Kharif crop, harvested in November.	Nigarrd at any time the weather permits from September 1st to October 15th but not allowed to dry enough to crack the soil.	1,512	1,447	1,667	3,101	1,943	2,377	1,370	2,306	781	1,512	1,305	1,746
	Nigarrd at the usual time . . .	1,746	1,676	1,950	2,065	1,610	2,113	..	..	854	1,476	..	..
	Not nigarrd . . .	1,500	1,438	1,809	2,407	2,094	2,452	..	..	603	1,476	..	..
												607	800
												698	977

Each series was in duplicate. The area of the plots varied slightly in each series, at Sohara they were about 0.22 of an acre, at Ageon in one series 0.08 of an acre and in the other from about 0.2 to and 0.3 of an acre. The figures are the average of the two plots and are calculated on the exact area of the respective plots.

C. MANURIAL EXPERIMENTS.

1. Chemical manures.

TABLE Q.
(Cuttack.)

Manure applied per acre	1914-15		1915-16		1916-17	
	Grain	Straw	Grain	Straw	Grain	Straw
160 lb. of sulphate of ammonia + 120 lb. of superphosphate + 100 lb. of muriate of potash.	2,406	6,602	2,577	3,193	1,837	3,946
160 lb. of sulphate of ammonia + 120 lb. of superphosphate.	2,470	6,995	2,470	4,150	1,919	3,125
160 lb. of sulphate of ammonia + 100 lb. of muriate of potash.	2,388	6,611	2,542	4,130	2,024	3,459
120 lb. of superphosphate + 100 lb. of muriate of potash	1,999	4,546	2,031	2,649	1,809	2,767
Unmanured	1,947	4,433	1,901	2,008	1,498	2,995

Each year the experiments were in duplicate on 0.2 acre plots, the figures are the average of the two plots.

TABLE R.
(Bankipore.)

Manure applied per acre	1914-15						1915-16					
	RICE			GRAM			RICE			GRAM		
	Grain	Straw	Profit	Grain	Straw	Year's profit	Grain	Straw	Profit	Grain	Straw	Year's profit
300 lb. of basic slag . . .	1,558	2,285	29 2	345	323	R a. 44 14	1,444	2,224	8 8	497	400	R a. 24 13
1,640 lb. of lime . . .	1,403	2,096	22 6	424	338	38 7	1,064	2,709	-23 14	536	570	-8 1
Unmanured . . .	1,501	2,106	37 15	400	300	53 10	1,464	2,291	26 4	717	609	33 16

Each year the experiments were in duplicate on 0.2 acre plots, the figures are the average of the two plots.

TABLE S.
(Cuttack.)

Manure applied per acre	1916-17		1917-18		1918-19	
	Grain	Straw	Grain	Straw	Grain	Straw
Green manure + 1,230 lb. of lime.	2,425	3,305	2,204	3,229	1,773	2,998
Green manure (<i>dhaincha</i>) . .	2,395	3,408	2,239	3,280	1,760	3,562

Each year the experiments were in duplicate on 0.2 acre plots, the figures are the average of the two plots.

2. Simple Manures.

TABLE T.
(Bankipore.)

Manure applied per acre	1914-15						1915-16					
	RICE			GRAM			RICE			GRAM		
	Grain	Straw	Profit	Grain	Straw	Profit	Grain	Straw	Profit	Grain	Straw	Profit
	R a.	R a.	R a.	R a.	R a.	R a.	R a.	R a.	R a.	R a.	R a.	R a.
100 manure of cowdung .	1,274	2,172	20 5	438	504	20 6	1,730	2,850	19 2	718	505	29 0
50 manure of cowdung .	1,222	2,024	24 12	495	561	24 7	1,582	2,492	16 14	684	612	25 6
5 manure of castor cake .	1,218	1,968	15 12	363	425	15 8	1,570	2,542	8 11	475	382	15 9
2 manure of khari salt .	1,187	2,203	27 9	280	307	9 13	1,673	2,543	26 8	433	379	14 0
Green manure (dhaincha) .	1,139	1,973	26 0	568	582	27 12	1,550	2,306	23 2	666	614	26 11
Green manure (sunn) .	1,187	1,993	26 11	532	641	25 5	1,464	2,190	16 15	520	381	17 4
Unmanured .	933	1,717	20 1	379	439	16 11	1,391	2,158	20 14	636	537	23 11

Each year the experiments were in duplicate on 0.2 acre plots, the figures are the average of the two plots.

TABLE U.
(Bankipore.)

Manure applied per acre	1916-17.						1917-18.					
	RICE			GRAM			RICE			GRAM		
	Grain	Straw	Profit	Grain	Straw	Profit	Grain	Straw	Profit	Grain	Straw	Profit
	R a.	R a.	R a.	R a.	R a.	R a.	R a.	R a.	R a.	R a.	R a.	R a.
2 manure of khari salt .	2,436	3,000	60 13	484	400	14 1	1,830	2,828	31 5	550	507	16 0
Green manure (dhaincha) .	2,144	2,768	52 1	508	428	15 2	1,496	2,898	26 13	507	455	13 15
Unmanured .	1,980	2,370	49 10	538	440	16 1	2,032	3,968	46 12	600	576	18 11
2 manure of khari salt .	1,730	2,560	31 3	1,112	1,032	37 10	2,026	2,178	30 5	1,003	848	30 5
Unmanured .	1,067	1,612	10 6	745	722	22 6	1,525	2,031	21 3	648	545	13 13

Each year the first three (those above the blank line) were in duplicate on 0.25 acre plots, the last two (those below the blank line) in duplicate on 0.2 acre plots, the figures are the average of the two plots.

