# MANURING OF RUBBER—II.*

# TECHNIQUE OF PLOT EXPERIMENTATION.

BY

W. B. HAINES.

Owing to the very variable results which have so far been obtained from the manuring of old stands of rubber it is evident that a further long period of experimentation must elapse before the data are sufficient for a proper elucidation of the different factors that are at work. In order to cover varieties of soil and varying age-class of trees it will be necessary that such experiments be conducted on different estates. It is the purpose of this article to indicate, for the assistance of estates, the more important points in the design and carrying out of field experiments in rubber. Experiments may fail through want of care in recording or lack of continuity in their conduct, but much more frequently the failure of an experiment to provide conclusive figures can be attributed to want of knowledge in designing the original plan. No amount of care and accuracy can increase the value of an experiment which has not been properly planned in the first instance.

Any kind of controlled treatment that affects a crop may be made the subject of a field experiment. The only essential is the provision of such plots as will give a legitimate comparison between areas which receive the treatment and those which do not. Although the applications of fertilisers in various combinations and various amounts are the treatments that are most usually under test, treatments of other kinds are equally susceptible of examination by experiment. All debated points regarding the effects of covers, drainage, silt-pitting, methods of tapping, and so on, are far better referred to the test of experiment than to the judgment of the theorist. The point most usually overlooked is the provision of the untreated or control area to give a basis of reliable comparison. In rubber cultivation, it has been usual for any estate to pin its faith to a particular practice and to apply it to the entire area. Such an experiment is "out of control" in the sense that results are left to guess-work for want of a standard of comparison. Guess-work may be shrewd and well-informed, but the scientific and direct approach is quicker and more sure. If, in the past, control plots had been left in cases where a difference of opinion was possible, or other side-by-side comparisons

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made of different treatments, estate practice would now be more advanced by the accumulation of reliable information on points at issue.

The comparisons afforded by experimental plots have most usually to be reduced to a series of numbers by means of some method of measurement (in rubber, measurement of yield, height, girth or bark thickness) in order that accuracy may be attained. A numerical statement is, in any case, a concise and convenient method, although its interpretation will usually require some contribution from personal judgment. There will always remain, in any field experiment, factors which are ponderable to intelligent judgment but not susceptible of exact numerical measurement. It has often been the experience during the first years of manuring a field of rubber that there is great improvement in appearance but no recorded improvement in yield. Although the statistical result is nil, the subsidiary observations in such a case prevent one from delivering a negative verdict, and call rather for a suspension of judgment till a later date.

Scientific design aims at bringing every point possible concerning an experiment within the range of analytical methods applied to the numerical results. In some cases, indeed, the results of a treatment may be so striking that no close analysis is required to prove its value; for instance, a fifteen-times increase in a tomato crop was produced by the use of manganese on certain American calcareous soils. A mere glimpse of such a field experiment without any measurements would suffice to establish the practical conclusion. Or again, the cost of a treatment may be so large that unless the result is striking it can be at once rejected without closer analysis. But, as a general rule, the cost of the treatment on the one hand, and the definite return which it gives on the other, are so nearly balanced that only a careful analysis of the results can properly decide the practical issue; that is, whether to adopt the proposed treatment on an extensive scale or to reject it.

The requirements to be met by the method of laying out plots can best be approached by considering what we wish to do with the figures obtained finally as an expression of the result. Suppose that we have the yield figures from two plots of rubber, one of which has received a certain fertiliser and the other has been left as a control. The difference between the two yields cannot be attributed to the fertiliser *alone*, since a variety of other causes may have produced effects which are not equal in the two plots. For instance, every planter is familiar with the better conditions shown by a plot near the bottom of a slope, down which the soil has been washed. The particular factor whose effect on the yields it is required to assess is the manuring, but, before this can be accurately arrived at, it must be possible either to eliminate or at least evaluate the effects which may be put down to all other causes together (such as effect of location, personal skill of the tappers, chance differences in the time of tapping, and so on). It is not enough to know that a certain disturbing influence exists. It must be removed or spread equally over all the plots if such adjustment is possible, or it must be allowed for by some reliable means of estimation if it is beyond all control. As an example one may quote the case of a series of manured plots of rubber in Ceylon which have been carried on for many years, the results of which are impossible of precise interpretation because the control plot is known to have a great advantage as regards position; this is the only control and so there are no means of estimating a correction. The best plot has sometimes been deliberately chosen as control in experimenting, on the assumption, apparently, that artificial treatments must be expected to outweigh entirely the differences due to natural advantages. Such reasoning and methods are obviously not sufficiently judicial.

