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The Manuring of Cotton.

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The growth of cotton, as in the case of every other crop depends on the maintenauce of the correct balance in the three agents, constituting the system, soil—soil solution—plant.

It is the business of the Agricultural Chemist to study the several factors that contribute to the harmonious working of this system, ascertain how the one influences the other and to devise ways and means of correcting any abnormality and finally reduce his findings to a simple formula so that the cultivator can profitably work it with the means at his disposal.

He has to study the constitution and composition of the soil, the likes and dislikes and the whims and fancies of the plant that grows on the soil, how the nutrition of the plant and animal is influenced by soil conditions and how men and animals that live on the produce of the land can return to the soil a major portion of what they have taken. This, briefly stated, is the function of the Agricultural Chemist and the aim of chemical research as applied to agriculture.

Other conditions, such as climate, texture of the soil and its water relations being satisfactory, the two factors that contribute to increased production are (1) the quality of the seed and (2) manure. The introduction of improved varieties of crops will not in itself be sufficient. The fullest advantage from an improved seed cannot be realised unless it is aided by liberal and judicious manuring. I say judicious manuring, advisedly, because the conception of a manurial scheme should aim not only at improving the quality and the quantity of the resulting crop but it should be capable of reacting beneficially on the soil, the rotation and the live stock and finally the general welfare of the farmer. I shall, therefore, confine my attention to the subject of manuring Cotton.

With the establishment of Experiment Stations in the important cotton tracts of the presidency systematic field experiments began about the year 1910 but these were, however, of a diverse nature and of varied conditions. The results of these experiments were, in the light of recent experience, contradictory and inconclusive in many cases. They have, however, added much of value to our knowledge and indicate certain conclusions.

The direct application of manures, even of farm yard manure has had no consistent beneficial effect on cotton and has even resulted adversely in some instances. This was especially so in the case of rainfed cotton.

We are, thus, not yet in a position to formulate any definite schemes of manuring for a given set of conditions and foretell the result with any degree of accuracy.

With a view to find out the requirements of the cotton plant, its chemistry has been under investigation for six years now and covers a wide range. This is neither the time nor the place for a detailed discussion of these investigations, except by way of making brief references in so far as they are pertinent to the manuring of cotton.

A field study of the development of the cotton plant and the distribution of the mineral matter at different stages of its growth has shown that the production of dry matter by the plant occurs at an accelerated rate during the period of growth corresponding to the formation and maturity of bolls and that this accelerated growth is due mainly to boll formation and development.

The increase in the mineral content of the plant keeps pace with the increase in dry matter and an accelerated rate is evident also during boll forming period indicating a strong pull on the soil constituents. This pull is strongest on lime.

Nitrogen and potash seem to be most in demand during the early stages of growth, an accelerated demand for phosphorus coming later during the branching and flowering stages.

Lime accumulates in the leaves during the stages of flowering and the formation and development of boll, making its appearance in the flowers and young bolls. It seems to be largely concerned in the formation and maturity of bolls.

The mineral nutrient requirement of the cotton plant is high and it is interesting to note that lime is absorbed in the largest quantity. This, perhaps, is why soils with high lime content are more suitable to cotton.

Seeing that the cotton crop is cultivated for the yield of kapas and that the plant has a definite partiality for lime, it being absorbed in lage quantities during the bolling stage, the formation and development of the boll is also under study.

In the early stages of boll development, a very rapid increase in the production of dry matter takes place in the boll. This coincides with the alternate accumulation of nitrogen and potash on the one hand and lime, magnesia and phosphoric acid on the other, the former set of substances always preceding the latter

The available evidence points to the direction that nitrogen and potash are utilised first in the development of the boll and that lime and phosphoric acid are subsequently used functioning, perhaps, in the condensation of the lower carbohydrates of the types of simple sugars found in young bolls, into the series of higher carbohydrates finally resulting in the form of lint in the matured and burst boll.

Analyses of young bolls, of bolls that burst too early and too late, as also of bolls burst normally on the plant and artificially in the laboratory, show that the composition of the seed, while varying greatly in its early stages attains a marvellous uniformity when the seed formation is complete. The wide variation in the composition of the immature seeds and of immature lints and the constancy in the composition of the mature seed coupled with the persistent variation in the composition of the mature lint would point to the direction that the surplus material after the formation of the seed is conveyed to or through the lint. The quality and the composition of the lint appears, therefore, to be determined by the surplus amount available after seed formation. The general trend of the experimental evidence is that the quality of the lint can be correlated with its lime and phosphoric acid contents. Analyses of lints of different lengths lend support to this view.

The effect of the different mineral constituents on the growth of the plant and the yield of kapas was next studied, in artificial *cum* solution cultures. In this study, the basal solution was so made as to resemble in composition and dilution that of the soil solution and the effect of the different constituents was tested by superimposing on the basal solution the constituent under test.

