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Agricultural Research Institute, Pusa

The Value of Phosphatic Manures in India and the Possibility of their Manufacture on a Larger Scale

Being evidence submitted to the Committee appointed to discuss this question (Subject IX) at the meeting of the Board of Agriculture, Poona, 1917.

Edited, with an Introduction, by

W. A. DAVIS,

Chairman of the Committee.

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Introduction

THE Committee appointed to discuss this question at the Poona Meeting of the Board of Agriculture consisted of—

Mr. W. A. Davis, B.Sc., A.C.G.I., F.C.S., Indigo Research Chemist to the Government of India (Chairman).

Mr. H. A. F. Lindsay, I.C.S., Director-General of Commercial Intelligence, Calcutta.

Mr. R. S. Finlow, B.Sc., F.I.C., F.C.S., Fibre Expert to the Government of Bengal, Dacca.

Dr. Harold H. Mann, M.Sc., F.I.C., Agricultural Chemist and Principal, Agricultural College, Poona.

Mr. H. C. Sampson, B.Sc., F.H.A.S., F.B.S.E., Deputy Director of Agriculture, 5th and 7th Circles, Trichinopoly.

Mr. A. A. Meggitt, B.Sc., F.C.S., Agricultural Chemist, Assam.

Mr. C. Somers Taylor, B.A., Agricultural Chemist and Officiating Principal, Agricultural College, Sabour.

Mr. R. G. Allan, M.A., Principal, Agricultural College, Nagpur (Secretary).

Mr. R. D. Anstead, B.A., Deputy Director of Agriculture, Planting Districts, Bangalore.

Mr. E. Thompstone, B.Sc., Deputy Director of Agriculture, Northern Circle, Burma, Mandalay.

Mr. S. K. Kelavkar, Bar.-at-Law, Bombay.

Mr. A. B. Modak, Bombay.

The terms of reference were :—

To report—

(*a*) Whether deterioration of soils has been noticed in the various provinces and, if so, whether this is due to phosphate deficiency ;

(*b*) Whether the needs or the efficacy of manuring with phosphates have been noticed or enquired into ; and

(*c*) The possibility of procuring superphosphates in India at a figure which will render their application profitable to the cultivator.

The report of the Committee was as follows[1]:—

(*a*) The committee after considering the evidence available came to the following conclusion:—

The committee have not sufficient evidence before them to enable them to state definitely that any deterioration of the soil arising from depletion of phosphates has occurred generally throughout India. To decide this point experiments over a number of years would be necessary. Mr. Davis' results with indigo soils in Bihar point to actual deterioration having occurred in this area; but for India as a whole no such evidence at present exists.

(*b*) Under the second heading evidence showed that enquiries had been made with regard to the effects of phosphatic manuring in different provinces.

In the indigo districts of Bihar such manuring is plainly beneficial.

In Bengal and Assam on the old alluvium there is ample evidence that phosphatic manuring is of value and has given considerable increase with paddy (40 per cent.), mustard and other crops. On the old alluvium lime is also deficient and is probably necessary to enable phosphates to produce their maximum effect.

On the silt alluvium evidence is variable and no general conclusion can be drawn.

Pending further investigations, on the tea garden soils evidence shows that phosphatic manures are of great value. Basic slag and basic superphosphates give the best results. Bone manures and mineral phosphate when applied to the soil have not given noticeable results except indirectly through green crops.

In the United Provinces in the eastern districts on opium soils it is possible that phosphate manuring may be useful. There is no evidence of phosphate deficiency in other areas.

In the Punjab results appear to indicate that very little benefit is at present found in the use of phosphatic manures in most of the ordinary systems of agriculture adopted in that province.

In Burma soils of the delta show great variations. In some areas the phosphate supply is ample, in others deficient. In general, however, it appears that phosphates will probably prove to be an essential manure in the great rice-growing areas of Burma.

[1] *[illegible] Board of Agriculture in India held at Poona*, 1917, p. 56.

In Madras experiments with phosphatic manuring have been chiefly made with paddy. Marked deficiency in available phosphate is chiefly noticeable in old paddy soils. All forms of phosphates have yielded marked results. On the laterite high lands chiefly devoted to planting crops, tea, coffee, and rubber, paying results have been obtained by the use of basic slag and basic superphosphates.

In Bombay the need for phosphate was most felt in the rice lands of the Konkan, both superphosphate and bone-meal repaying the cost of application. Outside this area the scarcity of nitrogen and organic matter appears to be the limiting factor except possibly in the case of leguminous crops notably lucerne.

In the case of cane, phosphate alone has given poor results, but when used as a manure on a preceding green dressing crop the subsequent yield of cane was increased. Early ripening and greater purity of juice were noticed.

In the Central Provinces there appeared to be no indication of the need of phosphate in the black cotton soils. On the light soils of the province it has proved valuable in the case of paddy, sann-hemp, and cane. Experiments have not gone far enough to indicate which form of phosphate is preferable.

(*c*) At present manufacture of superphosphate in India is in so elementary a stage that no definite conclusion can be arrived at regarding the price at which it will be procurable in the future. The retail price of superphosphate before the war was Rs. 60 to Rs. 65 per ton ex-factory or port of entry.

Taking India as a whole, however, there are sufficient supplies of phosphatic manures from all sources to meet the present demands, but there are isolated localities where the question of the supply of superphosphate in the immediate future appears to be important. In these, special facilities should be considered to expedite either local manufacture or the import of this commodity.

With a view to encouraging the extended use of phosphatic manures the committee consider that a survey of the resources of the country in mineral phosphates should be undertaken by Government. In view of the vital importance to Indian agriculture of keeping the supply

of phosphates at a price within the reach of the cultivator the committee suggest that control over all the internal mineral sources of supply should be retained by Government.

The committee recommend to the attention of workers the question of investigation of forms of phosphatic manures other than superphosphate as there seems to be distinct evidence in India that the less soluble phosphates particularly in conjunction with bulky organic manures are of great value.

As the evidence submitted to the Committee seems likely to prove of general interest and of value for purposes of reference in the future, it has been decided to publish it in the form of a Bulletin.

PUSA,
28th February, 1918.

W. A. D.

Notes on the Value of Phosphatic Manures in India and the Possibility of their Manufacture on a Larger Scale.

(1)

(W. A. DAVIS, B.Sc., A.C.G.I., F.C.S., *Indigo Research Chemist to the Government of India.*)

In a paper read before the Indian Science Congress at Bangalore in January 1917 (Special Indian Science Congress Number of the *Agricultural Journal of India*, 1917, p. 77), I drew attention to the abnormal deficiency of available phosphate in the soils of Bihar and to the undoubted deterioration of these soils owing to their being systematically stripped of this constituent without any attempt being made to replace it. I have pointed out how this impoverishment of the soils of Bihar is also apparently responsible for a falling off in the quality of crops which leads to malnutrition of the cattle and men in certain parts of this province.

My practical knowledge of Indian soils is limited to Bihar. It seems, however, very desirable to obtain more complete information as to the phosphate requirements of the soils of other provinces, the efficacy of manuring with phosphate, and the desirability of arranging for the manufacture of superphosphate in India on a larger scale than has been carried out in the past so as to diminish the cost of this fertilizer. There is no doubt that the present practice of exporting large quantities of oil-seeds to Europe to be pressed there is gradually stripping many Indian soils of their fertility in an alarming way and that the yield of such oil-seeds and other crops in many parts of India could be increased by proper phosphatic manuring. Discussions by the agricultural officers of the different provinces should be invited on these points, particularly as regards any signs of deterioration of soils or the needs of phosphate as a manure that may have come to their notice.