The requirement of a valid experiment then is that the results shall fairly prove that the differences observed are due, not to chance advantages which the plots have enjoyed, but to the treatment under test. For the comparison of two plots only, it would be necessary first to prove that the two plots were absolutely uniform in all other respects before the difference in yield could be attributed with certainty to the manuring. Now uniformity cannot be proved nor tested for without taking a fair number of samples (or plots). Hence the requirement which we are considering is met by providing exact repetitions of the plots. Then the particular treatment remains the one controlled and constant factor throughout the repetitions, while the effects of the other factors may be estimated by comparing the various figures for plots of like treatment (whether controls or treated). The mistake is sometimes made of increasing the number of kinds of treatment with the number of plots, so that it is necessary to state that the repetitions should be identical in every controlled factor. The differences between the plots which have the same treatment provide a means of estimating the variation which has been produced by unknown and uncontrolled causes. This variation is called the error of the experiment, and it is plain that a difference between treated and untreated plots is not valid for a clear inference that it is a result of the treatment, unless it is much larger than the error. Such a comparison with the error allows one to state what is called the "significance" of the result. In mathematical terms it reduces to a statement of a probability, i.e. a statement that a result such as that given would be arrived at by chance once in so many times.

For an experimental increase of a given amount the significance will be the greater the smaller the error of the experiment. A scientific field experiment must therefore be so arranged that the error can be assessed accurately and also reduced to the smallest possible value. One might here use the analogy of a net which is being used to examine the fish in a pond, extracting them by straining the whole contents through it. The practical person who required the fish for food and had no need for small fry would be content with a fairly wide mesh, but a naturalist who wanted the greatest variety of specimens would use the finest mesh possible. In the same way the "error" of an experiment determines the size of mesh through which the results are to be strained or tested. If the error is too large compared with the experimental difference, then these results pass through and no reliable conclusion can be garnered. Conversely, the smaller the error the more reliable the experiment becomes for scientific interpretation. Reduction of the error depends upon care and elaboration. But one is guessing in the dark until the error (or size of mesh) can be estimated.

Since this article is purely practical it may here be pointed out that for practical purposes there is a limit to which elaboration of an experiment needs to be pushed. It is possible to estimate beforehand how large a return must be given by a treatment to balance the cost. The experimental result must be at least as large as this, for there is no practical interest in a treatment which results in economic loss. An experiment will be satisfactory for its purpose if the standard error is small enough to establish results of the order of magnitude which is determined in this way by costs. In rubber this magnitude is often a good deal larger than for general field experiments on other crops. The cost of a continuous manuring programme for rubber might be put down for the sake of argument at about $15/- per acre per year then if the profit from the *extra* rubber produced as a result of manuring be placed at 15 cents per lb, an increment of 100 lbs. of rubber per acre must be looked for before manuring becomes economical. This would be a yield increase of some 25 or even 50 per cent. on a poor-yielding area. If the profit is placed at a lower figure this percentage increase must be still larger. Hence an experiment of great elaboration is not usually required. A probable error of 5 per cent or more would still allow the test to be classed as a "success" or "failure" in the economic sense.

The above remarks will have served their purpose if they establish in the mind of the reader the two points that a good experiment must provide (1) controls and (2) sufficient replication of plots for an estimate of error. The rest of the article may be devoted to a discussion of the details of experimentation which require attention for the attainment of accuracy.

