MANURING EXPERIMENTS ON YOUNG RUBBER TREES

1. Effect of Fertilisers on Growth

C. G. AKHURST and G. OWEN

Summary

Twenty three manuring experiments in young rubber areas are described and the results are discussed. The experiments are divided into five groups on the basis of similarity of lay-out and manuring treatments, and each group is considered separately. The first four groups consist of experiments on newly planted areas cleared of jungle (except one experimental area where rubber was planted in lalang land), while the fifth group consists of manuring experiments in replanted areas.

The brief description of the experiments and the discussion of results are given a practical bias, but the conclusions are based on a detailed statistical analysis of the data. Owing to war and occupation of the country by the enemy, recording of growth measurements was interrupted, and therefore the effect of fertilisers on early growth of the plants is considered briefly, whereas the final effect of the pre-war manuring on the growth of the trees at maturity in the post-war period is considered separately and in more detail.

The practical application of the results in relation to manuring recommendations for young rubber areas is discussed.

The paper by H. Fairfield Smith, J.R.R.I.M. Comm. 266, entitled "Effect of Fertilisers on Growth of Hevea," gives in considerable detail the mathematical or statistical analysis of growth measurement data derived from a number of manuring experiments on young rubber during the early life of the trees. The emphasis in that paper is given to the statistical methods of analysis used for examining the combined results from twenty-three experiments by which both inferences on the overall effects of manuring can be drawn, and also the special effects peculiar to certain experiments can be evaluated.

It is the purpose of the present paper to consider the experiments and the results more particularly from an agricultural and practical planter's point of view. The planting technique and the field conditions and procedures adopted for the experiments will be mentioned in sufficient detail to enable areas on other estates to be more accurately identified with those where the experiments are sited. The difficulties and setbacks which were encountered will be mentioned, and it is hoped that the additional information which is given will enable planters to be more certain whether their own rubber trees are going to respond to fertilisers according to the results obtained in the twenty-three experiments.

The experiments are sited over a wide area in Malaya—one in South Johore, two in Central Johore, five in North Johore, four in Negri Sembilan, one in Central Pahang, six in Selangor, three in Central Perak, one in South Kedah.

A diverse range of soils and topography are to be found on the land used for the experiments. The soils are representative of coastal alluvium (clays, organic clays, peat over clay), inland alluvium, and most inland soil types (granites, sandstone, shales and phyllites, with and without laterite). The topography varies from the inevitably flat coastal lands, through gently undulating terrain to hilly inland areas.

Almost all of the laboratory data (physical and chemical analyses) for the soils were lost during the war, or, if available, could not be identified accurately or related to individual soils after the re-occupation of the country, and cannot be included in the present paper.

Of the total number of experiments, the majority (18) are new plantings, four are replantings and one was planted on old lalang land. The object of the tests was, in all cases, to determine the relative effects of different fertiliser treatments on rubber trees growing on different soil types.

The areas of jungle were chosen after careful inspection had been made, chiefly in 1936 and 1937, during which period some hundreds of blocks of jungle and many thousands of soil samples were examined. Less choice was possible with the replantings because areas could only be used as replanting programmes developed and where the general circumstances were favourable for experimental work.

One of the principal requirements in land that is being selected for an agricultural experiment is that, in order to ensure greater accuracy when comparing the effects on the crops of different treatments, soil conditions over all the plots in the experiment should be as uniform as possible. Whilst every attempt was made to ensure such uniformity, low lying land and ravines have in some experiments interfered, as will be seen later, and in presenting results special allowance has been made for such abnormalities.

Where jungle had to be cleared, the methods of preparation were kept to a definite pattern. After felling and stumping (usually up to 8 inches), all debris was completely burned off, i.e. a normal burn was used, and planting strips were in straight lines on flat areas, or on contours where hills were found. A stand of 180 trees per acre was the theoretical planting density, but slight variations from this were unavoidable where contour planting was required. Standard two feet cube holes were prepared, and seeds at stake were planted in all but three cases, two of which had budded stumps, and one had clonal seed. Mixed leguminous covers, usually *Centrosema pubescens* and *Pueraria javanica,* were planted immediately after lining and holing were completed. No manuring of these covers was permitted, and the standard method of control was to maintain terraces and planting rows clear of covers for a width of 6 feet.

