Original Articles.

Manuring Experiments and Experimentation with Rubber.

L. LORD, M.A.,

Economic Botanist, Ceylon.

IT may be said that the present time,* with the slump in rubber showing no signs of abating and with restriction of production still in force, is singularly inappropriate for any discussion of possible means of increasing production, particularly if such means involve additional expenditure of money. Restriction, however, even if the slump does not, will end in October, and low prices for rubber will not continue indefinitely. Moreover, properly designed manurial experiments may show that manuring under Ceylon conditions is unprofitable and thus point the way to economies in working. For these reasons, therefore, a discussion of manurial experiments with rubber and methods of laying down experiments may not be so ill-timed as may at first sight appear, particularly as there is now available not only the results of the last eight years of manurial experiments in the Dutch East Indies (4 & 5)† but also the results of those carried out at Peradeniya during the period 1914-1927 (6).

In addition, the writer wishes to take the opportunity of replying to certain criticisms which have been levelled at a paper (7) on field experimentation with rubber which was published at the beginning of this year. The paper was written jointly but the responsibility for the views expressed rests entirely with the present writer.

In 1924, Ashplant (1) wrote, "Although the manuring of rubber has long been a regular practice in Ceylon, where many of its adherents claim to have considerably increased their rubber outputs by manurial treatment, the almost universal failure of scientifically controlled manuring experiments in rubber to demonstrate a measure of improvement which exceeds the experi-

* Written in September, 1928.

† Numbers in brackets refer to literature cited, a list of which will be found at the end of this article.

mental error, unavoidable in all such tests, has made planters elsewhere sceptical of the value of manuring rubber. The results of manuring generally have, indeed, been so unimpressive as to lead to the view that the lactiferous mechanism of Hevea is unaffected directly by manurial stimulus, and that immediate crop improvement cannot be obtained by manuring." He goes on to say, however, that the (then) recent experiments of Grantham (4) will necessitate a modification of these views. Since that time, Grantham (5) has published further results of those experiments.

The experiments reported by Grantham were laid down in Sumatra on the estates of the Holland-America Plantations Company (H.A.P.M.) and are already familiar to most rubber planters. They differ from the majority of rubber manurial experiments in that they were scientifically laid down and that the results admit of statistical interpretation. The design of the experiments, in the light of the knowledge of field experimentation then available, is admirable, and deserves the highest praise.

Experiments were laid down on the two prevailing soil types, one a sedentary red soil of volcanic origin and the other the "whitish soils," water transported, found nearer the coast. In brief, the experiments show that on the red soil, nitrogen, and on both red and white soils, basic slag, potassium chloride and lime have no effect. On the white soils, however, nitrogen, whether in the form of nitrate of soda or sulphate of ammonia, gives high and significant increases. By 1927 plots on white soil which got 5 lb. of nitrate of soda per tree per year gave an average yield of 580 lb. of rubber per acre whereas the control plots had declined to 258 lb. During the four years 1923-24 to 1926-27 the plots getting 5 lb. of nitrate of soda per tree gave each year more than 100% more than the control plots. These figures are based on means of eight plots of 90 trees each and are reliable within small limits.

It is not necessary for our purpose to discuss in greater detail the results of these experiments or to mention the relative efficiency of the different nitrogenous fertilisers. It is sufficient to emphasise the fact that on one soil type in Sumatra the application of certain nitrogenous fertilisers has been proved to be a paying proposition whereas on another soil type it is not. The inference to be drawn is that on certain soils in Ceylon also it may pay to use nitrogenous fertilisers and that on certain soils it may not.

The available evidence on manurial experiments in Ceylon has lately been published by Holland (6). The Ceylon experiments differ materially from those carried out on the H. A. P. M.

estates in that the different manurial treatments occupied only one plot each. There were no replications and thus there is no means of working out the error of the experiments for each year. To deal first with the "Old Manurial Experiment." An examination of the graph (not reproduced here) shows that the plots treated with the general mixture, and the excess of nitrogen mixture, whose yield at the beginning of the experiment was below that of the control, have since 1916, with the exception of one year (1922), consistently yielded more than the control plot. The evidence as to the effect of potash and phosphoric acid is confusing. Up till 1922 the excess of phosphoric acid plot had gained, but not consistently, on the control plot; the excess of potash plot had lost ground. In 1923, though the treatments of the two plots were interchanged, the plot originally getting phosphoric acid now getting potash and *vice versa*, there was little change in the trend of the yields of the two plots. In discussing the experiment Holland (*loc. cit.*) says, "In view of the evidence previously noted, however, it appears at least extremely doubtful whether phosphoric acid or potash has had any effect on the yields of the plots."