### Choice of an Area.

The first requirement in choosing a site is that it should fairly represent the whole area (of a particular age or condition) which it is desired to benefit. As regards the trees themselves, areas which have not been stagnating too long give the greater promise of result. As regards the soil conditions it must first be ascertained that proper attention has been paid to matters like drainage and conservation measures. Very sandy soils are not so economical to manure as those having a fair proportion of clay to act as an absorbing complex.

The area covered by the plots should be as uniform as possible, in all respects—the lie of the land, age of trees, history of cultivation, height of the tapping cut, spacing of trees and so on. Lack of uniformity of tapping may render an area very unsuitable. It is not possible to correct yields for varying density in the stand of trees, so that areas which have become very variable by reason of disease are unsuitable for plot experiments.

SIZE OF PLOT.

Theoretically the size for the individual plot of rubber depends upon obtaining a large enough number of trees to form a total sample which shall not be unduly affected by the large variation between individual trees. The question has been investigated by several workers and the number of trees required variously assessed between 16 and 100. Although the smaller number might provide a large enough plot theoretically, it has the practical disadvantage of requiring special arrangements for recording. For practical reasons it is advocated that plots should be adjusted to the natural unit for estate recording; thus, for daily tapping, a plot may be half a task so that each cooly brings in two buckets representing the yield from two plots. For alternate daily tapping the same unit can be used; each cooly covers 4 plots altogether (2 each day), or the size of the unit may be enlarged to one task, in which case the cooly brings in the yield from one plot each day but alternates between two plots. On the whole the half-task plot gives the more compact experimental arrangement, but the whole-task plot may be chosen if it seems to give greater simplicity in recording, which ensures greater accuracy. The whole-task plot also avoids the risk that a cooly tapping two plots on the same day may mix or confuse the latex.

For other treatments which are distinguished from manuring by being applicable to individual trees, such as the application of substances for bark renewal, the lay-out of an experiment may be in rows of trees instead of plots. The results are then recorded for each tree. This gives more information than taking average values over a large number of trees, since it enables one to distinguish the variation of the results for trees of different types. For instance, some methods of stimulating latex yield might prove to be worth applying to trees which have run dry, although they might have disadvantages for trees in a more normal state.

ISOLATION OF PLOTS.

The best method of isolating plots so that one treatment does not affect the trees on the contiguous plot is the use of 'guard rows' which are excluded from the experiment and isolated by a trench on each side. This may be viewed as a rather extravagant method since the 'guard' trees must either be rested or tapped separately. It is usually sufficient to isolate plots with a single trench between the border rows of trees. It is impossible to prevent edge effects entirely, but with a trench and plots of one acre or more, the edge effect is not large. The edge effect is reduced to a minimum by making plots approach a square in form as far as possible. Where the trench would run downhill it may even be advisable to dispense with it on grounds of the erosion produced.

RECORDING OF RESULTS.

The results may be recorded in various ways depending upon the estate organisation and the programme for the area concerned. Good results have often followed manuring when the rubber has been rested for a year or more after the application. In such a case records would be limited to bark thickness and girth, which could be taken at the beginning of the experiment and at yearly intervals afterwards. A suitable position on a panel to begin measurements of bark thickness is where the renewed bark is eighteen months to two years old. Test tapping over one or two months can be undertaken on areas which are otherwise being rested. As regards recording of yields, estates must suit their methods to their own organisation of labour. In the final returns it is sufficient to enter the monthly totals of rubber produced from each plot. A convenient method of arriving at the results is to dilute the latex from each tapping of each plot to a standard volume; an aliquot part of this is then taken for test coagulation and weighing while the remainder passes into the factory. Another method which has been found practicable is to manufacture separately the rubber from each tapping and to weigh the final factory product. Calculation from the amount of latex and the hydrometer reading is also a convenient method, but not the most accurate. If conducted in a careful manner by the same person each time the errors should smooth out, since a large number of readings go to the total for each entry of the results. Estate managers will easily utilise methods such as painting trees, buckets and tapping cups in distinctive colours, or the use of tapping cups of different kinds, in order to avoid mistakes between the field collection and the factory recording.