The replantings received adequate root disease treatment and had all old stumps taken out (felling was done by jacking down the old trees). All light branches were burned and the main stems and heavier branches were swung round to support the lower edge of terraces or else, on flat land, were left between the planting rows. Under the legume covers which were established the old rubber timber disintegrated and became incorporated into the soil in about 4 years.

The important task of dividing the area into plots was usually done when lining and holing had been completed. The average area of an experiment is from 40 acres to 60 acres, and plots vary in size from approximately ½ acre to 2 acres. Frequently a strip, just inside the experimental perimeter and extending for about three or four rows of trees, was left as a boundary belt in which any effects of the surrounding old rubber or jungle trees could be absorbed.

Plots were distinguished by boards having the plot number and letter and by corner posts. In the contour plantings galvanised iron wire was placed along the plot boundaries as an additional means of demarcation.

The basic principle of the experimental designs was to have randomised treatments in replicated blocks of contiguous plots. In some cases a Latin Square design was used, but in most experiments the lay-out of plots was in randomised blocks. It was possible to use 'factorial' lay-outs in about half the cases — seven experiments being of the 2x2x2 design, two experiments of the 3x3x3 design, and two others of modified factorial design.

For each of the five series of experiments a programme of manuring was laid down, starting at time of planting which was planned to continue to maturity. The first applications were made either in the planting hole, the fertilisers being mixed in the top six inches of soil, or within a few days shortly after planting, when the fertilisers were scratched into the surface layer of soil, immediately around the seedlings. Subsequent fertiliser applications were all made in an annular ring around the plants, after which the manure was lightly forked into the soil.

Owing to the war, the full programme of manuring could not be carried out, and applications ceased after two or three years from planting.

The amounts of fertilisers applied were graded so as to increase, after budgrafting, with the size of the plant, and keeping the ratios of fertiliser ingredients, within a treatment, constant throughout successive years. Delays in attaining buddable size allowed plants in some experiments to receive an additional dressing of fertiliser during the waiting period before budding took place. The quantities of fertilisers were always measured in the field from specially prepared tins, whose measurements had been worked out beforehand in the Soils Division laboratory.

The problem of budding in the field, when applied to an experimental area, was much greater than had been anticipated and the ideal of having all plots within an experiment budded and cut back at the same time was very difficult to attain. Growth variations arose owing to pest damage (mainly from rats and squirrels), to soil variations which initially had not been apparent, and in some cases to the effects of fertilisers. Supplying in particular plots in certain instances had to be carried out. Where such variations occured, partial levelling up was attempted by delaying budding until all plots were buddable (i.e. 80% of all planting points of buddable size) and by doing additional rounds of budding but having one time for cutting back. Further interfering factors have been disease, chiefly of the roots, storms, and occasional damage by elephant and deer, and these appeared as the plants grew older.

Height measurements were taken by R.R.I. field staff at six monthly intervals during the early stages until the plants were sufficiently large to allow for recording girth at 50 inches above the union of stock and scion. Thereafter, girth measurements were taken regularly at six monthly intervals up to the end of 1941. Owing to war and occupation of Malaya by the Japanese it was not possible to record growth measurements (nor apply fertilisers) during the period 1942 to 1946. Unfortunately all detailed growth records collected up to the end of 1941 were lost during the period of occupation, but growth summaries showing the mean height and mean girth per treatment were recovered. Our brief observations on early growth are based mainly on these skeleton data. The more important conclusions on effect of fertilisers on growth of Hevea however are based on growth records taken since 1946 which have been analysed statistically. Only the more important practical conclusions will be reported herein. Methods of analysing the data are described and detailed conclusions based on the statistical analysis are given by Fairfield Smith, (Communication 266).