There is, however, evidence to show that the general mixture which contained 50 lb. nitrogen, 30 lb. phosphoric acid and 30 lb. potash per acre and the excess of nitrogen mixture, which contained 80 lb. of nitrogen and 9½ lb. phosphoric acid, did increase yields and it would appear from what has been said previously that the increase must have been due almost entirely to the nitrogen in the mixtures. Are the increases due to the use of these two mixtures significant? Although the absence of replications precludes the calculation of an experimental error each year it is possible to treat the years as replications and so arrive at an experimental error, an error, however, not so reliable as one derived from a replicated experiment for one year only.

The Manager, Experiment Station, Peradeniya, has very kindly given the writer the yearly yields of the plots used in the experiment. Those of the control, general mixture and excess nitrogen mixture will be found in Table I. The yields of the potash and phosphoric acid plots are not included as they are not so suitable for any calculation of error owing to their treatments having been interchanged during the period.

Where these two plots have shown increases—e.g., the original phosphoric acid plot during the period 1914 to 1922 and the same plot after the change to the potash mixture—1923 to 1927—the standard errors of the increases have been worked out by "Student's" method. As would be expected neither of the two increases is significant.

Table I.

Old Manuring Experiment, Peradeniya.

Yields of dry Rubber per Tree in lbs.

Year	Control Plot Lbs.	General Mixture Plot Lbs.	Excess of Nitrogen Plot Lbs.
1914	2·69	2·25	2·37
1915	3·62	3·00	3·50
1916	4·00	3·81	3·87
1917	4·00	4·31	4·44
1918	3·81	4·50	4·50
1919	3·87	3·81	4·50
1920	4·94	5·25	5·20
1921	4·31	4·56	4·50
1922	4·75	4·37	4·62
1923	4·44	5·25	5·25
1924	5·44	5·87	7·06
1925	5·44	6·06	6·06
1926	5·50	6·37	6·06
1927	5·44	5·56	7·31
Total 1917-1927	51·94	55·91	59·50
Mean Annual Increase over Control 1917—27	—	0·361	0·687

It will be noticed that totals and increases have been calculated for the eleven years 1917—27 only. From 1914 to 1916 the two treated plots were below the control plot in yield but by 1917 the effect of the manures had been sufficient to raise the yields slightly above the control plot. It would appear reasonable, therefore, to judge the effect of the manures during the period 1917—27.

In Table II. will be found the results of applying the analysis of variance method (Fisher, 3) to the yields for the eleven year period.

Table II.

Variance between	Degrees of Freedom	Sum of Squares	Mean Square	S. D.	Log S. D. E
Years	10	19·72	—		
Treatments	2	2·60	1·30	1·14	0·1310
Experimental Error	20	2·96	0·15	0·387	1·0507
Total	32	25·28			z = 1·1817

The sum of squares for years is relatively large. An inspection of Table I. will show how the yields have increased, as is to be expected, as the trees become older and this has caused a greater total variation which, however, is not allowed to effect the experimental error. The standard deviation of any one plot is 0·387 lb., the standard error of the mean of eleven plots is 0·117 lb. and the standard error of the difference between two means is 0·165 lb.

The mean differences from the control plot of the general and nitrogen mixtures respectively are 0·361 lb. and 0·687 lb. These differences are respectively 2·18 and 4·16 times the S. E. (d) and (when n = 20) show that the odds in favour of these differences being real and not due to chance are respectively 20 to 1 and more than 100 to 1.