TABLE V.
(Bankipore.)

Manure applied per acre	Grain	1918-19	
		Straw	Profit
			R a.
5 maunds of mustard cake	1,285	2,395	37 13
5 maunds of castor cake	1,315	2,765	34 9
55 maunds of cowdung	1,155	2,215	31 4
2 maunds of khari salt	1,335	2,480	64 15
Unmanured	1,330	2,965	51 11

The experiments were in duplicate on 0.2 acre plots, the figures are the average of the two plots.

TABLE W.
(Cuttack.)

Manure applied per acre	1907-08			1908-09			1909-10			1910-11			1911-12		
	Grain	Straw	Profit	Grain	Straw	Profit	Grain	Straw	Profit	Grain	Straw	Profit	Grain	Straw	Profit
Unmanured	1,845	5,002	58 12	2,460	5,871	56 0	1,568	4,715	42 11	1,824	3,362	42 11	2,308	4,802	42 0
Green manure (dhakha)	2,378	5,166	56 0	2,911	5,801	56 0	2,132	5,022	46 11	2,419	4,805	46 11	2,542	5,504	46 15
50 maunds of cowdung	..	..	60 15	..	..	61 13	..	..	..	..	..	..	2,439	4,940	62 6
50 maunds of village khado	..	..	..	..	..	..	..	..	..	..	..	..	2,429	5,033	64 1
5 maunds of gingelly cake	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
100 maunds of cowdung	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
3 maunds of khari salt	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Manure applied per acre	1912-13			1913-14			1913-14			1913-14		
	Grain	Straw	Profit	Grain	Straw	Profit	Grain	Straw	Profit	Grain	Straw	Profit
Unmanured	2,517	3,782	30 7	1,445	1,907	30 7	1,906	3,088	42 11	1,486	2,511	42 0
Green manure (dhakha)	2,434	3,938	38 11	1,784	2,091	38 11	..	..	..	..	..	..
50 maunds of cowdung	2,690	3,870	26 10	1,464	1,907	26 10	2,200	2,808	46 11	..	..	..
50 maunds of village khado	2,373	3,354	..	..	..	..	..	..	..	..	..	..
5 maunds of gingelly cake	..	..	19 7	1,451	1,722	19 7	1,876	2,870	30 11	..	..	..
100 maunds of cowdung	..	..	..	..	..	..	2,122	3,177	43 2	..	..	..
3 maunds of khari salt	..	..	..	..	..	..	..	..	..	1,702	3,023	35 3

TABLE W.—concl'd.
(Cuttack)—concl'd.

Manure applied per acre	1915-16			1916-17			1917-18		
	Grain	Straw	Profit	Grain	Straw	Profit	Grain	Straw	Profit
Unmanured	1,505	2,229	R a. 43 4	1,368	2,808	43 5	1,492	2,306	R a. 39 6
Green manure (<i>dhaincha</i>)	1,957	2,721	65 6	1,563	3,063	47 1	1,806	3,382	55 5
50 maunds of cowdung	1,763	2,654	56 5	1,470	2,716	43 6	..	..	..
50 maunds of village <i>khaffo</i>	1,688	2,562	54 5	1,424	2,680	41 4	..	..	..
5 maunds of gingelly cake	..	..	..	..	..	..	..	..	..
100 maunds of cowdung	..	..	..	..	..	..	..	..	..
3 maunds of khari salt	..	..	..	..	..	..	..	..	..

From 1907-08 to 1911-12 inclusive the experiments were on 0.2 acre plots, the first two series of 1913-14 were on 0.16 acre plots, all the remainder were in duplicate on 0.2 acre plots, the figures in these cases being the average of the two plots. The second series in 1913-14 were on broadcast rice, the others as usual on transplanted rice.

Agricultural Research Institute, Pusa

Ustilago Crameri Koern.

ON

Setaria italica Beauv.