The clones used in the experiments were principally Prang Besar 86, Pilmoor B.84, and Tjirandji 1, although the following clones also were used in one or two experiments:— Prang Besar 186, Pilmoor D.65, Tjirandji 16, Glenshiel 1, and Bodjong Datar 5. In the experiments first designed, as many as five clones were budded in one experiment, and these were arranged in strips, of four or five tree rows per clone, running across the whole experiment, with each series of five strips containing the five clones arranged in a randomised* order. The disadvantage in this arrangement of the juxtaposition of clones of very different growth habits which might result were not immediately appreciated, but in all the later experiments single clones were arranged to cover blocks or groups of plots. Strips containing five clones per plot occur only in three of the experiments under review.

The condition of the experiments just prior to the commencement of the war in December 1941 was very satisfactory, and their upkeep and the regular application of fertilisers were proceeding according to plan. A small divergence from the original schedule has to be noted, in that owing to difficulties of supply during 1940 and 1941 the plant nutrients had, for the last applications before the war, to be supplied by different types of fertiliser, e.g. Enpekay no. 1 was substituted with a mixture containing sulphate of ammonia, concentrated superphosphate and muriate of potash, muriate of potash replaced sulphate of potash, etc.

*By "randomisation" or "random arrangement" is meant that the order in any one group in which clones or treatments occur is purely chance arrangement obtained by picking the clones or treatments in turn from a hat.

Although the war caused a complete cessation of manuring and abandonment of the planned schedule of fertiliser applications, the experiments as a whole came through the war with surprisingly little damage. Tree losses, through a variety of causes, were few, although whole blocks of plots were cut down in two or three instances in other experiments not discussed in this paper. The chief interference was from heavy cover growth and the intrusion of lalang on external plots and in open spaces; other minor damage occurred through bark injury by animals, lack of attention to drainage and root disease.

For the experiments now being considered, the original plots have all been re-identified so that post-war growth measurements are comparable with those taken pre-war, and, equally important, the fertiliser treatments can be resumed according to the original plan.

The immediate post war work required, in a number of experiments on the inland soils, was attention to the covers, which had changed from dense creeping legumes to tall 'forestry' covers, and from 1946 to 1948 the gradual control of covers was achieved — high belukar was slashed and lalang patches were either sprayed with sodium arsenite or dug out. In the replanting experiments, the legume covers had disappeared without being replaced by 'forestry' covers; on the coastal alluvial soils covers were less of a problem than on inland areas.

Girth measurement recording was resumed in 1946 and 1947, and experimental manuring commenced in 1947 and 1948. Tapping of the matured trees was undertaken by estates as soon as conditions permitted, and most experiments commenced tapping during 1947. Yield recording commenced on some experiments at the end of 1947, and gradually was extended through 1948 and 1949 to other experiments. A report on these yield records will be made in a subsequent communication.

The existing stand of trees in the experiments has been reduced, by natural means and by thinning out, to the region of 150 trees per acre, but the figure varies somewhat from estate to estate (see Table A, Communication 266, by H. Fairfield Smith). The variation is unavoidable and no account of it has been taken in considering the growth differences to be discussed subsequently.

SECTION I. **SIX TREATMENT SERIES**

The seven estates on which experiments were sited and the summarised planting histories are listed below:—

Key Letter	Estate	Planting date	Budding date	Soil
D	Rengam, Johore	October 1937	July 1939	Inland
E	Sungei Kawang, Pahang	January 1937	Apr./May 1938	,,
F	Victoria, Kedah	Sept/Oct. 1937	Nov/Dec. 1938	,,
G	Prang Besar, Selangor	November 1936	Nov/Dec. 1937	,,
H	Mengibol, Johore	March 1937	July 1938	,,
F 31	R.R.I.E.S., Selangor	December 1935	October 1937	,,
L	Bukit Rajah, Selangor	December 1937	Budded stumps	Coastal alluvial

Experiment L is situated on flat land where the soil is a peaty loam over clay of alluvial origin. The area forms part of the large expanse of coastal alluvium. Soils in the other six experimental areas, situated on gently undulating land, are sedentary soils derived from a variety of rocks. At D for instance, the soil is a brownish red clay loam derived from granite, while experiment E is sited on yellow silty clay derived from shale. Other soil types represented in the group under discussion are those derived from sandstone (F. 31) and from quartzite.