The z test (Fisher, *loc. cit.*) is also significant and shows that the nitrogen plot at least has given a significant increase. The yields of the control and nitrogen plots were also examined by the method of direct differences—the so-called "Student's" method. The differences in favour of the nitrogen plot over the control plot for the 11-year period are, starting in 1917, as follows:—0·44, 0·69, 0·63, 0·26, 0·19, 0·13, 0·81, 1·62, 0·62, 0·56, and 1·87 lb. The mean difference is, as before, 0·687 lb. and the S. E. of the difference 0·177 or slightly higher than by the first method owing to the fewer degrees of freedom. Again the odds against the mean difference between the nitrogen and control plots being due to chance are over 100 to 1.

The fact that the nitrogen and general mixture plots which started at a lower level than the control plot have steadily increased in yield and have finally exceeded the yield of the control plot is strong presumptive evidence that the differences in the mean yields of the plots, statistically significant, are in reality due to the treatments associated with these plots and not due to the fortuitous circumstance of initial soil fertility. At present prices the cost of the nitrogen mixture may be taken as about from 60—65 cents per tree, and the value of the increase at about 32 cents. While no estate will spend 60 cents to obtain

32 cents it must be remembered that (i) the price of rubber, will, it is hoped, increase; (ii) a cheaper form of nitrogen may be used; and (iii) the increased yield through the application of nitrogen is apparently becoming greater each year.

An examination of the "Avenue Manurial Experiment" at Peradeniya unfortunately discovers no evidence of the benefit of manures. Holland (*loc. cit.*) states, " As regards yields, there fore, the evidence that the differences which appear are due to manurial treatment is inconclusive and contradictory."

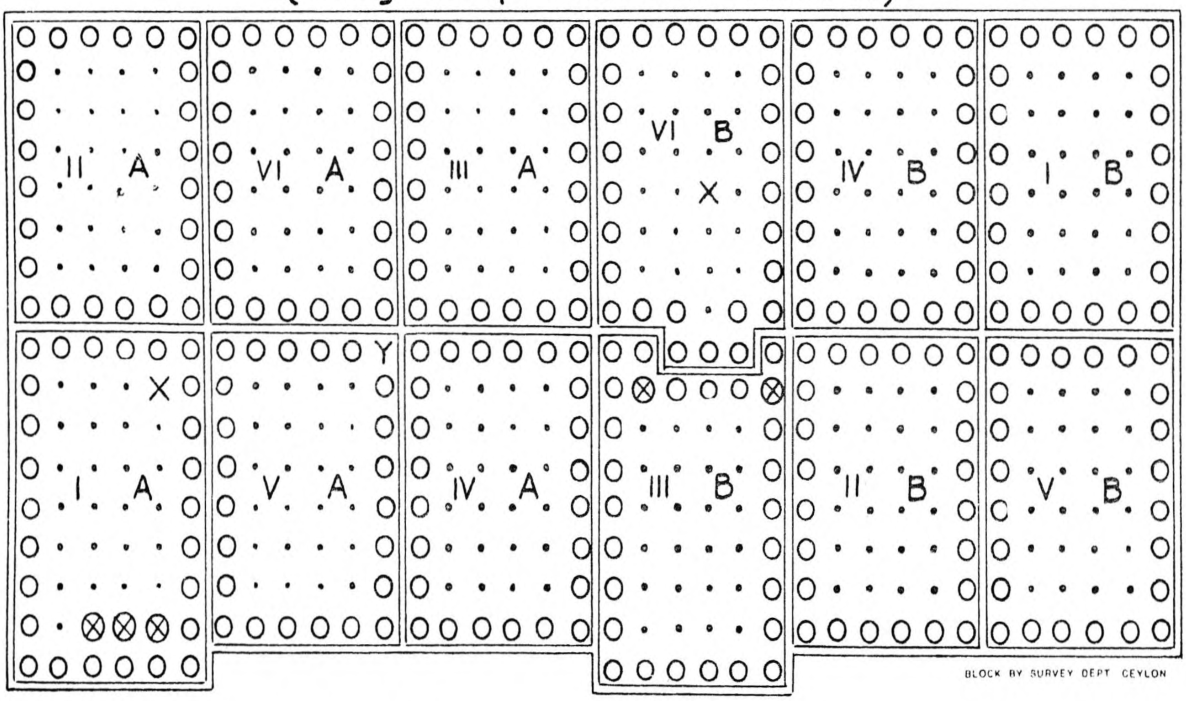
Again, in this experiment no replications of the different treatments were laid down, and, moreover, as is pointed out by Holland, the control plot which is at the end of a block gets more light and space than the other plots. The nitrogen used in the experiment was in the form of nitrolim and it is possible that this form is unsuited to rubber—*cf.* the failure of ammo-phos in a carefully designed experiment in Sumatra (Grantham, 5.)