BY

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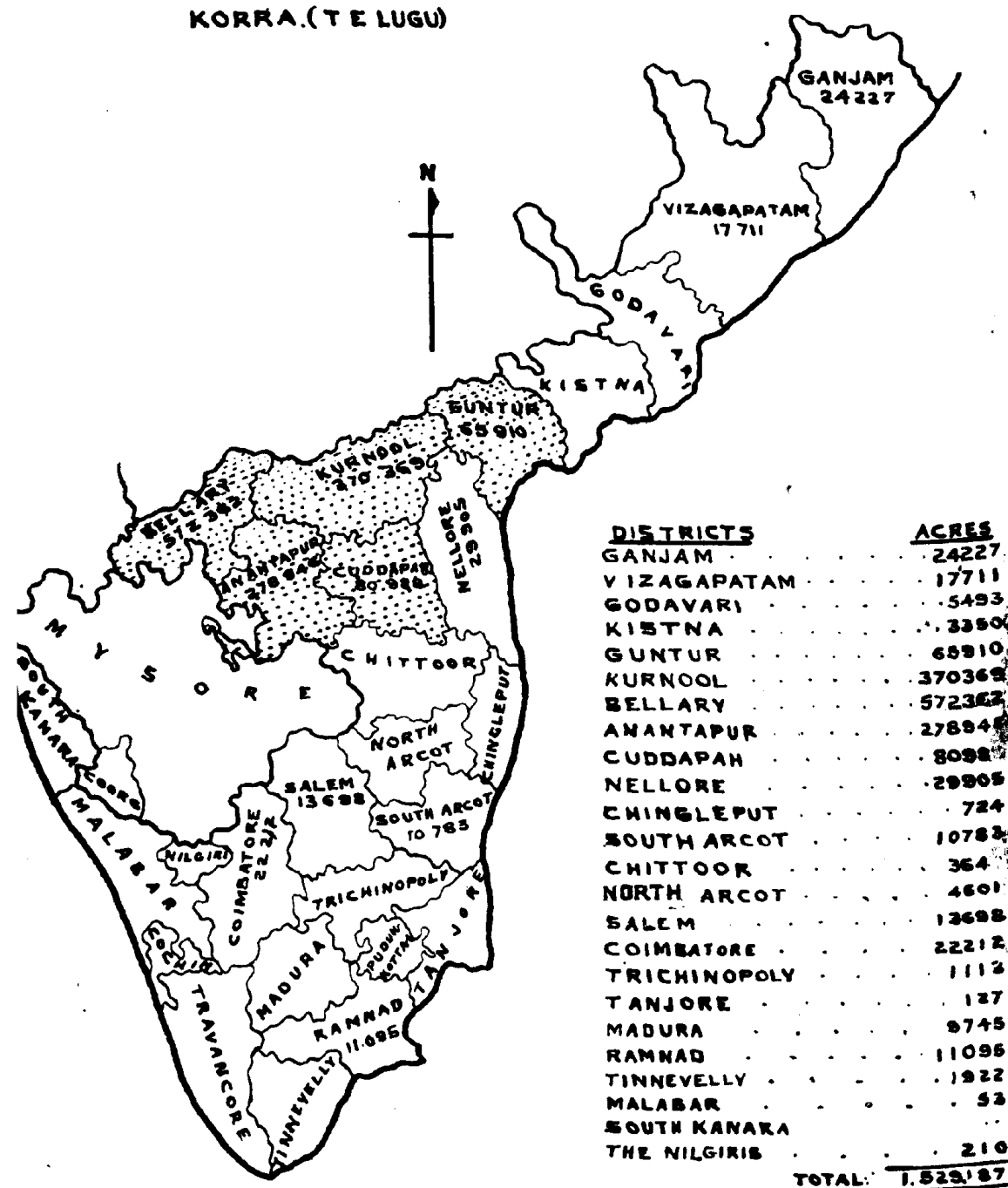
MADRAS PRESIDENCY.

AREA UNDER.

ITALIAN MILLET.(SETARIA ITALICA).

TENAI.(TAMIL)

KORRA.(TE LUGU)



Ustilago Crameri Koern. on *Setaria italica* Beauv.

[Received for publication on 18th March, 1920.]

Setaria italica is grown in all the districts of the Madras Presidency except Malabar and South Kanara. It is called 'Tenai' in Tamil and 'Korra' in Telugu. The total area of this crop in 1918 was 1,529,187 acres. The northern central districts of Cuddappah, Kurnool, Bellary, Anantapur and Guntur among themselves accounted for an area of 1,368,575 acres which is nearly 90 per cent of the total. Most other districts raise this crop to a greater or less extent wherever rain conditions permit. The importance of the crop as a food is well known. The map shows the extent of its cultivation in the several districts. It is grown as a pure crop in limited areas, but is generally grown mixed, the chief crop associated with it being cotton. In fact, this has given a name to the mixture which is known as "Korrapatthi" in the Ceded Districts.

Setaria italica is subject to the attack of some fungus diseases which cause much damage, the most important being *Sclerospora graminicola* Schroet (green-ear disease), *Uromyces Setaria italica* Diet. (rust) and *Ustilago Crameri* Koern. (smut). In the flowering stage the green-ear disease fungus causes proliferation of all parts of the flower so that the earhead becomes a mass of leafy shoots. The rust fungus produces brown spots on the leaves. The one that causes by far the greatest loss, however, is smut which converts the valuable food stored as starch in the seeds into a mass of black powder.

Symptoms. Outwardly the grains are the only parts that appear infected. The smutted grains are only very slightly larger than healthy ones. In the early stages when the healthy grains are still green, the smutted ones have become grey, while at a later stage the former become yellow, while the latter are brown. When the membrane of the smutted grain bursts (Pl. I, figs. 1 and 2), the black spores are liberated and give the grain and the glumes a dark dusky appearance, readily seen and much dreaded in certain tracts, where the cultivators aptly call it *katika korra* or sooty millet, though when pressed between the fingers, the

spore mass is not jet black but slightly brown. The spores are formed only in the spikelets. Sometimes all the shoots of the plant are affected and almost all the grains in the ear may be attacked. In some cases the upper spikelets may be free. In a partially attacked earhead the tip may be sound but the base is always affected. In no case has the upper portion of the earhead been found diseased, while the lower was sound. This gives an indication that infection proceeds from the bottom upwards and that when the inflorescence began to elongate the fungus did not keep pace with the development of the inflorescence and did not reach the uppermost part of the panicle.