There is, I think, little doubt that the deficiency of one single constituent in a soil leads to the spread of fungal or insect disease in crops. This is well shown on the experimental plots at Rothamsted, and Mr. Andrews, Entomologist to the Tea Association, has recently stated (*Journal of Indian Tea Association*, 1915, p. 107) that incorrect manuring

will often lead to a sickly condition of the bush and render it unable to throw off the attack of insect pests.

The present price of superphosphate in India is very high and a large proportion of the fertilizer has to be imported. It is very desirable that larger quantities should be manufactured in India.

There is one aspect of this question which I should like to emphasize. If larger quantities of superphosphate were required it would lead to an increased output and diminish the cost of production of sulphuric acid, the high price of which in India at present prohibits its use in many industries.

Deterioration of the indigo soils of Bihar.[1]

In 1907 Dr. Leather pointed out that, judged by analysis, the soils of Tirhut were in a dangerously depleted condition as regards available phosphate. In Muzaffarpur District 40 per cent., in Saran 60 per cent., in Darbhanga 75 per cent., and in Champaran 80 per cent. of the soils examined at Pusa in 1907 contained less than 0·0007 per cent. of available phosphate.

Since that date practically no attempt has been made by planters to remedy the condition of their soils by proper manuring, and it has not been realized that the gradual and increasing failure to obtain second cuttings of indigo and the almost complete impossibility of obtaining Java indigo seed have been due to a steady and continuous impoverishment of the soil. This year (1917) a large number of analyses have been made of the soils of indigo estates, and it has been found that they are now in an even worse condition than in 1907: many of the soils contain less than 0·0002 per cent. of available phosphate, whilst in several not even a trace of available phosphate can be detected. In the latter soils crops die out shortly after germination, owing to starvation.

There has been a rapidly increasing failure of indigo crops of recent years, the progressive character of which may be judged by an example taken from the experience of one factory (Belsand) at which data have been preserved. Between 1904 and 1908 there was no pronounced failure of the leaf crop of indigo, but that the soil was deteriorating rapidly is shown by the steady falling off in the seed yield of the Java indigo plant the first sign of phosphate starvation.

	Yield of indigo seed per acre
1905-1906	15 maunds.
1906-1907	8 "
1907-1908	"Yield disappointing."
1909	"Very poor" (less than 2 maunds).

[1] See "A study of the indigo soils of Bihar," by W. A. Davis. *Indigo Publication No. 1, Agricultural Research Institute, Pusa.*

In 1909 the green plant itself began to fall off and the *khoonties* (second cuttings) to fail more or less completely. In later years the first cuttings also began to deteriorate in quality and quantity, until in 1912 there was a falling off of 65 per cent. of indigo as compared with the yield in 1908.

In 1908 total produce of cake indigo 604 maunds from 1,334 bighas.
„ 1912 „ „ „ „ 220 „ „ 1,470 „

At the present time the majority of the Bihar indigo soils are so impoverished that they regularly fail to give seed crops of indigo, whilst on most estates *khoonties* are no longer obtainable. This is especially the case in Champaran, where at some factories (*e.g.*, Byreah, Mullayah) *khoonties* have not been obtainable at all for several years, the amount of phosphate in the soil barely sufficing to give a single cutting.

This year (1917) the failure of the *khoonties* has been general, and, in consequence of this, although the area under indigo was increased by 12 per cent. as compared with last year, the indigo crop is estimated to be 5 per cent. lower than last year, that is a falling off in all of 17 per cent.

Year	Area (acres)	Yield (cwt. of 60 per cent. indigo)
1916-1917	76,500	10,800
1917-1918	85,900	10,300

The failure is all the more remarkable because at most factories the climatic conditions were more favourable than last year: there was less rainfall during the actual months of *mahai* (June, July, and August) and less loss from flooding. The position is a very serious one, and unless steps are at once taken to remedy the deterioration of the soil by manuring with superphosphate, it seems certain that within the next few years there will be a widespread and increasing failure of indigo crops similar to that which occurred at Belsand between 1908 and 1912.

Soil deterioration affecting other crops.

That the lack of available phosphate in Bihar soils causes low yields of other crops is clear from the data showing the effect of phosphate manuring given in the paper referred to above. It is also very strikingly brought out by considering the low yield of opium between the years 1900 and 1907 for certain districts of Bihar as compared with districts further west, especially in the north-western portions of the opium area. The following average returns are taken from Messrs. Oakden and Butler's "*Note on the Opium Question*" (March 31, 1909, p. 43).

	Average annual yield of opium per bigha, seven years ending 1906-1907	
	Seers	Ch.
Bihar—		
Muzaffarpur District	3	15
Darbhanga ,,	3	15
Saran ,,	3	13
Champaran ,,	*2*	*6*
Patna ,,	3	14
Monghyr ,,	3	3
United Provinces—		
Ghazipur District	3	15
Ballia ,,	4	1
Allahabad ,,	4	7
Fatehpur ,,	4	7
Farrukhabad ,,	5	2
Cawnpore ,,	5	2
Mainpuri ,,	5	2
Bareilly ,,	5	7
Budaun ,,	5	10
Bara Banki ,,	5	10

It was pointed out in the report by Messrs. Oakden and Butler referred to, that "the areas of low yield are clearly defined and *comprise the whole of Bihar* and the eastern and submontane districts of the United Provinces, *viz.*, the districts of Ballia, Ghazipur, Benares, Mirzapur, Jaunpur, Azamgarh, Gorakhpur, Basti, Gonda and Bahraich. *Westwards the yield increases* and it reaches its highest limit in the Rohilkhand Division at the north-west extremity of the opium area—Budaun, Bareilly and Shahjahanpur being the most important districts."

It seems more than a mere coincidence that by far the lowest yield of opium for the seven years ending 1906-1907 was obtained in the Champaran District of Bihar where in 1907 the so-called wilt disease of indigo first appeared (at Mullayah) and where the yields of indigo, owing to failure of *khoontie* crops, are at the present day worse than elsewhere in Bihar. It was in Champaran, too, that analysis showed the soils to be far more depleted of phosphate in 1907 than those of other districts of Bihar, and the same holds true to-day. There is no doubt that the gradual improvement in opium yield passing westward from Bihar into the United Provinces follows a gradual increasing content of the soil in available phosphate, until the high yielding areas (Cawnpore, Bareilly, etc.) are reached, which are known by analysis to be rich in available phosphate. It would appear that by phosphatic manuring the yield of opium in districts such as Ghazipur, Ballia, etc., could be considerably increased.

(2)

(C. SOMERS TAYLOR, B.A., *Agricultural Chemist to the Government of Bihar and Orissa.*)

There are one or two points in Mr. Davis' note to which I wish to draw attention.

Firstly, as regards the impoverishment of soils in Bihar. This abnormal deficiency of phosphate, available as well as total, has long been known and a considerable amount of work was done upon it by Dr. Leather at Pusa in the early days of the Department.* I gather that Mr. Davis in referring to Bihar, more especially refers to Tirhut as that is the area upon which I understand he is working. Such work as I have done on the soils of this province would indicate that the soils to the south of the river Ganges are in the main also very deficient in this constituent, particularly the laterite soils of Chota Nagpur and Orissa. (This of course does not apply to such soils as have been artificially or naturally manured.) As striking instances of such deficiencies in phosphate, I may quote the following analyses of soils in tabular form :—

Soil No. of samples	Mean available phosphate	Standard deviation of series from mean
	per cent.	
Ranchi farm, 2	0·002	..
Cuttack farm untreated with phosphate, 14 . .	0·005	+0·0008
Cuttack farm treated with phosphate, 16 . .	0·007	+0·0011
Unmanured soils in the neighbourhood of Cuttack farm, 20.	0·0038	+0·0018
Khurda Sub-division, 19	0·002	—0·0017

I have other data and am still collecting information as to the requirements of soils from different parts of the province, but the majority of soils which I have examined up to the present have shown an amount of available phosphoric acid far below that usually considered in Europe to be necessary for a satisfactory plant growth.