Although the inland soils show widely different morphological characteristics, we have found that their reactions to treatment with fertilisers show little variation. As will be shown later in this report, response on the sedentary soils, even though they may be derived from a variety of parent materials, is remarkably consistent. Coastal alluvial soils on the other hand show little or no response to treatment with fertilisers. Therefore, when discussing the effect of fertilisers on growth of rubber trees it is convenient to recognise two main groups of soils which we shall refer to as inland soils and coastal alluvial soils. That this arbitrary distinction is justified is supported by general observations on growth and yielding capacity of rubber trees in all parts of the country.

None of the experiments discussed in this report is situated on very sandy soils (sand fraction over 80%). These, we know, react differently but they cover only small areas in the country and are relatively unimportant. They are mentioned in order that the reader may bear in mind that comments on the effect of fertilisers on inland soil types, based on experiments described in this report, do not necessarily apply to very sandy soils.

Experimental design in the six treatment series is either a Latin square or randomized block arrangement. Experiments D, E, F and L consist of 36 plots arranged in 6 blocks of 6 treatments, while experiment G consists of 24 plots arranged in 4 blocks of 6 treatments. Experiment H is divided into two sections, each consisting of 30 plots arranged in 5 blocks of 6 plots; in one section the felled jungle was burnt before planting while no burning was done in the other section.

All experimental areas in this series were previously covered with jungle vegetation which was felled and, except for the one section at H, was burnt before planting. In all experiments except L planting was done with ordinary unselected seeds and the young seedlings were budded in the field a year or more later. Experiment L was planted with budded stumps. At D, E and F 31 planting was done on contour, while at the other four centres planting was done in straight rows. Planting density was 180 per acre at D, E, F, F. 31 and L, 140 at H and 270 at G A creeping leguminous cover of *Centrosema pubescens* and *Pueraria javanica* was established between the planting rows, or between the terraces, and subsequently controlled by regular rounds of weeding and pulling the creeper away from the young rubber plants. Where planting was done in straight rows, clean weeded strips along the planting rows were maintained throughout the early period of growth. Elsewhere the terraces were kept free of cover.

Manuring Treatments

The six treatments, replicated four, five or six times in each experiment, were as follows:—

a. Control — no fertiliser applied
b. Nitrogen — sulphate of ammonia
c. Nitrogen and potash — sulphate of ammonia and sulphate of potash
d Nitrogen and phosphate — Nicifos B.
e. Phosphate and potash — concentrated superphosphate and sulphate of potash
f. Nitrogen, phosphate and potash — Enpekay No. 1.

The quantities applied were such that unit application (i.e. application at time of planting) supplied amounts of the three major plant nutrients equivalent to those contained in $2\frac{1}{2}$ ozs. sulphate of ammonia, $1\frac{1}{4}$ ozs. concentrated superphosphate and $1\frac{1}{4}$ ozs. sulphate of potash per planting point.

In all areas the initial dressing of fertilisers was mixed with the top eight inches of soil in the planting hole immediately before planting. The number of subsequent applications prior to budding varied according to rate of growth in any one particular experiment. In experiments E, F, G and H fertilisers were given once only (at 6 months) between the times of planting and budding, but experiment D. received three applications at 6, 12 and 18 months after planting because early growth was backward in this particular area.

At twelve months after budding the feltiliser dressings were doubled and subsequently, as the age of the plants increased, the rate of application was increased in multiples of the unit application. Particulars of manuring for the period under consideration is summarised briefly in Table I.

TABLE I.

Relative Dressings in Fertiliser Units.