Origin. In Siruguppa Taluk of Bellary District the disease was very severe in 1917, and a report by the Agricultural Demonstrator there led to the investigation of this subject. The grains of ten smutted earheads sent to the Laboratory were counted with a view to find out the proportion of healthy to smutted grains. There were 2,261 healthy grains and 9,005 smutted grains. The proportion of healthy to smutted grains was 1 to 4. Details are given below:—

No.	Healthy grains	Smutted grains
1	115	314
2	123	580
3	237	678
4	488	1,232
5	34	789
6	89	802
7	587	1,352
8	25	684
9	58	589
10	525	1,895
TOTAL	2,261	9,005

Loss. The area under Italian millet in Siruguppa Taluk in 1918 was 23,800 acres. The estimated loss because of smut was more than a quarter of the crop: but if it be taken at a quarter of the crop and

the average yield at 1,000 lb. per acre, then the total loss for the Taluk would be 250 lb. per acre, which at the price current at the time amounts to a money value of 11,90,000 rupees. The area under this crop in Siruguppa Taluk is only one-sixtieth of the total area of the Presidency, and though the smut was not so severe in most other tracts still it was present to some extent in all and this gives an idea of the great loss caused by this smut in one year. It thus became important that a method of treatment suitable to the means and capabilities of the ryot should be devised and demonstrated in those tracts where smut was severe and recurring.

Spores. In bulk the spore masses are black but when in a thin layer they look dull brown. They are aggregated into spore-balls (Pl. I, fig. 3) which readily disintegrate under a cover slip into the component spores. In shape they are globular to ovoid, and some show irregular indentations (Pl. I, fig. 3). They are smooth and their contents appear more or less granular. They measure $7.7-11.1 \times 5.3-8.2\mu$.

When placed in water, the spores begin to germinate usually in 6 to 9 hours. A germ tube is produced and the protoplasm contained in the spore passes into the tube (Pl. I, fig. 4). The rupture of the wall of the spore is so pronounced that the projecting portions of the spore-wall are seen along each side of the base of the germ-tube. It becomes divided by three or four septa (Pl. I, fig. 4). From each of the cells small buds arise near the septum and form sporidia. These, when detached, may either put forth a germ tube or two adjacent sporidia may become connected by a transverse branch. There are instances where the promycelium may not develop sporidia but becomes an ordinary hypha and penetrates the tissue of the host plants by its pointed extremity. Again a kind of fusion takes place by means of a tube from one segment of the same promycelium. Thus the upper segment becomes connected with the lower segment of the same promycelium by means of a curved tube which Brefeld¹ calls a "buckle-joint" or "knee-joint" (Pl. I, fig. 4, a, b, c). This is common when spores are germinated in water. But when germinated in sugar solution, these fusions do not occur, but the sporidia multiply in the manner of budding of "Yeast," thus giving rise to copious sporidial formation. This goes on until all the nutritive medium is exhausted. The course of infection is as follows:—

Penetration. The germ tube penetrates the wall of an epidermal cell and grows through the cells beneath the surface layer (Fig. 5). In

¹ Brefeld. *Untersuchungen aus dem Gesamtgebiete, etc., der Mykologie*, Vol. V, 1883, pages 101 to 102.

Germination of the spores of this smut has been dealt with in detail.

the early stage of the seedling the hyphae in sections of the nodes, are very numerous and very clearly seen. A month after the infection, hyphae are only seen in the nodes (and near the apex of the shoot) (Pl. II). The fungus is found in masses. Perhaps this is due to the fungus not being able to keep pace with the rapid growth of the plant and the fungus gets torn up and isolated into fragments. Infection takes place when the seed begins to germinate and penetration has been seen only through the epidermal cells of the hypocotyl. The young mycelium grows inside along with the seedling, showing no external signs of its presence until the earheads are produced, when it forms its spores in the ovary.

Prevention—local. The seriousness of this disease and the necessity for its prevention are not unknown to the ryot of the Ceded Districts, only the steps taken are primitive. He thinks that a mixture of cattle-urine, garlic, asafoetida, sweet-flag, is effective, but this has been on various trials found to be ineffective. Various preventive measures¹ are used against this and similar smuts on cereals in other parts of the world as washing the grains in water, steeping the grain in copper sulphate solution or in formalin or in hot water or exposing it to hot air. Copper sulphate is known to the ryots and is available in the local bazaar. It is the cheapest, safest and most acceptable method so far as he is concerned and hence it is recommended. Formalin, though as effective as copper sulphate, is difficult to handle except under skilled supervision. The hot water, and the hot air methods, however, are not suitable to the ordinary cultivator, as he has no knowledge of the meaning or use of a thermometer. The limits of safety were considered too narrow for the satisfactory adoption of this method.

Other references.

1. G. P. Clinton in "North American Ustilagineae" has described this smut on the Italian millet as *Ustilago Crameri* Koern. His description is "Sori in the spikelets, infecting all of the spike, ovate, about 2-4 mm. in length, chiefly destroying inner and basal parts; spores reddish-brown, chiefly ovoid to subspherical though occasionally more elongated and irregular with usually pitted contents, chiefly 8-11 μ in length.

¹ Hecke, L. Vorversuche zur Bekämpfung des Brandes der Kolbenhirse. *Zeits. Landw. Ver. Oesterr.*, 1902, 933, 1902.

(Gives results of treatment with hot water, formalin, corrosive sublimate, and copper sulphate on germination of *Ustilago Crameri* and *U. Panici-miliacei*.)

Stuart, W. Formalin as a Preventive of Millet Smut. *Ann. Rep. Ind. Agr. Exp. St.*, 13, 25, 1901, shows from experiment that seed soaked 1-4 hrs. in formalin, rate of 1 lb. to 45 gals. of water, was effective in preventing this smut.