I may mention that the series of analyses from Cuttack was undertaken in connection with the appearance of a peculiar disease which was appearing in the rice crop and that the figures of my analyses have been for some time in the hands of the Deputy Director of Agriculture, Orissa Division.

* This work has been referred to in my paper on the "Phosphate depletion of soils of Bihar" in the *Agri. Jour. of India* and more fully in *Indigo Publication No.* 1. [W. A. D.]

It is obvious, however, that no increase will appear in the consumption of phosphatic manures until their use has been proved to be profitable, and such results as have been published on the subject from the Cuttack farm do not indicate profit from the use of phosphatic fertilizers. It will, however, be noticed that these soils of the Cuttack farm show a distinctly higher percentage of available phosphoric acid than the soils of Ranchi or Khurda. It is possible that, under the different conditions of India, we may have largely to revise our ideas as to the minimum amount of available phosphoric acid necessary for plant growth, and that an amount of 0·004 or 0·005 may be ample for the needs of the rice plant.

I have not quoted figures for the Sabour soil, as nearly the whole of Sabour farm is amply provided with phosphoric acid. The Ranchi farm is the farm under the Bihar Government which shows most strikingly a lack of available and total phosphoric acid, and certain experiments are I understand, being carried out on the effects of phosphates upon the soil of that farm. These experiments are being carried out by Mr. Dobbs in connection with the "Tikka" disease of groundnut, with a view to determining whether this disease may be successfully combated by the plant when properly fertilized. This is of interest in view of Mr. Davis' remark as to the spread of fungal disease in badly nourished crops.

As regards the present price of superphosphate the problem is a very difficult one. There is no doubt that it is desirable that larger quantities should be manufactured in India, and every practical man has long been convinced of the advantages which would accrue if sulphuric acid could be made cheaply in India. I doubt, however, whether the cost of production of this acid could be very much reduced under present conditions.

One of the great drawbacks, if not the great drawback, to this manufacture in this country is the absence of easily accessible sources of cheaper sulphur. In England the commerical acid is exclusively made from iron pyrites, while in India the acid is made from imported sulphur. The pyrites are found on or near the spot in England, and, in consequence, the price of production is enormously lower in England than in India. Mr. Tutwiler, the Manager of Messrs. Tata's works at Sakchi, has kindly informed me that in normal times the cost price of sulphuric acid of 1·6 sp. gr. manufactured by his plant is Rs. 75 per ton while in normal (pre-war) times in England the cost was only £2 per ton. To increase the size of the plant will of course reduce the cost, but it can hardly be brought down to as low a cost as in England where pyrites is both abundant and easily accessible. It is of course cheaper to make

the acid than to buy it, but very careful calculations would have to be made before we could see how much less it would cost to make Indian superphosphate than to import it from Japan as is being done at the present time.

Finally, a large and steady demand for superphosphate would have to be created before any progress could be made in increasing the quantities manufactured. The knowledge of the value of superphosphate in conjunction with green-manuring in the Tirhut area is not by any means a new thing. When I arrived in India in 1907 experiments were being carried out by Dr. Leather on the effect of superphosphate on certain crops. Increased yields were obtained, and I believe that the results were placed by Dr. Leather before the Bihar Planters' Association. If superphosphate could be obtained cheaply there can be no doubt that its use would be of great use in the Tirhut area where it has long been used in conjunction with green-manuring by many scientific agriculturists.*

It still remains to be proved, however, that its use will be profitable outside this area, and it is possible that the constitution of the laterite soils of South Bihar and Orissa is such as to necessitate a more basic compound than superphosphate. The problem is, however, in its infancy, and our knowledge of the value of superphosphates on the soils of this province is hardly in such an advanced state as to warrant the sinking of large sums of money in sulphuric acid plant purely for the manufacture of superphosphates.

There can, however, be no doubt that it is high time to take steps to develop our knowledge in this direction. The examples I have given of various typical soils of this province show that phosphoric acid is notably poor in quantity over large areas. A soil survey for phosphoric acid content is one of the first essentials, and this should be taken in hand at once. The survey should be made of the large river basins in Bihar and Orissa as practically the whole of the soils of these two divisions of the province are alluvial, and their character will be largely determined by the character of the rocks at their head waters.

Experiments should be made in the various areas found to be deficient, and, if they are financially successful, there is no doubt that a demand will at once be created. Until this demand has been created, however, it is doubtful whether a commercial man would look at any project for making large quantities of superphosphate in India. It is for the Department to create this demand after carefully finding the best method in which the fertilizer may be used.

* My enquiries among the planters show that up to the present time, only two or three of the planters have even experimented with superphosphate. All the available cases are referred to in *Indigo Publication No. 1.* [W. A. D.]

(3)

(B. C. BURT, B.Sc., F.C.S., *Deputy Director of Agriculture, Central Circle, United Provinces.*)

The only information I have about superphosphate is that it yields satisfactory results in connection with green-manuring for wheat. I have no evidence that the soils in any part of my Circle are particularly deficient in phosphate, and, as far as field experiments on wheat at Cawnpore go, this does not appear to be the case. I cannot hold out any hope that there will be any demand for superphosphate on a large scale in the United Provinces at present.

(4)*

(S. MILLIGAN, M.A., B.Sc., *Offg. Director of Agriculture, Bengal.*)

Soil Improvement. There are two very distinct classes of soil in the province: (*a*) The laterite or old alluvium; (*b*) The silt or new alluvium. There is a general lack of carbonate of lime and phosphates in both. The laterites, however, are much more acid than the silts, and consequently respond more readily to basic phosphatic manures like bonemeal. On the other hand, potash, which is deficient in the laterite soils, is present in sufficient and sometimes large quantities in the silts. A soil survey is in progress and is at present confined to a chemical examination of soil samples. Demonstration work is, however, being continued in West Bengal on the laterite soils with bonemeal, where satisfactory results have already been obtained.

On similar soils in East Bengal both lime and bonemeal have given results of economic value, and it is proposed to attempt the extension of the use of these manures through co-operative societies.

It has been definitely proved that the application of potash manures for jute on laterite soils yields a profitable increase and at the same time acts as a preventative against the fungus disease *Rhizoctonia*. The water hyacinth (*Eichornia crassipes*), which grows in abundance in low-lying tracts of the province, has been found to be a valuable source of potash. It is proposed to carry out demonstrations of the use of the ash of this plant on laterite soils.

(5)

(O. T. FAULKNER, B.A., *Deputy Director of Agriculture, Lyallpur, Punjab.*)

The results appear to indicate that very little benefit will accrue from the use of phosphatic manures in most of the ordinary systems of Punjab

* Extracted from the Programme of the Department of Agriculture, Bengal, 1918-1919.

agriculture. Some of the experiments referred to in this note might be adversely criticized; but their consistently negative, or practically negative, results must lead towards the conclusion that there are factors in our conditions in the Punjab canal colonies which make the effects of phosphatic manures very much less beneficial than in England.

(I) Experiments in square 27 at Lyallpur farm.

The experiment was rather elaborate and involved the use of a large number of different artificial manures. There is also little doubt that the unmanured strips are too narrow and are probably affected by the manures diffusing in from the adjoining manured plots. Great weight cannot therefore be attached to these results; but the fact that such slight differences in yield are apparent after the annual application of these manures to these same plots for six years, suggests that they can have had no very great effect. A new experiment which we trust is better designed has been started in place of this.