### Tapping Errors.

The results of an experiment may be affected by differing skill of the tappers, or by some plots deriving benefit from earlier tapping than others, or again by cessation of tapping half-way through from weather conditions. These possibilities need to be clearly realised and dealt with. In a simple experiment with one treatment plus control, the error from tapping skill is covered if each tapper works on one plot of each kind. In more elaborate experiments where this is impossible, the band of tappers change their tasks at regular intervals according to a set rota. The point to be aimed at is so to distribute the error that, over the period of a year or so, all plots have an equal chance of good or bad tapping. The error from time of tapping can be looked after by seeing that the cooly begins at different ends of his task for alternate tappings. The lay-out may make such arrangements unnecessary. Effects of weather conditions can only be minimised by adopting a very cautious policy as regards tapping on a doubtful morning. If a "wash out" occurs, then treatment of trees should be equalised as far as possible but no record taken.

### Covers.

For a strict experiment areas may be maintained clean-weeded. Since, however, clean-weeding is practically abandoned as an estate practice and it is of advantage that an estate experiment should be conducted under ordinary estate conditions, it is often advisable to permit the disturbing element of the presence of a cover. For a long range experiment it is possible to take the view that the manuring in the first stage can be mainly devoted to the encouragement of the cover. The usual course of events is that the rubber derives benefit later, and, by virtue of its increased leaf canopy, overshadows the cover and reduces it to minor and finally to insignificant proportions. From a more limited point of view, and particularly where a natural weed cover already exists, matters may be compromised by simple strip or patch weeding of the cover and then concentrating the application of fertiliser to these strips or patches. This takes advantage of the fact that the rubber has a far more extended root range than the cover plants, and gives the maximum of benefit to the rubber with a minimum of benefit to the cover.

### Notes on Fertilisers.

By far the most general need of rubber is nitrogen. The soil becomes impoverished of its humus, the trees have a sparse leafage and show dieback. The leaves are small and of an unnaturally light green colour. If the trees have not lost all vigour, nitrogen will effect great improvement in foliage. When there is a good leaf canopy (as is usual on flat peaty areas) nitrogen is not required.

Signs of potash starvation are usually accompanied by stunted growth rather than die-back. Nitrogen is usually adequate in a virgin soil, but fails later on, so that die-back appears as a response of the tree in adapting itself to reduced supplies. With potash and phosphate, on the other hand, the deficiency is present from the start and growth is slow, with die-back less noticeable. The specific signs of potash starvation are a premature yellowing of the leaf, beginning at the edges. This may be specially looked for in a cover, if one has been tried. Sometimes the soil will still contain humus and nitrogen, so that dark green leaves and yellowing ones will form a striking contrast on trees much below their normal size. Potash deficiency is often marked on the more sandy soils.

Phosphates appear to be much more effective for young rubber than for old. They should form the main ingredient for leguminous covers.

When a fertiliser is soluble it can be applied by simple broadcasting, taking care not to choose a day when the soil is saturated and wet. Other fertilisers should be applied by envelope forking.

The trees have the greatest need for food during the flush of new leaf growth after wintering. Since most nitrogenous fertilisers reach their maximum effect only after some weeks from application, the best time for application is just before the first appearance of wintering. If this is missed, the dry season of July-August is the next best to fall back upon.

The following list gives suggestions for the amounts of fertiliser to use at each application. The statement in hundred-weights per acre is easily reduced to amount per tree, from the known stand of trees. For young rubber the calculation may be made on the basis of the feeding area of the tree. It is not difficult to estimate the root spread from the size of the tree, and to calculate on the basis that 1 oz. per square yard is about 3 cwt. per acre. The amounts are based on general practice in the absence of better information. It may be remarked that other tree crops (for example citrus fruit trees) have been found to require very much heavier applications for the best economic return, but it would not be safe to argue from analogy. It is safe to say, however, that success is very likely to be missed by a too frugal approach. It is therefore recommended that an experiment should be begun with a full intention to give say, three yearly applications before applying the results for guidance as to the further programme.