"This fungus sometimes causes damage to the cultivated millets. It has been reported only during recent years from this continent. The ordinary hot water method of seed treatment is a preventive."

2. Brefeld. *Untersuchungen aus dem Gesamtgebiete, etc., der Mykologie*, Vol. V, 1883, pages 101 to 102.

Germination of the spores of this smut has been dealt with in detail.

3. Hecke, L. Vorversuche zur Bekämpfung des Brandes der Kolbenhirse. *Zeits. Landw. Ver. Oesterr.*, 1902, 933, 1902.

(Gives results of treatment with hot water, formalin, corrosive sublimate, and copper sulphate on germination of *Ustilago Crameri* and *U. Panici-miliacei*.)

4. Stuart, W. Formalin as a Preventive of Millet Smut. *Ann. Rep. Ind. Agr. Exp. St.*, 13, 25, 1901, shows from experiment that seed soaked 1-4 hrs. in formalin, rate of 1 lb. to 45 gals. of water, was effective in preventing this smut.

5. Butler, E. J. "Fungi and disease in plants," pages 234-235.

As is the case with *Clavetia Sorghi Vulgaris* on *Andropogon Sorghum* (Short smut on cholum Tamil and jonna Telugu), another smut known to the cultivator and whose method of prevention is gradually being adopted by them, the smut on Italian millet, also yields readily to preventive treatment. The method of infection in both cases is the same. As in *Sorghum*, the smut on Italian millet adheres to the surface of the seed, germinates along with the seeds and enters into the young seedling only during the seedling stage.

Preventive experiments. In the investigation of this preventive method, the points to be settled were:—

1. the concentration of copper sulphate solution which would undoubtedly prevent the germination of the spores,
2. whether that concentration of the solution would at all affect the germination of the seed, and
3. whether the results obtained by 1 and 2 were confirmed by field trials.

1. *The effect of copper sulphate solution on the spores.* A few smutted grains were broken up and a small quantity of spores collected and made into ten lots for treatment. Each lot was put in a test tube. A few spores from each lot were placed on slides in distilled water to germinate. In 24 hours almost every spore had germinated in all the eleven lots.

The tubes with the spores were thoroughly shaken several times during the period in which they were in solution and then left to settle. The fluid in each tube was removed with a pipette and distilled water

put in. The tubes were again well shaken. When the spores again settled down the water was taken off and the tube refilled with water. This rinsing was repeated a number of times until the last rinsing water contained no trace of copper sulphate. As a further test, the last rinsing water from each tube was poured into a tube containing spores and left for the corresponding period of time. In no case did this steeping in this rinsing water affect the germination of the spores. The details of the experiment are given in the tabular form.

Test tube No.	Concentration of copper sulphate solution used	Time soaked	Period taken for testing germination	Results
1	"	12 hours	12 hours	In distilled water 50 per cent germination in 6 hours, 95 per cent in 12 hours, and 100 per cent in 24 hours.
2	0.1 per cent	15 minutes	120 hours	About 50 per cent germinated in 24 hours. The germ tube of spores that germinated lengthened and even this stopped after 96 hours.
3	0.1 "	30 "	Do.	No germination.
4	0.5 "	15 "	Do.	Do.
5	0.5 "	30 "	Do.	Do.
6	1.0 "	15 "	Do.	Do.
7	1.0 "	30 "	Do.	Do.
8	2.0 "	15 "	Do.	Do.
9	2.0 "	30 "	Do.	Do.
10	5.0 "	15 "	Do.	Do.

Note.—6 slides with drops of distilled water were used for germinating the spores in each case.

From these experiments it is seen :

- (1) that the spores germinated in distilled water to the extent of 50 per cent in 6 hours and freely in twelve hours ;
- (2) that 0.1 per cent solution of copper sulphate for 15 minutes retarded germination and hindered growth: the promycelium was short and did not produce sporidia during the period of observation ;
- (3) that 0.1 per cent for 30 minutes stopped germination entirely as did all higher concentrations for periods of 15 and 30 minutes.

Under the conditions of the experiment, in working with small quantities of spores it is likely that the spore masses will be broken into their component parts to a greater extent than they will be in a field experiment where the seed is steeped in a copper sulphate solution. It may be anticipated that the spores may not be so well separated from each other and that the copper sulphate solution may thus not get at every individual spore, with the result that the same effect may not be produced in the field with any one concentration as is shown in the table of results.

2. *The effect of copper sulphate solution on the germination of the seeds.* In each experiment 100 seeds were placed in moist sterile sand. The sand was sterilized by being kept in hot-air sterilizer at 170 degrees centigrade for half an hour. In 48 hours all the 100 seeds germinated, showing thereby that the seeds were in a very good condition. With the seeds thus tested the following 15 series of experiments were tried with the results tabulated below :—

Serial No.	Strength of copper sulphate solution	Time steeped	Percentage of germination	Number of hours taken for germination
1	Untreated seed	...	100	48
2	0.5 per cent	15 minutes	99	96
3	0.5 "	30 "	100	120
4	1 "	15 "	98	Do.
5	1 "	30 "	99	Do.
6	2 "	15 "	99	Do.
7	2 "	30 "	99	Do.
8	2 "	10 hours	99	192
9	5 "	15 minutes	95	Do.
10	5 "	30 "	92	Do.
11	10 "	15 "	79	Do.
12	10 "	30 "	84	216
13	15 "	15 "	63	Do.
14	15 "	30 "	69	Do.