These experiments are explained and the results given in detail in the Appendices to the Annual Reports of the Department as follows:—1912, page iv and pages xxiii to xxvi; 1913, xvi to xix; 1914, xiv and xv; 1915, xxxii and xxxiii; 1916, xxi to xxiii.

(II) The experiments referred to in I having given negative results but being so open to criticism, the series was started of which the results are given at the references below. The design of these experiments cannot, I think, be very adversely criticized. The land was carefully selected: the plots are large enough, there are sufficient repetitions and plenty of controls. Any differences in yield observed are, as will be seen, mostly well within the probable experimental error, whilst the differences between similar plots indicate that the results seem to be reliable. One figure only calls for comment—the apparent negative or rather depressing effect of farmyard manure on *toria* (*B. campestris* var. *Napus*) in 1916-17. That the effect should be negative is not, I think, remarkable, for considering the extremely short, cool growing season of the *toria* crop it could only be expected to take advantage of the very readily available ingredients in the manure. It is generally considered by zemindars that manure applied to *toria* chiefly benefits the following cotton crop. The apparent depressing effect of the farmyard manure, if it represents anything more than experimental error, may be due to some secondary effect. None of the land at Lyallpur has yet been under cultivation longer than since the beginning of this century, though it seems to have settled down to a fairly steady level of productivity.

For abstract of experiments see pages 42 and 43 of Handbook[1] and 1916 Annual Report, Appendix, pages xxxi and xxxii.

(III) At Gurdaspur experiments with phosphatic manures have been carried out regularly for several years on the same plot in the *barani* (depending upon rain water) area, on land which has been under cultivation almost certainly without manuring for many years. For the first few years the phosphatic manures showed no important effect on the yields and the financial results were a loss. Now, however, that the residues have been accumulating for several years, there are slight differences in favour of the phosphatic manured plots, and thus the annual results apparently show very little economic loss or a slight profit. It might be mentioned that at a certain stage the wheat on phosphatic manured plots appears to be ripening ahead of the controls ; but the actual date of final ripening is very little affected.

(IV) There have been experiments made at times on the *chahi* (well irrigated) area at Gurdaspur as, *primâ facie*, there is more possibility of profits from manures on such land. The results of some of these have been more encouraging ; but in many other cases yields of the manured plots have been less than, or equal to, the controls. As a matter of fact the land on which these experiments have been tried is far too rich and variable for any very marked results to be expected. The question of phosphatic manuring on *chahi* land is one in which investigation will probably be continued and extended when suitable land becomes available.

(V) Experiments have also been started at Gurdaspur on the use of phosphatic manures in addition to green manures and farmyard manure. So far the phosphatic manures do not appear to have given any result ; but the experiments have not been carried sufficiently far to be conclusive.

The Gurdaspur results are given in appendices to Annual Reports as follows :—

Experiments on barani *land.*

1914	Statement 5,	page xxvi.
1915	„ 3	„ xlvii.
1916	„ 5	„ xli.

Experiments on chahi *land.*

1915	Statement 4,	pages xlviii & xlix.
1916	„ 4	„ xl & xli.

To summarize :—

In the canal colonies, under ordinary systems of cropping and cultivation, phosphatic manures have not paid up-to-date. But the land

[1] *Experiments, etc., at the Agricultural Station, Lyallpur, Punjab*, 1917.

has not been under cultivation very long. It is possible that artificials might pay under a system of intensive cropping, which would allow of a minimum of fallow cultivation. Experiments to test this here are only now being started at Lyallpur. But as such a system does not and cannot be introduced in the canal colonies in the present circumstances (as to irrigation and economics), the results will be of theoretical rather than of practical importance for the present.

Under *barani* cultivation in Gurdaspur artificial manures have not been profitable. On *chahi* land the experiments are not conclusive, but a consideration of the results obtained and general factors leads one to the conclusion that though the possibilities in connection with artificial manures on *chahi* land are no doubt worth investigation, yet there is not nearly such a hope of improving our crops by this means as there is in many other directions.

(6)

(G. D. HOPE, PH.D., B.Sc., F.C.S., *Chief Scientific Officer, Indian Tea Association, Calcutta.*)

The experience I have had in the manuring of tea estates in North-East India, which extends over the last ten years, makes me think that phosphatic manures are of very great value on most tea soils. Basic slag and superphosphate give the best results; bone manures and mineral phosphates, when applied directly to the soil and not for the purpose of promoting a green crop, have not given noticeable results. It is usual now to use phosphatic manures largely to manure green crops, which are grown in the spring and are hoed in after six weeks' growth; the plants used for this purpose usually being various species of *Phaseolus*, *Sesbania*, and latterly cowpeas.

Careful experiments have been carried out on soils in the neighbourhood of Tocklai Experimental Station near Jorhat in Assam, using various phosphatic manures, and as the result of six weeks' growth of cowpeas it was found that basic slag and superphosphate gave similar results which were very considerable, and steamed bonemeal was the next most successful manure, while rock phosphate derived from Egypt gave rather poor results, but all the experiments showed the value of these phosphatic manures. Similar experiments have now been carried out on soils which differ slightly from that on which the first experiments were made. They all demonstrate the great value of phosphatic manures, particularly when used on land which has recently been under grass.

The total phosphoric acid in the soils of North-East India ranges from about 0·3 per cent. to a mere trace, but the usual minimum is about 0·04 per cent. and the soils on which less than that has been found are few. The amount of available phosphoric acid as measured by the amount extracted from a soil by 1 per cent. citric acid solution is usually about 0·01 per cent. to 0·02 per cent. but is often lower. There are, however, certain soils of fairly recent origin which are now being chemically investigated, in which available phosphoric acid is as high as 0·09 per cent. In the soils which are older geologically the amount of available phosphoric acid, as determined by the citric acid method, is usually less than in those more recently formed. Few tea soils have large percentages of carbonate of lime. Consequently the presence of lime interferes but little with the determination of citric-acid-soluble phosphoric acid.

In view of the comparative cheapness of the unit of phosphoric acid when purchased as bones, an endeavour will be made by those working in the interests of the North-East Indian tea industry to understand how the best manurial value can be obtained from bones. When this has been worked out in regard to the different types of soil and climate, bones will probably be the class of manure most chiefly used, particularly in consideration of the fact that tea being a perennial crop rapidly acting manures are not usually required, if manuring be done in a systematic way. However, there is likely always to be a considerable use for basic slag and superphosphate on tea estates if these drop to a reasonable price. The tea industry will be a good customer to any one willing and able to put good superphosphate on to the Indian market at a reasonable figure.

(7)

(W. H. HARRISON, D.Sc., *Government Agricultural Chemist, Coimbatore.*)

During the past ten years manurial experiments with phosphatic manures have been carried out on most of the experimental farms in Madras, and the result has been to demonstrate the fact that there is a fairly general need for this form of special manuring. The soil surveys of the Tanjore, Guntur, and Kistna deltas also support this conclusion, and the permanent manurial plot on the College farm has shown that phosphoric acid starvation is felt the earliest in the dry soils. There is, in addition, a growing demand for phosphatic manures from the planting community based upon the result of past experience.

Unfortunately from the point of view of manufacturing superphosphate in South India, the sulphuric acid necessary must either be imported or else manufactured from imported raw materials, which

militates against cheap production, and, in addition, the available supply of raw phosphate is limited to Trichinopoly phosphates and bones. The Trichinopoly phosphates are of low quality as they contain excessive proportions of iron and alumina, but their worst feature is the large amount of carbonate of lime (up to 20 per cent.) they contain, which leads to an unduly large consumption of sulphuric acid in the process of manufacture into superphosphate and practically throws them out of court.

Apart from Trichinopoly phosphates the only indigenous supply of raw phosphate is bones, and as a matter of fact bone super and bone char super are manufactured in this presidency, so that this raw material will necessarily be the basis of any extended manufacture in the immediate future. Fortunately the supply is considerable and ample.