Expt.	Years from planting				Years from budding.						
	0	$\frac{1}{2}$	1	$1\frac{1}{2}$	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$
D.	1	1	1	1	1	2	3	4	—	—	—
E.	1	1	—	—	1	2	3	4	—	5	—
F.	1	1	—	—	1	2	3	4	—	—	—
G.	1	$1\frac{2}{5}$	—	—	1	2	3	—	$4\frac{2}{5}$	—	$5\frac{3}{5}$
F 31	1	$1\frac{1}{2}$	—	—	1	2	3	4	?	—	5
L.	1	Budded stumps			1	$1\frac{1}{2}$	2	—	3	—	4
H.	1	1	—	—	1	2	3	4	—	—	—

Planting Material

In experiments D, E, F, G, H and F.31. the young seedlings were budded at twelve or more months after planting with three or more clones in each area. In experiment L planting was done with budded stumps of five different clones.

At D and E two complete blocks of six plots carry one clone so there are three clones in each experiment. At F, H, F.31 and L each block of 6 plots is split to carry 3(at H) or 5 (at F, F.31 and L) clones, so that each plot consists of 3 or 5 clones.

The clones are:—

D and E	Tj.1., P.B.86, Pil.B.84.
F.	P.B.86, Pil.B.84, P.B.186, Tj.16, Pil.D.65.
G.	Prang Besar clones A, B, C and D.
H.	Tj. 1, P.B.186, G.1.
F.31	Tj.1, P.B.86, Pil.B.84, Pil.D.65, B.D.5.
L.	P.B.86, Pil.B.84, Pil.D.65, G.1, B.D.5.

Effect of fertilisers on early growth

No response to treatment was detected in the experiment on the coastal alluvium (Experiment L). In the six experimental areas on inland soils however the beneficial effect of phosphorus became apparent at a very early stage. At twelve months after planting the increased height of the seedlings, as a result of treatment with phosphate, varied from 5 to 50 per cent in the different areas, a greater effect being obtained in some areas than in others. At this stage the maximum effect occurred in Experiment D.

The beneficial effect of phosphorus was again clearly apparent after budding. Girths of the young budgrafts at 50 inches twelve months after cutting back of stocks were from 6 to 20 per cent higher in plots which were treated with phosphate. This improvement was maintained and, indeed, was slightly enhanced during the subsequent period of twelve to eighteen months up to the end of 1941 when observations were interrupted by the war.

The average height or girth was greatest at all times during this early period in the *np* and *npk* plots and the difference in effect between these two treatments was neither appreciable nor consistent, thus indicating that the addition of potash was relatively unimportant.

The effect of nitrogen in the absence of phosphate was small, but consistently positive. The mean values for experiments D, E and F were combined and studied in more detail. There were very highly significant responses to phosphate and to nitrogen, and there was a highly significant interaction of phosphate with estates; i.e. the magnitude of the response was significantly greater in some areas than in others. There was no evidence that the effect of nitrogen was significantly different in the various experimental areas, and there was no evidence for response to potash or for any treatment interactions. Furthermore there was no evidence that one clone reacted to treatment with fertilisers differently from another.