Name of solution.	Dry matter.	Kapas
Basal	5:75	2.17
do. N	9.28	0.64
do. P	5.88	Bolls shed
do. K	5.83	2.91
do. Ca	5.07	1.16
do. Mg	4.27	0.94
do. Ca plus P	6.47	3.97
do. Mg plus P	5.24	1.06
do. K plus P	4.54	1.06

In the basal solution the growth of crop and the yields of kapas may be taken as normal. Nitrogen has induced vegetative growth but depressed the yield of kapas while phosphate by itself contributed to the shedding of bolls. Lime by itself gave less than the normal but the combination of lime and phosphorous resulted in the largest yield of kapas. The next largest yield of kapas occurs in the solution containing potash.

The results of carefully controlled pot cultures with soil, are more or less, in a line with those of solution cultures in regard to the normal requirements of the cotton plant. Under field conditions, however, it is not such an easy matter to induce the plant to absorb the particular constituent applied to the soil. For instance, it was possible in solution cultures to apply lime and phosphate to the plant with beneficial results. Under soil conditions the direct application of these constituents resulted in almost the reverse effect.

An examination of soils and crop under differently manured conditions shows that the liberation of the different manurial constituents to the soil solution occurs in a series of base exchange processes.

Lime can be made available to the plant not by directly applying it but by the application of nitrogen in the form of ammonium sulphate or potash. Direct application of lime results in the withholding of potash to the detriment of the plant. The availability of phosphate is assisted by the application of nitrogen and likewise a sufficient supply of phosphates helps the use of nitrogen.

It is interesting to note that farm yard manure when applied to a soil controls the feeding of the plant to the best advantage as is reflected in the yields and analyses of kapas.

The findings of the Bio-chemical investigation may be briefly stated thus :—

(1) The physiological balance of the soil solution in which the cotton plant grows is of a very delicate nature and that the plant is easily susceptible to changes in the equilibrium.

(2) organic matter, especially farm yard manure assists considerably in the maintenance of this equilibrium by holding moisture and by inducing in the soil suitable base exchange reactions.

(3) apart from nitrogen and potash, the presence of lime and phosphoric acid are essential for the development of boll and the yield of kapas,

(4) it is preferable to make these mineral nutrients available by the ordinary base exchange reactions occurring in the soil than by direct applications.

We may now enquire how far this knowledge is capable of being put into practice.

A mature cotton crop is made up approximately, by weight of:—

Roots	 5
Stem	... 24
Leaves	... 37
Bolls, flowers, buds etc.	... 34
Total	... 100

Lint forms about 7 per cent of the weight of the whole plant.

The bolls being the important item in a cotton crop, its manuring may be done to increase their yield in several ways

(1) The number of bolls may be increased, without at the same time affecting their average size;

(2) both the size and number of bolls may be incrased;

(3) the size of the bolls and the quantity of lint per boll may be increased.

Treatment.	Average bolls per plant.	%shed per plant.	Yield of kapas per plant	Yield per boll.
N	5.3	57	5.5	1.0
N plus K	6.0	44	7.1	1.2
N plus P	7.2	47	6.8	0.94
N plus K plus P	7.5	44	7.2	0.96
K plus P	7.9	40	7.7	0.97
K	5.0	50	6.4	1.3
P	5.6	53	6.8	1.2
Farm Yard Manure.	8.6	40	7.7	0.95

Farm yard manure has given the largest number of bolls and so the largest yield of kapas, but it has not increased the quantity of kapas per boll.

Potash by itself has given the largest yield per boll but has given the least number of bolls. Its combination with nitrogen is not very helpful, but with phosphate it does very well occupying a place next to farm yard manure.

Phosphate, by itself, has behaved similar to potash.

Combinations of nitrogen, potash and phosphoric acid, rank third in the order of merit .

It is very probable that a larger number of bolls with increased content of kappas may be obtained by the application of artificials on dressings of farm yard manure. American experience in cotton manuring lends support to this view. It the manurial history of American cotton we find that the American farmer has had experiences similar to our own and he could increase his yields only when artificial fertilisers were combined with sufficiently large quantities of organic matter, either in the shape of farm yard manure or green manure or cotton seed meal alone or together.

Organic matter, exemplified by farm yard manure or green manure, helps the growth of cotton in holding supplies of moisture, and so keeping the soil solution sufficiently dilute and also in encouraging the smooth running of base exchange reactions suited to the requirements of the plant.

Liberal dressings of manures before sowing the crop are undoubtedly necessary; we have seen, that the largest intake of nutrients occurs at the time when bolls form and mature. We have also seen the prominent part which phosphoric acid and lime play in the maturity of the boll. Knowing, as we do, that the application of potash liberates lime, it would be worth while testing how applications of potash and phosphate in a soluble form just before the flowering stage would result.

Direct application of artificial fertilisers has not been very helpful even with irrigated cotton. It is worse still with rainfed cotton as here, the crop growth is governed more by moisture conditions in the soil than by manuring and consequently application of manures will do more harm than good especially in years of scanty and uneven rainfall. The circumstances warrant investigation into methods of indirect manuring. A recent experiment, at Koilpatti by Mr. V. Ramanathan, in which he used. Ammonium Sulphate or Groundnut cake for a cereal crop in a cereal-cotton-cereal rotation shows considerable promise and should be tested on a more extended scale.