Considering the subject as a whole, I feel that the main difficulty lies in the production of sulphuric acid cheaply and abundantly, and it is to this aspect of the problem that attention must be mainly directed.

[For an instance of marked phosphorus starvation in Madras Presidency see R. C. Wood, *Year Book of Madras Agricultural Department*, p. 112. For the results of manurial trials with phosphates on sugarcane see the *Reports of the Samalkota Agricultural Station*, 1906-1907 to 1909-1910, and the *Report of the Coimbatore Agricultural Station*, 1911. 1912. W. A. D.]

(8)

(H. C. SAMPSON, B.Sc., F.H.A.S., F.B.S.E., *Deputy Director of Agriculture, V and VII Circles, Trichinopoly, Madras Presidency.*)

With reference to this subject I wish to point out that the third term of reference presupposes that superphosphate is likely to be the main form in which phosphatic manures are to be applied and appears to neglect other forms of phosphatic manures.

Recent work, both in America and in the Madras Presidency (*vide* Reports of Manganallur Agricultural Station), clearly shows that otherwise "insoluble" phosphates become readily available when applied in conjunction with green manure, and the point to aim at seems to me to be not so much whether we can cheapen and increase the quantity of superphosphate but rather whether we can make more effective use of the cheaper forms of phosphatic manures already available in the country.

Apart from phosphatic manures of organic origin, there are large deposits of low-grade phosphate in Madras (containing 57 per cent. tricalcic phosphate, 17 per cent. calcium carbonate, 7 per cent. iron and aluminium compounds) which are unsuitable for the manufacture of

superphosphate unless sulphuric acid can be produced at a very low cost.

(9)

(RUDOLPH D. ANSTEAD, B.A., *Deputy Director of Agriculture, Planting Districts, Bangalore.*)

The experience I have had regarding the use of phosphatic manures as applied to tea, coffee, and rubber leads me to believe that they are of very great value on most of the types of soil which occur in South Indian planting districts. Finely ground bonemeal has been extensively used for many years by coffee planters in conjunction with poonacs, but basic slag and basic superphosphates give the best results especially when their application is followed by a green dressing crop such as *Crotalaria*.

Owing to the lack of established experiment stations no really reliable experiments have been carried out from which figures can be quoted, but in a series of rubber manurial experiments now being conducted on an estate the value of basic slag and mineral phosphates such as Ephos phosphate are clearly indicated.

A number of trials extending over several years have been made on an estate scale with manurial systems for tea, and that which has met with the greatest success and which is being generally adopted is to apply at the time of pruning a mixture of 3 cwt. slaked lime, 1 cwt. basic slag, and 50 lb. of sulphate of potash, followed some six months later by a general mixture containing about 7 per cent. nitrogen, 5 per cent. phosphoric acid, and 5 per cent. potash, the phosphoric acid in this mixture being supplied in the form of fish guano and bonemeal.

An examination of the soil analyses which have been made in my laboratory during the past eight years reveals the fact that in nearly all cases our soils are deficient in available phosphoric acid as estimated by Dyer's citric acid test. This is shown by the following figures :—

Phosphoric acid.

	Total			Available		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Coffee soils (32) .	0·01	0·21	0·095	0·003	0·083	0·013
Tea soils (21) .	0·02	0·27	0·11	0·002	0·015	0·006
Rubber soils (10) .	0·027	0·17	0·08	0·0007	0·006	0·003

All these soils are markedly deficient in calcium carbonate content so that the presence of lime interferes but little with the determination of the citric-acid-soluble phosphoric acid as determined by Dyer's method. As a rule there is also a comparatively high content of oxides of iron and aluminium, and this in conjunction with the low lime content renders the total phosphoric acid slowly available. Consequently it is found that a combination of liming and the application of soluble phosphatic fertilizers is as a rule beneficial and better results are obtained by the use of this combination than of lime alone.

The figures for the soils quoted above are as follows :—

—	Calcium oxide			Oxides of iron and aluminium		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Coffee soils (32) .	0·21	0·83	0·37	9·36	41·75	16·69
Tea soils (21) . .	0·10	0·56	0·21	13·97	30·06	23·43
Rubber soils (10) .	0·11	0·95	0·38	11·00	32·29	22·92

In view of the fact that the cost of transport to estates in South India is almost invariably high, the relative value of bonemeal, which gives the cheapest unit value of phosphoric acid, as compared with more soluble phosphates, needs study.

(10)

(N. KUNJAN PILLAI, M.A., B.Sc., Ph.D., *Director of Agriculture and Fisheries, Travancore.*)

On the basis of chemical composition the soils of Travancore can be divided into three classes :—

1. Soils of low-lying wet lands, mostly cropped only once a year, which receive an annual deposit of silt washed down by rivers from hills and forests. These soils contain on an average the following plant foods :—

	Per cent.
Nitrogen	0·17
Potash	0·28
Phosphoric acid	0·05

2. Soils of double crop wet lands cropped twice a year on which very little silt is deposited, containing :—

	Per cent.
Nitrogen	0·06
Potash	0·30
Phosphoric acid	0·05

3. Sandy soils found along the coast containing :—

	Per cent.
Nitrogen	0·01
Potash	0·02
Phosphoric acid	0·01

All the three types of soils are comparatively poor in phosphoric acid which varies from 0·01 to 0·05 per cent. The first two types are fairly rich in potash which is about 0·3 per cent. The potash content of the third type and the nitrogen contents of the second and third types are rather poor. As regards phosphoric acid there is practically no soil in Travancore which can be considered rich. Chemical analysis is not always a safe test to determine the fertility of a soil ; but in regard to the estimation of the requirements of Travancore soils in phosphoric acid the results of chemical analysis agree more or less with the results of manurial experiments conducted on the field. The application of phosphatic manures on wet lands as well as on dry lands has been found to increase considerably the yield of crops, chiefly paddy and coconut. Soils deficient in humus and nitrogen must naturally receive a good dose of organic manures, such as farmyard manure, green leaf, etc., in addition to phosphatic manures to produce adequate returns. In any case, there is no doubt whatsoever that all kinds of soils in Travancore respond readily to the application of phosphatic manures.

A large quantity of fish refuse is available in Travancore. It contains on an average 4 per cent. of phosphoric acid and 5 per cent. of nitrogen. The whole of this manure used to be exported to foreign countries till a few years ago. Now, however, through the efforts of the Agricultural Department a good portion of it is being used up here. Bone dust contains about 22 per cent. of phosphoric acid and 3·5 per cent. of nitrogen. The Department now imports several tons of this manure and sells it to the cultivators. Both fish refuse and bone dust are used largely on double crop wet lands and on coconut gardens, the soils of both of which are deficient in phosphoric acid and nitrogen. Superphosphate which is a simple and easily soluble phosphatic manure is also being imported by the Department to a limited extent and sold to cultivators for application on single crop

wet lands which are fairly rich in nitrogen, but deficient in phosphoric acid. When applied as top-dressing after the paddy seedlings are transplanted it is found to be very efficacious. The use of this manure and, to some extent, of bone dust is restricted by their comparatively high prices. Ordinary superphosphate containing about 20 per cent. of phosphoric acid, when imported into Travancore, costs about Rs. 120 per ton, and bone dust containing 3½ per cent. of nitrogen and 22 per cent. of phosphoric acid about Rs. 90 per ton, while fish refuse containing 5 per cent. of nitrogen and 4 per cent. of phosphoric acid can be purchased locally at about Rs. 45 per ton.