## Amount of Fertiliser per Acre.

### Nitrogen.

| | | | |
|---|---|---|---|
| Urea | Soluble | 2 — 3 cwt. | |
| Sulphate of Ammonia | Soluble | $3\frac{1}{2}$—$4\frac{1}{2}$ cwt. | |
| Calcium Cyanamide | | 4 — 6 cwt. | |

### Potash.

| | | | |
|---|---|---|---|
| Sulphate of Potash<br>Muriate of Potash | Soluble | 2 — 3 cwt. | |
| Kainit | Soluble | 5 — 8 cwt. | (according to grade) |

### Phosphate.

| | | | |
|---|---|---|---|
| Basic Slag | | 2 — 4 cwt. | (according to grade) |
| Superphosphate | Ordinary grade | 2 — 4 cwt. | |
| | Concentrated | 1 — 2 cwt. | |
| Ground Rock Phosphate | | 2 — 4 cwt. | |
| Perlis Guano | | 2 — 8 cwt. | (according to grade) |
| Sulphurophos | | 3 — 7 cwt. | |

### Nitrogen and Phosphate.

| | | |
|---|---|---|
| Leunaphos | Soluble | 3 — 5 cwt. |
| Ammophos | Soluble | 3 — 5 cwt. |

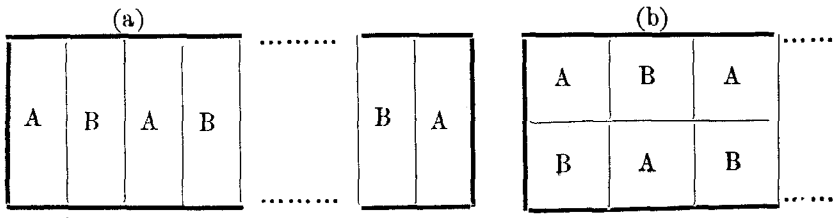
### Complete Fertilisers.

| | | |
|---|---|---|
| Nitrophoska | Soluble | 4 — 6 cwt. |
| Cresite (contains lime) | | 4 — 6 cwt. |

It is usually required by law that vendors of fertilisers shall supply therewith a statement of an analysis showing the content of nitrogen, potash or phosphoric acid as the case may be. Purchasers need this protection particularly in the case of compound fertilisers containing organic constituents. The analysis figures can be used as a basis for a rough comparison of value between various fertilisers offered. The price of basic slag, for example, divided by the percentage of phosphoric acid will give the price paid for one "unit" of phosphoric acid. Such comparisons must be weighed in conjunction with the special advantages offered by each variety. For many purposes, for example, basic slag may derive additional value by reason of its lime content, when being compared with another source of phosphoric acid such as superphosphate.

## SIMPLE SCHEMES SUGGESTED FOR PLOT LAY-OUT.

LAY-OUT I. One treatment, alternating with control.



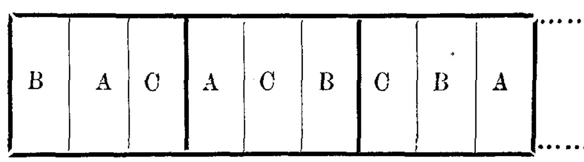

A. Control.

B. Manured. Nitrogen only or a complete fertiliser.

Unit, one or one-half tapping task, as convenient.

At least five replications: ten are better.

LAY-OUT II. Two treatments and control.




Treatments laid down in blocks of three.

Within each block of three the treatments appear in random order. Block repeated five or more times.

A. Control.

B. Nitrogen only.

C. Nitrogen plus one or both minerals, or nitrogen only in a larger application than B.

LAY-OUT III. Three treatments and control.

Gives a block of four plots. These are arranged in random order in each block. The blocks may be arranged together in any way convenient.

A. Control.

B. Nitrogen only.

C. Nitrogen plus potash.

D. Nitrogen plus phosphate (or a complete manure).

LAY-OUT IV. Latin square. This lay-out has many advantages for more elaborate experiments. The plots form a latin square arranged so that each row of plots (considered in either direction) contains one plot of each treatment (including a control). With that restriction the arrangement is otherwise at random. Block 6 at the Rubber Research Institute Experiment Station is an example of this arrangement and may be found described in this Journal (Vol. I. No. 4. p. 241).