The experiment shows that the lower concentrations have no effect on germination, that the lowest concentration that has a definite effect is 5 per cent and that after steeping for 30 minutes, and that, above that

concentration, the germination is lowered in proportion as the concentration is greater. It is thus obvious that 5 per cent concentration of copper sulphate solution is the limit within which we can safely steep seeds. However, smut spores fail to germinate with even 0.5 per cent copper sulphate solution for 15 or 30 minutes. As a working formula, therefore, the strength of solution which is required to kill the spores and at the same time not affect the germination of the seed may be taken at somewhere about 2 per cent and the ordinary length of time may be half an hour. This allows a large limit for possible errors both in making the solution in the rough way in which a cultivator does it and in the time of steeping and still ensures success to the treatment.

Test as to whether the results obtained by (1) and (2) are confirmed by making a trial on a field scale. Seed was obtained from the stores at the Central Farm, Coimbatore. In order to get clean seed for this experiment it was steeped in 2.5 per cent formalin (i.e., Schering's formalin diluted) for 15 minutes. That this treatment completely destroys the spores but does not hinder the germination of the seed was proved by repeated experiments. 32 plots were laid out in the compound of the Pot-Culture house of the Government Mycologist and were sown with seeds treated in the manner detailed below:—

1. Seed as obtained from the Central Farm stores without any treatment k. 1.
2. Seed soaked in 2.5 per cent formalin solution for 15 minutes k. 2.
3. Part of k. 2 was mixed with spores of *tenai* smut and this is k. 3.
4. Part of k. 3 was treated with copper sulphate solution as detailed below:—

Series	Strength of copper sulphate solution	Time of soaking
4	0.5 per cent	15 minutes (k. 4)
5	0.5 "	30 " (k. 5)
6	1 "	15 " (k. 6)
7	1 "	30 " (k. 7)
8	2 "	15 " (k. 8)
9	2 "	30 " (k. 9)
10	2 "	10 hours (k. 10)
11	5 "	15 minutes (k. 11)
12	5 "	30 " (k. 12)
13	10 "	15 " (k. 13)
14	10 "	30 " (k. 14)
15	15 "	15 " (k. 15)
16	15 "	30 " (k. 16)

Duplicate plots were laid out in each case, the seeds were sown on 20th November, 1918, and harvested on 13th February, 1919. The

plots that were sown with seed infected with smut, i.e., (k. 3), showed 208 smutted (earheads) plants out of 350 that grew. All the other plots were entirely free from smut.

Thirty-two plots of one-cent each were laid out in field No. 2c₂ in the Government Agricultural Station, Hagari, with the kind co-operation of Mr. Hilson, Deputy Director of Agriculture, Circles II and III. The seeds were sown on 23rd September, 1918. The plots were harvested in January, 1919. Only the artificially infected plot produced smutted earheads. The germination in all the plots was for some reason very uneven and the experiment is taken only qualitatively.

The following experiments were made to determine the place in the *tenai* plant through which the smut gains entrance. *Tenai* seed obtained from the Agricultural Demonstrator, Bellary, was disinfected with 2.5 per cent formalin for 15 minutes, dried, smeared with spores of the smut, and sown in pots with sterilized soil on the 17th December, 1917. Another lot of seeds was also sown at the same time, but these were disinfected with formalin but not smeared with smut spores. The pots used were new and were immersed in a 0.1 per cent solution of corrosive sublimate and dried. The soil that was put in the pot was kept in small lots in a hot-air sterilizer at a temperature of 170 degrees centigrade for half an hour. These pots were watered with sterilized water till the seeds came up to a seedling stage. When seeds germinated, some of them were carefully removed from the pots and examined under the microscope. But spores were seen to have germinated and to have produced lots of sporidia in two days. The germ tubes from the germinating spores were seen on the surface of the seed-coat and on the epidermal layer of the plumule and of the hypocotyl. The course of infection is as follows. The germ-tube penetrated the wall of the epidermal cell of the hypocotyl (Pl. I, fig. 5) and grew through the cells beneath the surface layer. In the early stages of the seedling, hyphæ are seen to be very numerous in sections of internodes and nodes. A month after infection, however, the hyphæ were only seen in the nodes, in the form of masses. Infection takes place when the seeds begin to germinate and the young mycelium grows along with the seedling showing no external signs of its presence until the flowers are produced, when it again forms its spores in the ovary. The seedlings grew up under sterile conditions in the pots for about a month. When they had grown sufficiently high they were transplanted into big pots. The soil used to fill up the pots was obtained from the Central Farm, Coimbatore. Sections from the nodes and internodes of some seedlings showed thick nodulose hyphæ, Pl. II. Out of 100 plants in the pots 95 showed smutted earheads. In the 100 plants grown out of seeds

that were not smeared with smut, no smutted earhead was seen. In a field in the Central Farm Coimbatore, sown on the 17th November, 1917, and harvested on the 5th February, 1918, out of 300 plants that grew from seeds smeared with smut spores, 165 plants showed smutted earheads. In the 300 plants that grew from seeds not smeared with smut spores, not a single plant was smutted.

To determine if the spores of the smut infect flowers of Italian millet and produce smut on the ears, the following experiment was laid out.