Taking the unit value of soluble phosphoric acid as Rs. 5, of insoluble phosphoric acid as R. 1, and of nitrogen in bone dust and fish refuse as Rs. 11, the manures in question may be theoretically valued as follows :—

	Per ton Rs.
Ordinary superphosphate	100
Bone dust	60
Fish refuse	59

Thus, comparatively speaking, superphosphate and bone dust are both more costly than the locally available fish refuse. If the prices can be brought down by the manufacture of these manures on a large scale in India, the demand for them in Travancore, I can safely assure, is bound to increase. In spite of the high prices the demand is increasing though slowly, and the increase will certainly be more rapid if the manures are made cheaper.

(11)

(T. COUPER, M.A., I.C.S., *Director of Agriculture, Burma.*)

Analysis of twenty-four samples of soil from Lower Burma which are believed to be typical of large paddy-growing areas has been carried out in the laboratory at Mandalay. Several Upper Burma soils also have been analysed. A preliminary note (Bulletin No. 13) has been published and another is under preparation. The total phosphoric acid in these soils has been found to vary as follows :—

	Per cent.
Upper Burma—	
Soils	0·13—0·02
Lower Burma—	
Stiff clay	0·11—0·03
Clay loam	0·05—0·02
Sandy loam	0·09—0·02

In the sandy soils the phosphoric acid has been found much more readily available for the growing paddy plant than in the clay. Mr. Warth writes as follows :—

"1. Chemical analysis and pot cultures have shown that Hmawbi and many other Lower Burma soils lack a sufficient supply of P_2O_5. In this respect many samples are much poorer than Hmawbi.

"2. In pot cultures the crops from such soils are found to be strikingly deficient in P_2O_5.

"3. At Hmawbi it was observed one year that phosphoric acid gave a notable increase in the crop. The Deputy Director of the Southern Circle, who was closely observing this and the control crop, informed me that the crop to which phosphate had been supplied seemed fairly immune whilst the unmanured crop was badly attacked by insects and the difference in yield might be attributed to the effect of pests alone. Next year on fresh but similar land phosphate gave no benefit. These results lead one to conclude that at Hmawbi phosphate is necessary only to ward off pests during unfavourable years. They bring out also very strikingly the significance of the low P_2O_5 content of the crop when grown in this soil.

"4. These last observations combined with (*a*) analytical results showing extreme poverty of many soils in P_2O_5 and the concurrent abnormally low P_2O_5 content of the crop and considered together with (*b*) the fact that there are many areas in which when conditions are at all unfavourable the crop is extraordinarily reduced or fails entirely, indicate that P_2O_5 will probably prove to be an essential manure in the great rice-growing areas of Burma. Whether the paddy crop can afford to pay for superphosphate or must be ameliorated more slowly by crushed bone is a question of crop economics to which the agricultural experts must find a reply."

Prolonged experiments with phosphatic manures have been made on the departmental farms. At Hmawbi in the past four years the use of bonemeal and superphosphate in quantities to supply 20 lb. phosphoric acid an acre to the paddy crop has brought about an average increase in out-turn of 28 per cent. and 40 per cent. respectively. In Upper Burma similar results have been obtained. But it has not been established so far that these manures can be applied at a profit. Mr. McKerral writes :—

"In the case of bonemeal, dissolved bones, and superphosphate it was found that profits of Rs. 5 and Rs. 6 per acre could be got from their application. This profit, however, is liable to fluctuation and last year bonemeal which cost Rs. 80 per ton in Calcutta barely paid for itself. There is no doubt about the value of bonemeal for exhausted paddy land

and all that is required is to be able to purchase it cheaply enough. Its use is at present unknown among paddy cultivators, although the amount of bones produced in the country must be very large and the pre-war export was considerable. This manure ought to be available in this country and if obtained at from Rs. 40 to Rs. 50 per ton would in most cases be a valuable manure. My recommendations are as follows :—

"(*a*) An attempt should be made to retain in the country bones and other products of an animal nature.

"(*b*) Government should either promote itself or subsidize a company to begin an internal trade in the above materials. Prior to the war bonemeal was made in Rangoon by a German firm which, it is well known, made enormous profits in this business. A Rangoon firm has this year erected a bone mill at Thazi and is prepared to sell at Rs. 65 f. o. r. The product consists of half-inch bones and this kind of bonemeal has not yet been tested. Besides it is almost certain that Rs. 65 will prove to be much too high a price for its use in paddy cultivation. The German firm bought bones from the Rangoon Municipality at Rs. 20 per ton and it should not cost more than Rs. 10 to convert a ton of bones into bonemeal. Allowing another Rs. 10 for profit it should be quite possible to sell bonemeal to cultivators at Rs. 40 to Rs. 45 per ton and at this price good profits could be got from its application. The amount of bones exported must be a mere fraction of the amount available and every effort should be made to organize collection and extend the industry.

"(*c*) A survey of the possibilities of Burma with respect to supplies of fish manure should be made. This material which is got from prawn refuse, is made mainly in the Mergui District and is almost all exported to the Straits and Hongkong. In America there is a very large trade in fish-oil and fish-cake, and it is possible that a similar industry might be started in Burma, where the coast line is large. This would require scrutiny by a fisheries expert. An industry of this kind has recently been started in Madras."

The position then, despite the temporary cessation in the export of bones, seems to be that such phosphatic manures as are produced in the province are not available to the local cultivator, as paddy is not of sufficient value to enable him to compete for these manures against

growers of more valuable crops in other countries, while superphosphate and basic slag cannot be manufactured in the absence of the necessary mineral deposits. It would seem that in the cheapening and increased use of these manufactured manures in other countries is the main hope of locally produced phosphatic manures being set free for local use.

Export (in tons) of manures from Burma.

Bones—

	1912-13	1913-14	1914-15	1915-16	1916-17
Great Britain . . .	384	..	..	1,080	..
Ceylon	100	..	100	100	..
Germany	683	300	699	..	..
Belgium	702	784	2	..	..
Japan	75	560	100	..	..
Total (including countries not separately enumerated).	1,966	1,681	913	1,235	76

Fish manures and guano—

	1912-13	1913-14	1914-15	1915-16	1916-17
Straits Settlements . .	3,082	4,997	4,297	2,452	3,275
Hongkong	31	32	55	24	114
Total . . .	3,113	5,029	4,352	2,476	3,389

(12)

(H. A. F. LINDSAY, I.C.S., *Director-General of Commercial Intelligence, Calcutta.*)

I have approached this subject solely from the commercial point of view. That is to say, what are the sources of supply, and at what prices and in what quantities are superphosphates available ?

I. *Pre-war conditions.* For the year ending 31st March, 1914, the imports of superphosphates into British India totalled 582 tons, of which

Madras and Calcutta took 315 and 263 tons respectively, and between them practically all the trade. The average landed values for the year varied from Rs. 70 at Madras to Rs. 88 at Calcutta.* The *Chemical Trade Journal* quotes £2-17-6 as the market price of mineral superphosphates (18 %) in the United Kingdom for March 1914.

II. *War conditions.* I have no statistics of imports during the war, but understand that Japan is now the principal source of supply. Her exports to all destinations increased from a total value of about £57,000 in 1914 to £258,000 in 1915 and £412,750 in 1916. The Calcutta landed price is now, I understand, Rs. 100—120 per ton.

III. *Prospects of manufacture in India.* In this industry India is handicapped at every turn. The two main factors required are :—

(*a*) Cheap and plentiful supplies of sulphuric acid.

(*b*) Cheap and plentiful supplies of phosphatic material.