It must be concluded, after examining the available evidence on manuring of rubber, that under certain conditions certain manures—probably nitrogenous ones—will increase the yield, and economically so at certain prices. The problem now is to ascertain, with a degree of precision hitherto not aimed at, the increases which may be expected from the application at different times of different manures applied at varying rates. It was with the object of pointing the way to obtaining this greater precision with field experiments with rubber that the writer jointly undertook the study of this subject. The results of the investigation have been published (7) as a bulletin of the Department of Agriculture. In the bulletin it is stated (p.2) that " . . . . even if the Peradeniya figures proved beyond doubt that manuring of rubber did not pay at Peradeniya, they do not prove that manuring will not pay elsewhere. It is obvious that reliable evidence of the effect of manures is necessary and, owing to the variation in soil conditions, that it must be obtained not at one place only. It is hoped that this investigation will enable experiments to be laid down in such a manner as to obtain this evidence."

The method of experimentation recommended, was, briefly, by the use of "randomized blocks," i.e., all the plots of each replication laid down purely at random within a compact block, with results examined statistically according to the analysis of variance method. Lately in this journal, Eden (2) pointed out some of the advantages of these methods and referred to the automatic elimination of tapping error which results from their use. The 'latin square' which may further reduce errors due to soil differences was not recommended owing to the difficulty, in Ceylon at least, of obtaining of sufficiently uniform contour the necessary large area of land required for rubber experimentation. The size of the plot recommended was 24 trees, and the number of replications, six.

DIAGRAMMATIC LAYOUT OF A RUBBER MANURIAL EXPERIMENT

in randomized blocks and with border rows.
(Only 2 replications shown)



4 replications not shown here.

LEGEND

A = 1st Replication.

B = 2nd Replication.

C = 3rd Replication. Not shown here. etc.

═ 2'—3' drains dividing plots

· —Tree in 24-tree plot proper.

O—Tree in border.

X—Gap in plot proper.

Y—Gap in border row (may be ignored.)

⊗—Extra trees in border included to square off plot.

As manures are applied per tree and as latex yields can be calculated per tree there is no objection to extra trees in the border rows.

MANURIAL TREATMENT PER TREE

i. Control.

ii. 4 lbs. Sulphate of Ammonia applied yearly.

iii. 4 lbs. Sulphate of Ammonia applied every 2 years.

iv. 5 lbs. Nitrate of Soda applied yearly.

v. 5 lbs. Nitrate of Soda applied every 2 years

vi. 2½ lbs. Nitrate of Soda applied yearly.

The recommendations of that bulletin have been criticised on two grounds:

(i) That (presumably chiefly and almost entirely in manurial experiments) 24-tree plots are open to what has been called "marginal error" or border effect, due to the manures of one plot becoming available to the border row or rows of trees of adjacent plots, and that in such relatively small plots as 24 trees the marginal error will be very large.

(ii) That although precise methods of experimentation in randomized blocks may be desirable academically, the practical difficulties are so numerous as to introduce a human error large enough to counterbalance any academic gain.