Tenai seed was disinfected with 2.5 per cent formalin for 15 minutes, dried, and sown in pots. The pots were new and dipped in 1 to 1,000 parts of corrosive sublimate solution and the soil sterilized by being kept in a hot-air sterilizer at 170 degrees centigrade for half an hour. The experiment was divided into two series with 20 plants in each series. When the plants grew up and were in shot-blade, the tops of these 40 plants were covered over with paper bags. As soon as the earheads came out of sheathing leaf, the stigmas of the flowers were dusted with smut spores in the following way. Dry spores of the smut were placed in a paper bag and shaken on to the flowers by inverting the bag over the earhead and shaking thoroughly. Sometimes the spores were placed with a camel hair brush. Examination of the dusted earheads with a hand-lens showed spores on the stigmas of flowers. The other set of 20 plants that were bagged, were not interfered with in any way, i.e., they were not dusted with spores. After the earheads matured, the paper bags were removed and none of the earheads in either of the two sets were found to be smutted. This was repeated three times. It is thus seen that the spores of the smut are not capable of infecting the flowers of the plant. It may sometimes be suggested that the spores may lie dormant in the soil for one season and affect the later crop. This is against the life-history of the smut as the spore germinates quickly in water in a short time and the field is likely to have received a shower or two in the fallow period.

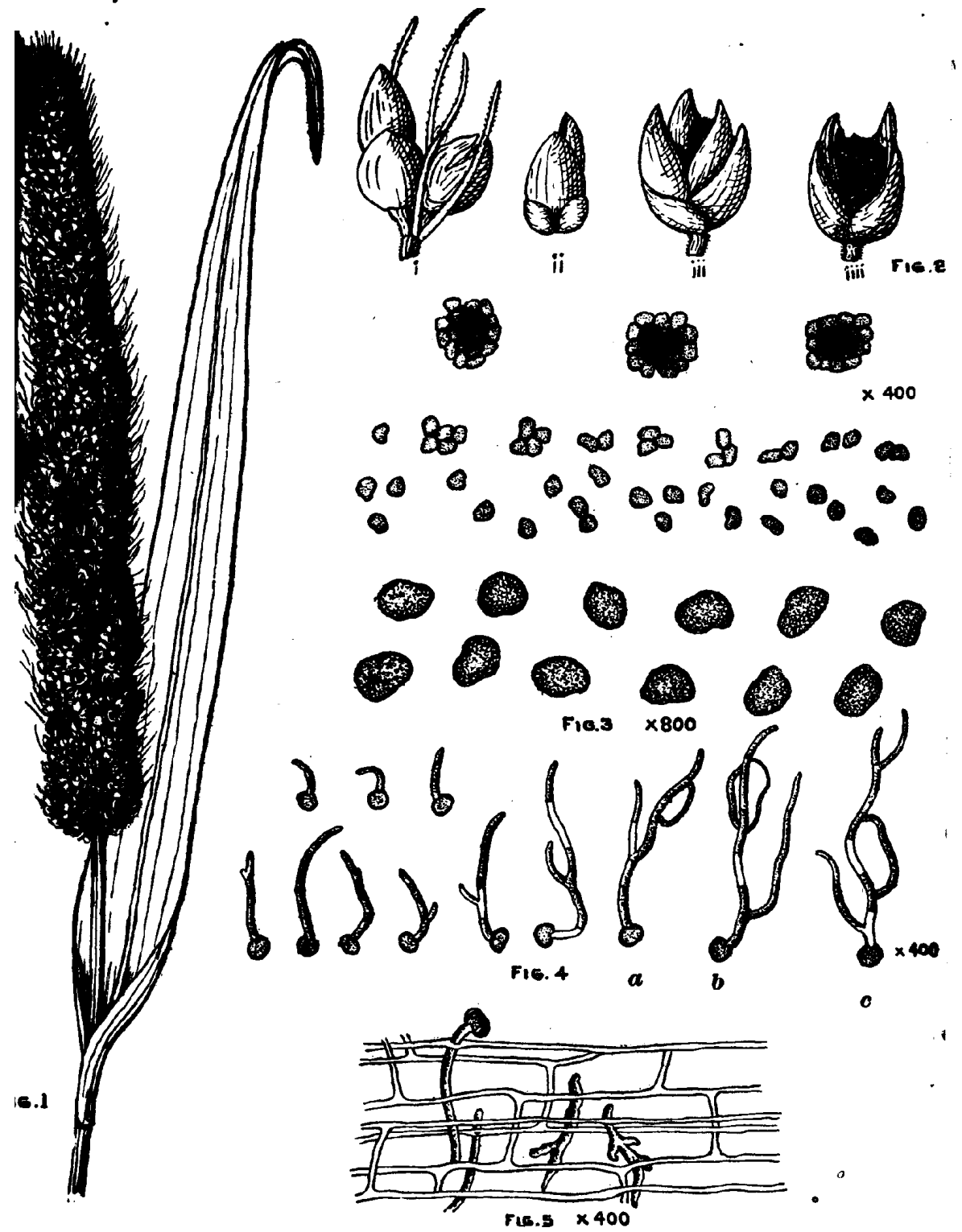
From the foregoing experiments the limits for copper sulphate solution both with regard to the fungus and the seed have been determined to be 0.5 per cent and 5 per cent, and 2 per cent has been shown as a good working concentration. The formula is easily translated into the measures understood by the ordinary cultivator. A kerosene bottle ordinarily available in the bazaar can be taken as a measure for water, and a rupee as the weight for the copper sulphate. To secure 2 per cent strength of solution he has to dissolve a rupee weight of copper sulphate in a bottle of water. The cultivator has thus to remember only two things, i.e., one rupee weight of copper sulphate and a kerosene oil bottle of water. Steeping in 2 per cent solution for 10 minutes has been re-

commended in Bombay. But the bulk of the ryot population have yet to become familiar with the means of gauging accurately sub-divisions of an hour. The ryot has a rough and ready method of determining the time. Generally he keeps no clock or time-piece. He is guided mostly by the shadow cast by an object and he is always very nearly correct. He has inherited this method from time immemorial and it has not failed him: and a method he would understand better is to be preferred. Half an hour is easily understandable, a better unit which leaves a sufficient margin of safety.