I have consulted several firms interested in the manufacture either of sulphuric acid or of superphosphates or both and have obtained the following information :—

(*a*) With regard to sulphuric acid, there are, so far as we know at present, no crude sulphur deposits of commercial value in India. Indian pyrites (an alternative base) are not rich in sulphur. The usual trade quality of English and Spanish pyrites contains 48 to 49 % of sulphur. The Indian deposits vary from 17 % (not at present commercially workable) to 30 % (barely workable). Practically all the sulphuric acid hitherto manufactured in India has been made from Sicilian sulphur, costing approximately Rs. 90 per ton landed in India before the war, or Japanese, costing slightly less. The present price of sulphur in India is Rs. 200 to Rs. 210 per ton. There is therefore no prospect at present of cheap supplies of sulphuric acid. It might be manufactured from the 30 % pyrites locally available, but so far as I can gather this quality is only commercially workable as a result of war conditions, and any scheme depending on the use of 30 % pyrites would not be able to face a return to ordinary trade conditions after the war. Firms known to be manufacturing sulphuric acid at present are :—

1. The Bengal Chemical and Pharmaceutical Works, Ltd., 91, Upper Circular Road, Calcutta.

* The high price is probably due to the imported superphosphate partly consisting of double-strength (40 per cent.) superphosphate. This is especially the case with the Calcutta import [W. A. D.]

2. Messrs. D. Waldie and Company, Konnagar, Calcutta.
3. The Tata Iron and Steel Company, Ltd., Sakchi.
4. The Eastern Chemical Company, Ltd., Messrs. Shaw Wallace and Company, P. O. Box 203, Bombay.
5. The East India Distilleries and Sugar Factories, Ltd., Madras.
6. The Burma Chemical Industries, Ltd., 38, Sule Pagoda Road, Rangoon.

(*b*) Superphosphates are manufactured, by sulphuric acid treatment, either from bonemeal or from mineral phosphates. The price of the former is about Rs. 70 per ton. The commercial value of mineral phosphates in India is still a matter of enquiry. If competition with imported superphosphates is to be successful in peace time they should be marketed locally at Rs. 20 to Rs. 25 per ton. Apatite occurs in Hazaribagh, apatite rock deposits in Dalbhum, and triplite in the Gaya District. Phosphatic nodules also occur in Trichinopoly. It is understood that the Dalbhum and Trichinopoly deposits are being worked at present, but with what success is not known. Firms manufacturing superphosphates are :—

The Great Indian Phosphate Co., Ltd., Messrs. Andrew Yule & Co., P. O. Box 150, Calcutta, in addition to the Eastern Chemical Company, Ltd., and the East India Distilleries and Sugar Factories, Ltd., and Messrs. Waldie, already mentioned. The Bengal Chemical and Pharmaceutical Works, Ltd., would be willing to take up the manufacture if there were reasonable prospects of a steady demand.

IV. If I might be allowed to make a suggestion, I think the following might be found a workable scheme :—

(1) To make a beginning with the indigo districts of Bihar where need for superphosphates and their commercial value as a fertilizer for the indigo crop are known.

(2) To lay the facts before the Bihar Planters' Association, drawing special attention to the value of superphosphates and the results anticipated, and asking for support.

(3) To ask Messrs. Shaw Wallace and Company and Messrs. Andrew Yule to tender for the supply of, say, * 500 tons superphosphates to be delivered at Muzaffarpur, as an experiment, for the next season.

* Or any other quantity arrived at in consultation with the Association.

(4) On receipt of tenders, to accept them in consultation with the Association if they are obviously likely to give a good return—distribution to factories and the recovery of the cost price *pro rata* from the recipients to be made through the Association.

(5) If the prices asked are not reasonable, they at any rate afford a basis for negotiation, and lower prices might be secured for a larger quantity ordered.

(6) Subsequently, for other crops, purchase and distribution might be effected either by the Agricultural Department or by the Co-operative Credit organization of Bihar and Orissa.

(7) It is not unlikely that a reference to the railways concerned would ensure a reduction of freight at any rate on the experimental consignments.

(13)

Copy of letter No. 5347, dated 7th September, 1917, from the Director-General of Commercial Intelligence, Calcutta, to the Agricultural Adviser to the Government of India, Simla.

With reference to your letter No. C.-211 of the 12th July last, I have the honour to inform you that I have taken up an enquiry into the possibility of the manufacture of superphosphates on a large scale in India. In the course of the enquiry I addressed a number of firms interested in the manufacture both of superphosphates and of sulphuric acid and propose if convenient to discuss the replies with you at Simla this month.

2. As you are aware I am particularly interested in the commercial aspects of the proposal and have studied it chiefly from this point of view. There are three outstanding points on which I will be glad of your views before proceeding further. I may add that they were suggested to me in personal discussion with Messrs. Shaw Wallace and Company who are interested in the manufacture of superphosphates.

3. In the first place there is the question of price. Imported superphosphates fetched Rs. 60 to Rs. 65 per ton in Calcutta before the war. At this price I understand they were chiefly taken by tea gardens and large agricultural concerns and scarcely reached the small cultivator if at all. My first question therefore is roughly at what price superphosphates would have to be landed, say, at a station on the Bengal and North-Western Railway in order to make their purchase profitable to cultivators within easy reach of the station. Would this landed price have to be Rs. 60 or Rs. 50 per ton or less? As already stated it did

not apparently attract the cultivator at Rs. 60 *c. i. f.* Calcutta, although this absence of interest may have been due either to ignorance of the need for artificial fertilizers or to the fact that the suppliers have hitherto made little or no attempt to get into touch with the cultivators. If we could ascertain what price the ryot ought to be able to pay for superphosphates we should have definite ideal at which to aim.

4. In this connection and secondly, I may say at once that with raw bones at Rs. 30 per ton up-country and mineral phosphates not yet locally available in sufficient quantities or of satisfactory quality, sulphuric acid would have to be extremely cheap if local superphosphates were to undersell those imported. I am given to understand that bone superphosphates are superior to imported mineral superphosphates, in that they contain nitrogen in addition to phosphoric acid, and can be prepared in varying proportions of nitrogen and phosphoric acid to meet local requirements. I would like to know whether you endorse this view and whether you consider that local enterprise should seek as much as possible to specialize on bone in preference to mineral superphosphates.

5. In the third place I am uncertain what machinery is contemplated to bring the producers in touch with the cultivators; possibly the Co-operative Credit authorities or the Agricultural Department could assist. In any case it is certain that the organization for distribution would have to be on an extensive scale, and not merely the production.

(14)

(*Note on Superphosphate Costs and Returns in Bihar, by W. A. Davis.*)

If superphosphate could be produced in India at the same price as imported superphosphate before the war, *viz.*, Rs. 60 to 65 per ton, there should be a very good market for it in Bihar and probably in other provinces. I have, in my article in the *Agricultural Journal of India*, Special Indian Science Congress Number, 1917, drawn attention to the extraordinary impoverishment of most of the soils of Bihar in this constituent, and pointed out how, wherever superphosphate has been used on the large scale, it has given surprising increases of crops. I will here add data of the actual increases of crop required to pay the cost of manuring with super and show that the probable increases obtained are likely far to exceed these so that manuring would be very profitable.

Indigo. Assuming superphosphate to be applied at the rate of 2 cwt. to the acre, if the manure cost Rs. 60 per ton, cost per acre = Rs. 6.

If the ryot be paid As. 4 per maund which is the current rate for plant an *increased yield of 24 maunds of plant* would just pay the cost of manuring.

There is little doubt that the increased yield would be far greater than this. At present the yield of plant per acre, with Java plant and Sumatrana plant, shows extraordinarily great variation, *viz.*, from about 40 maunds of green plant to as much as 120 maunds.

The impoverishment of the low-yielding soils as shown by a very large number of analyses is in practically all cases due to nearly complete depletion of available phosphate. There is therefore good reason to think that the increase of yield on most estates would be far more than the 24 maunds required to pay for the cost of the manure.