From every point of view, our greatest requirement is organic manure in sufficient quantity and of good quality. Research work elsewhere and the recent work of our department has proved beyond doubt the supremely important part which organic manures play in our agriculture. Leaving aside the question of exports—of oil seeds and the consequent loss to the country of oil cake, of fish manure and of bone meal—over which we have no control—we can still think of cattle manure and the composting of vegetable refuse to meet our needs.

Mr. Hilson has laid stress on the necessity of making farm yard manure of good quality and on the importance of litter. I wish to further emphasise his statement by saying that if litter is used and the manure is allowed to ferment properly in the loose-box system, the total quantity of the manure as well as the important manurial constituents are considerably increased as will be seen below.

	percent increase on account of loose-box system over heap.
Dry matter ...	 62
Nitrogen	 100
Phosphoric anhydride (P_2O_5)	 70
Potash (K_2O)	 155

All these constituents are in a form in which they are easily but steadily available to the crop.

There is also experimental evidence to show that with a properly made loose-box manure the composition of the crop, especially of straw is improved in regard to its phosphate and potash content, which circumstance is beneficial to the nutrition of cattle.

		Straw from heap manure.	Straw from loose-box manure.
Paddy Straw	P_2O_5	0·16	0·23
	K_2O	1·97	2·66
Cholam Straw	P_2O_5	0·10	0·15
	K_2O	2·24	2·19
Cumbu Straw	P_2O_5	0·62	0·84
	K_2O	3·07	3·30

The use of litter in the manufacture of loose-box manure adds to the comfort and cleanliness. That it is so will be seen on inspecting a properly kept and managed loose-box. In addition to these obvious advantages, it is useful in several other ways.

(1) It increases the bulk of the manure.

(2) It renders the manure more porous and therefore, better able to absorb the valuable urine.

(3) It contributes to the production of a large amount of humus which plays a very important part in the absorption and base exchange reactions in the soil.

(4) Its porosity aud its absorptive capacity assist greatly in the fermentation of dung.

That litter is as important as the dung, will be seen from the results of certain recent experiments in which the dung was removed from a loose-box and in its place ground nut cake equivalent in nitrogen to that of the dung was put in. This was compared with complete loose-box manure on a series of crops.

	Complete loose-box manure.	Litter, urine, Ground-nut cake,=nitrogen. of dung and ashes of dung.
1924 Chitrai cholam F. No. 60 A.		
Average of 4 repetitions:—		
Grain	1945	1950
Undried straw	10320	11740
1925 Fodder cholam F. No. 50		
Average of two repetitions:—	7760	6400
1927 Ragi F. No. 44.		
Average of 14 repetitions:—		
Grain	2342	2311
Undried straw	20485	20377
Fodder cholam (residual effect).		
Average of 14 repetitions.	23614	23554
1928 Ragi F No. 44.		
Average of 14 repetitions:—		
Grain	1678	1700
Straw	13493	14723

So then litter is an item of great importance in the production of farm yard manure either with or without the intervention of animals.

It is, therefore, necessary that fodder should be in quantities sufficient not only to meet the food requirements of farm animals but also sufficient to provide bedding for the animals.

In order to produce sufficient fodder and straw without if possible, unduly cutting down the area under other money crops, there appears to be one method and that is the intensive method of rapidly converting fertilisers into cattle food. In other words, it is the use of concentrated fertilisers on light dressings of farm yard manure in the production of cereal and fodder crops. This system is advantageous in three ways :—

(1) The quantity is increased,

(2) the composition of the crop aud consequently its food value is enhanced, and

(3) there is the likelihood of residual effects on the succeeding crop in the rotation.

Here, then, we have a new angle of vision in looking at the economics of manuring cheap cereal crops like cholam, cumbu and ragi. In a balanced scheme of manuring it is not merely the range of profit and loss from the particular crop that is directly manured that counts, but the effect on the crops that follow in rotation and on the farmstead as a whole.

There need be no fear of the production of straw and fodder in excess of the requirements of the numbers of farm animals. The excess can always be converted into valuable manure either by putting it in the loose-box or by fermenting it separately without being fed to animals and convert it into what is called the " Synthetic Farm Yard Manure."

In spite of this, for some time to come, we shall still be producing farm yard manure natural or synthetic less than the demand. Consequently, the question arises, which is better ; to give larger dressings at longer intervals and thus restrict the application to a limited area in a given year or give smaller dressings at shorter intervals and thus give farm yard manure to a more extended area in a given year.

Seeing that very intensive oxidation of organic matter occurs in our soils, the latter method is to be preferred. As an instance in support of this view, we find that in a plot that has not received any manure for 20 years the amount of organic matter is found to be 1.93 per cent on the weight of the soil ; whereas it is only 2.62 per cent on the weight of the soil in a plot that has received 200 tons of farm yard manure in 20 years at the rate of 10 tons per annum.