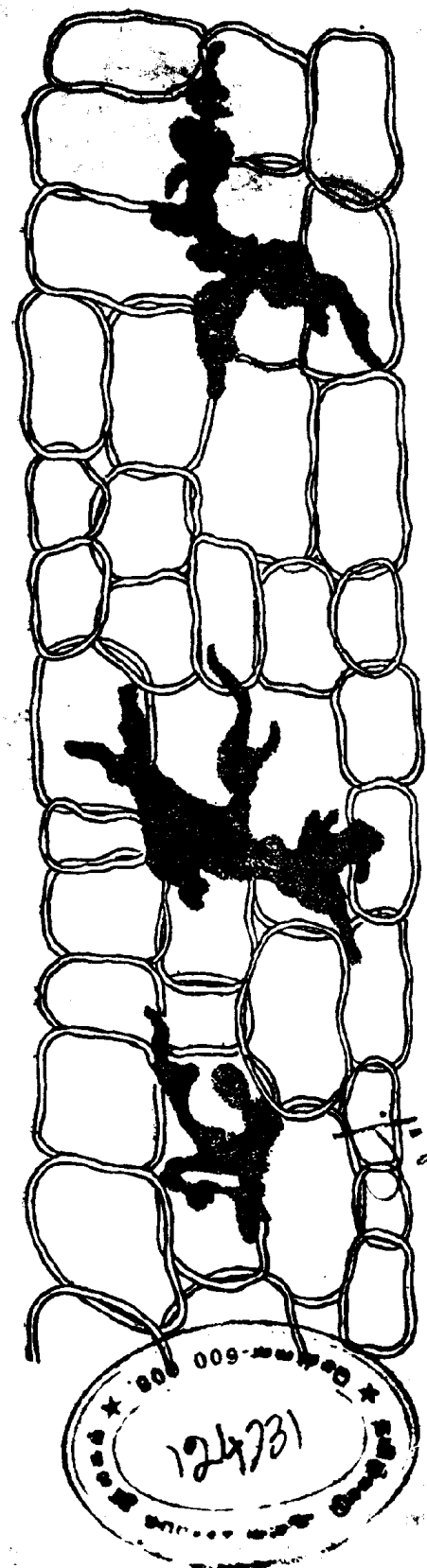
The Deputy Director of Agriculture of Circles II and III conducted field trials with seed treated with 2 per cent copper sulphate solution. This was done consecutively for three years. A definite set of instructions was prepared for guidance and Agricultural Demonstrators visited villages several times before and after sowing. They showed the people how to prepare the solution and how to treat the seed in solution. In some plots treatment of seed and sowing were done under their personal supervision, while, in the majority of cases, the ryots did this part of the work closely following their instructions. During the several inspections of the treated plots by the Agricultural Demonstrators it was found that the treated plots presented no appearance of smut. This was the case not in one or two plots, but in hundreds of plots. One may realize the efficacy of this treatment, when one realizes that in 1917 ryots, usually extremely conservative, had grown 9,312 acres in Bellary District alone with treated seed. At the same time, it is necessary that only good seeds should be used as old grain may be injured by the treatment. The seeds should be dried quickly or sprouting may result. Sowing should be done soon after treatment.

SUMMARY.

- (1) Smut causes great loss in *Setaria italica* (Italian millet) in certain districts of the Madras Presidency.
- (2) The spores germinate freely in distilled water to as high a percentage as 95 in twelve hours; but fail to germinate when placed in solutions of copper sulphate of 0.5 per cent and higher concentration for 15 to 30 minutes.
- (3) That steeping seed of *Setaria italica* in solutions of copper sulphate of 5 per cent concentration for 30 minutes and higher concentration for 15 to 30 minutes reduces germination.
- (4) That the smut enters the plant in the young seedling stage.
- (5) That the spores do not infect the flowers.
- (6) That to secure safety from infection, seed should be steeped in a 2 per cent solution of copper sulphate for 30 minutes.

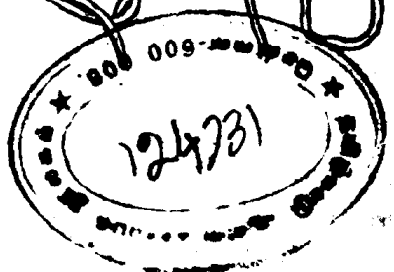


Ustilago Crameri Koernon *Setaria italica*.



X 500
Hyphae in sections of the interoplia.

12
13-2025
N20



EXPLANATION OF PLATE I.

- FIG. 1. Earhead of *Setaria italica*, Italian millet, with smutted grains.
- „ 2. Smutted grains enlarged.
- „ 3. Spores of *Ustilago Crameri* Koern. $\times 400$ and $\times 800$.
- „ 4. (a) Germinating spores in different stages.
(b) Promycelia showing the "buckle-joint" $\times 400$.
- „ 5. Germ-tube entering the epidermal cells of the young hypocotyl of the millet seedling $\times 400$.