As regards the indigo planter on his own *zerat* lands, with indigo at pre-war prices, say, Rs. 170 per maund, and yield of indigo of, say, 9 seers per 100 maunds Sumatrana plant (which is a low estimate that should be capable of considerable increase by improvements in manufacture), it can be calculated that an increase of 16 maunds of plant would cover the cost of manuring with 2 cwt. of super to the acre, super being taken at Rs. 60 per ton.

At the present time with indigo at Rs. 450 per maund and super in Bihar at Rs. 125 per ton (of which freight from Calcutta represents Rs. 23) the cost of manuring with super 2 cwt. per acre=Rs. 12½. An increased crop of only 12 maunds of green Sumatrana plant per acre would cover the cost of manuring even if the yield of indigo were as low as 9 seers per 100 maunds of plant. In the case of the Java plant yielding, say, 18 seers of indigo per 100 maunds, an increase of only 6 maunds of plant per acre would cover the cost of manure.

At the present time the *zerat* lands largely fail to yield *khoonties* at all, mainly because of their impoverished conditions as regards phosphate. By proper manuring with superphosphate these *khoonties* can be greatly increased, and made to yield crops nearly equal to the first cutting. The falling off in *khoonties* this year has been very marked as compared with last year, owing to drastic stripping of the small reserves of phosphates left in the soil.[1]

Oats. Mr. Mackenzie of Sapaya informs me that by manuring his lands with superphosphate *plus* green manure he has increased his crops of oats in the three last years as follows :—

	Mds. of 82 lb.
1st year average out-turn per acre	12·00
2nd year " " "	19·50
3rd year " " "	23·00

[1] See *Indigo Publication* No. 1. "A study of the indigo soils of Bihar."

If oats be taken at the current rate of Rs. 2-8-0 per maund and manuring be at the rate of 2 cwt. per acre, an increase of about $2\frac{1}{2}$ maunds per acre would pay the cost of manuring (super at Rs. 60 per ton). On most estates I have little doubt the increase would be far greater than this—in the above case the increase by manuring was 11 maunds per acre. The Pusa Experimental Farm results for 1915-1916 show that with oats, superphosphate alone *doubles* the crop. The return on unmanured land was only 665 lb. per acre ($8\frac{1}{2}$ mds.), whilst with super 1,162 lb. per acre ($14\frac{1}{2}$ maunds) were obtained. That is an increase of 6 maunds to the acre. With combined green-manuring and superphosphate the increase at Pusa was from 665 lb. ($8\frac{1}{2}$ maunds) to 1,840 lb. (23 maunds) per acre, that is an increase of $14\frac{1}{2}$ maunds per acre.

Wheat and Barley. With *wheat* at the current price of Rs. 3-14-0 to Rs. 4-12-0 per maund according to quality, the increase of crop required to cover the cost of manure (2 cwt. super per acre) would be considerably less than 2 maunds per acre. In actual practice where super has been applied the increase has been far greater. Thus at Dooriah an increase of 4 to 7 maunds of wheat per acre was obtained with only 2 maunds of super per acre.

With barley at Rs. 2-6-0 to Rs. 2-10-0 per maund an increased yield of the same order as with oats would be required to cover cost, *viz.*, $2\frac{1}{2}$ maunds. At Dooriah increases of 4 maunds were obtained in one field, whilst in another, clearly a badly impoverished field, the increase was as great as 16 maunds per acre.

Maize. With maize at Rs. 1-14-0 to Rs. 2-2-0 per maund an increase of about 3 maunds produce per acre would pay manuring with 2 cwt. superphosphate per acre at Rs. 60 per ton. The actual increase of yield in Bihar would probably far exceed this. Last year at Pusa in one field super alone increased the crop from 806 lb. per acre (10 maunds) to 1,201 lb. (15 maunds). In another set the increase was from 474 lb. (6 maunds) to 1,151 lb. ($14\frac{1}{2}$ maunds), that is an increase of $8\frac{1}{2}$ maunds per acre. By combined green-manuring plus superphosphate the yield in the latter field was increased from 474 lb. (6 maunds) to 1,552 lb. ($19\frac{1}{2}$ maunds), or an increase of $13\frac{1}{2}$ maunds per acre.

More valuable crops such as Mustard and Tobacco. With more valuable crops such as mustard (at Rs. 5-2-0 to Rs. 6-4-0 per maund) an increase of only one maund per acre would pay the cost of manuring with 2 cwt. super per acre.

Actually the largest increases have been found with this crop in Bihar. The field trials at Dalsing Serai by Bernard Coventry showed with mustard an increase of 800 per cent. in 1899, 300 per cent. in 1900, and 250 per cent. in 1901. The use of superphosphate in 1899 increased the

crop from 6 maunds to 27 maunds per acre, that is a gain of 21 maunds; whilst in 1901, 2 cwt. super per acre increased the crops from 13 maunds on the unmanured portions to 25 maunds on the phosphate-treated fields, an increase of 12 maunds. Manuring with 5 cwt. of super per acre increased the crops to 28 maunds, that is an increase of 15 maunds per acre. Experiments made this year (1917) by Francis Coventry at Dalsing Serai confirmed the extraordinary increase in mustard by manuring with superphosphate.

With this crop Coventry calculated that the actual net profit after allowing for the cost of manure was greatest on the *most heavily manured* portion. Thus with 5 cwt. of super the net profit was Rs. 110 per acre, whereas on the unmanured land it was only Rs. 51 per acre.

With *tobacco* there are few reliable data at hand for Bihar, but there is little doubt from experiments recently made at Pusa that superphosphate would considerably increase both yield and quality. In the experiments at Dalsing Serai in 1901, the net profit was greatest (Rs.74 per acre) on the plot treated with 2 cwt. of super and ½ ton oil-cake (no experiments with superphosphate alone are recorded), whereas with no manure the profit was only Rs. 51.

Thus if superphosphate could be supplied at the pre-war price of Rs. 60 per ton, there is little doubt that in Bihar at any rate the increased returns would far more pay than the cost of manuring at the rate of 2 cwt. per acre and in most cases give very substantial increase of crop. That superphosphate has not been more widely used in the past in Bihar is, I think, largely due to ignorance of the vital necessity of such manuring. Its use will, I think, increase greatly as its value is more generally recognized.

It is probable too that in many other provinces its use would prove beneficial. Thus, for example, in the current report of the Madras Department of Agriculture (1916-1917) it is stated that "the use of superphosphate as a manure for paddy is becoming popular in the South", and that it gives a return of at least 100 per cent. on the money invested on it.

Use of superphosphate in preference to raw bones. In Bihar where the soil contains an abnormally high proportion of calcium carbonate (30-40 per cent.) crushed or powdered bonemeal does not as a rule give any useful result; the high proportion of lime in the soil, by neutralizing the acids, particularly carbonic acid, produced by bacterial action, prevents the liberation of water-soluble phosphoric acid. Consequently for such districts bones as such are frequently useless as manure, and they must be treated with sulphuric acid before they have a fertilizing

value. It is possible that in conjunction with green manure they would be more readily assimilated.

It is quite possible, however, that for *paddy*, which is grown under water, the use of superphosphate might prove less economical than crushed bones, and that the latter would give useful results as the bacterial conditions of the paddy crop are exceptional. But I have no reliable information as to the relative value of crushed bones and superphosphate in the case of this crop.

Cost of sulphuric acid. A superphosphate factory would necessarily have to run its own sulphuric acid plant and any excess of acid if produced could be put on the market. The price of sulphuric acid in India is prohibitive of its use in many industries. If it could be produced at a low price such as ruled in England before the war (say £2 per ton) it would be a great advantage and make several industries possible which at the present cannot be even considered on account of the excessive cost of sulphuric acid—the starting point of so many industrial processes.

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