To deal first with border effect, or marginal error. The possibility of border effect was not overlooked. On page 18 of the bulletin it states, "Owing to the wide lateral range of the roots of rubber trees it is advisable to have a border row of untreated trees round each plot and outside of that row a 2—3 ft. ditch . . ." It was, by an oversight, stated in the bulletin, that the border row should be untreated. The trees in the border row should receive the same treatment as the plot proper but the latex from those trees should be dealt with separately. Fig 1. shows a diagrammatic lay-out of a manurial experiment designed on the lines suggested. The treatments which are shown as examples are somewhat similar to the treatments in the H. A. P. M. experiments. The six "A" plots form one compact block and the six "B" plots another. The position of the six plots in each replication or block is assigned wholly at random. Without a dividing ditch the roots of the outside (border) row of one plot may, and to some extent will, penetrate as far as the border row of the adjacent plot but such roots will form a very small proportion of the total feeding roots of these particular trees and the effect of their entering another and dissimilarly treated plot will, probably, not be very large. Exact figures on this point are not available. The presence of a 2 to 3 ft. ditch between border rows will prevent most, if not all, of the lateral roots crossing to the next plot. It is satisfactory to learn that the plots in the H. A. P. M. manurial experiments were separated by a 2 ft. drain and there is no mention of border rows. It is quite possible that a 2 ft. or perhaps 3 ft. ditch or drain alone will prevent border effect. Experiments will prove or disprove this. If the ditch alone is sufficient the experiment will be made simpler and, owing to the smaller area necessary for each replication, less affected by soil heterogeneity. It is realised that the H. A. P. M. experimental plots contained 90 trees. If there were any border effect 36 trees would be affected proportionately more so. In a 24-tree plot surrounded by a border row the 24 trees used for the experiment should be entirely unaffected.

As said previously, however, a 2—3 ft. ditch may effectively prevent border effect and so render the use of border rows unnecessary. If so this is all to the good and in experiments which have been designed with border rows all trees can be used for determining yields. This is an important point. The variations in the yields of various-sized plots were calculated from trees whose female parent was common to all. It is possible that the variations in yield of such trees is less than those of trees of mixed parentage and that *ipso facto* with mixed trees a slightly larger plot will be more efficient. In the absence of border effect, the border row could then be included in the plot proper.

But even in experiments with trees of mixed parentage laid down without border rows if it is found that the variations of 24-tree plots are somewhat larger than those for the Peradeniya plots, carrying on the experiment an extra year or two will give a precision equal to that obtained from larger plots. It must be remembered, too, that as time goes on more and more experiments will be laid down with trees whose parentage is the same and that, therefore, variations in yield will probably be reduced.

In short, there would appear to be no reason to anticipate errors, due either to border effect or to the use of too small a plot interfering with the accuracy of an experiment laid down on the lines suggested.

The second criticism has frequently been levelled against the elaborate technique of field experimentation that modern research has found to be necessary in order to obtain really reliable results. In the "Second Nitrate Manuring Experiment" described by Grantham (*loc. cit.*) there were eight replications of five treatments making forty lots of latex to be dealt with at each tapping. There is no reason to believe that the latex from an equally elaborate experiment could not be handled accurately in Ceylon. It may be found necessary to tap the trees of border rows separately. If so, such trees could bear a distinctive mark (as would the trees of the plot proper) and could be tapped by a different cooly. There would thus be two tapping coolies for each replication and each would be furnished with as many buckets for latex as there were treatments in the replication.

But when all is said, it cannot be maintained that accurate field experimentation is a simple matter. As was stated in the bulletin, "The laying down of field experiments is obviously a task to be undertaken in no light-hearted manner."

The difficulties have been vividly put by Engledow and Yule* who say, "It is nearly as difficult to make sure of the yielding capacities of two varieties" (or of two manurial treatments), "as it is to get your ball through the hoop at a game of croquet, when the mallets are flamingoes and the balls are hedgehogs."

Literature Cited.

1. Ashplant, H. Recent developments in the rubber planting industry. *Reprinted by the Rubber Growers' Association.*
2. Eden, T. Modern field experiments. *Tropical Agriculturist* LXXI 2, 1928. pp. 67-76.
3. Fisher, R. A. Statistical methods for research workers.
4. Grantham, J. Manurial experiments on *Hevea*. *Arch. voor de Rubbercultuur* VIII jaar. 8, 1924 pp. 501-519.
5. Grantham, J. Manurial experiments on *Hevea II—ibid.* XI. Jaar 10, 1927. pp. 465-471.
6. Holland, T. H. Report on rubber manurial experiments, Experiment Station, Peradeniya for 1927. *Tropical Agriculturist.* LXXI. 1, 1928. pp. 46-50.
7. Lord, L. and Abeyesundera, L. Field experimentation with rubber. *Dept. Agric. Ceylon Bul.* 82.

* Engledow, F. L. and Yule, Udny G.—The Principles and Practice of Yield Trials.—*Empire Cotton Growing Review.* III. 2. 1926.