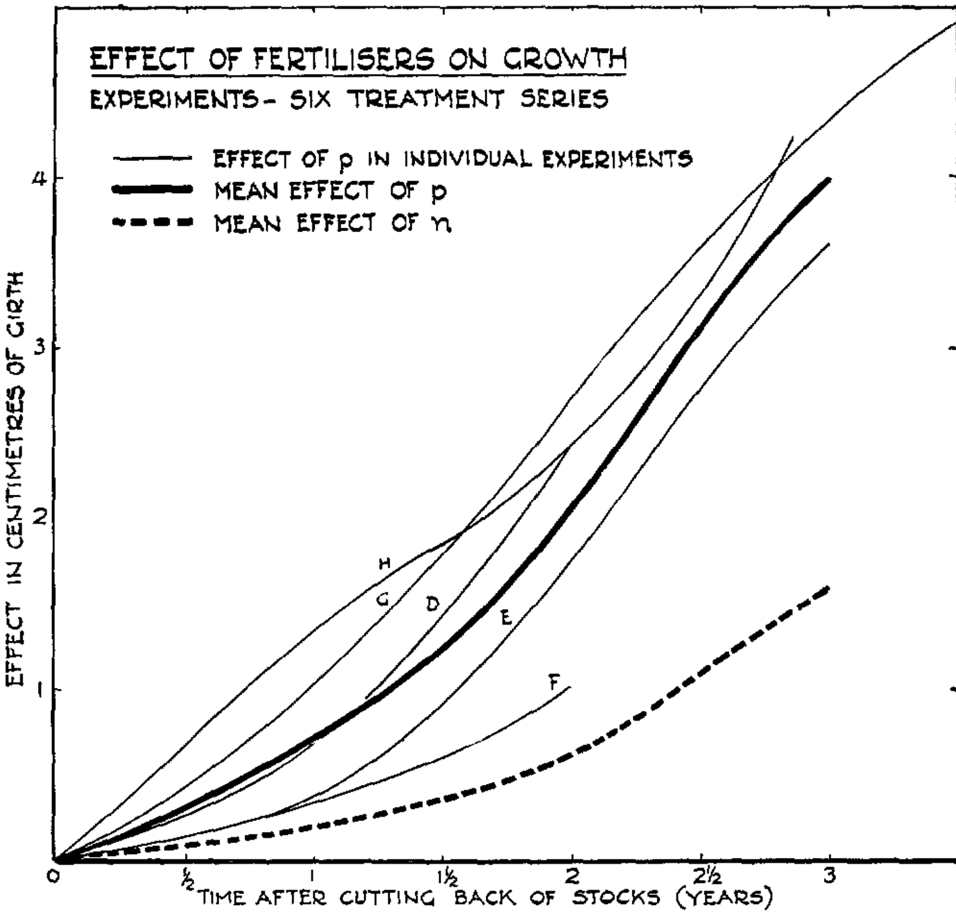

FIG. 1. SHOWING EFFECT OF p AND OF n AT DIFFERENT TIMES IN THE SIX TREATMENT SERIES OF EXPERIMENTS.

At 24 months after cutting back of stocks the mean effect on girth at 50 inches above the union of stock and scion was 0.67 ± 0.045 inches due to phosphate and 0.21 ± 0.048 inches due to nitrogen.

Although statistical analysis of the pre-war data for each individual experiment has not been possible owing to loss of detailed records, the differences between the mean values, which are available, are sufficiently consistent to justify the conclusion that in this series of experiments the application of nitrogen has resulted in a small increase in the rate of growth of young rubber on inland soils, addition of phosphate has had a marked beneficial effect while added potash has had no apparent effect. The effects of nitrogen and phosphate are shown graphically in Fig. 1.

Effect of fertilisers based on post-war measurements

A detailed statistical analysis of the data collected since 1946, and the conclusions drawn from this study of the data, are given in the report by Fairfield Smith, (Communication 266). It will suffice here to make brief statements on observations on effect of fertilisers on growth.

The first post war girth measurements taken in 1946 and 1947 showed that, on inland soils, trees in plots treated with phosphate between time of planting and 1941, were still significantly larger than those which received no phosphate. The effect of nitrogen was much smaller and reached significance in only some of the experimental areas. Response to added potash was still not detectable.

On the coastal alluvial soil however the beneficial effect of phosphate was very much smaller and just reached significance; no response to nitrogen was detected while the effect of added potash had been to depress growth.

We may summarise the results of the first post-war measurements recorded in this group of experiments as follows:—

Inland Soils:—The chances are nineteen to one (i.e. 95% confidence) that, at 7 to 9 years after budding, the magnitude of the increase in girth of trees due to application of nitrogen lies between 0.12 inches and 0.49 inches; the increment due to application of phosphate lies between 1.15 inches and 1.89 inches; the evaluated effect of potash lies between —0.25 inches and 0.14 inches, which is clearly not significant.

Alluvial Soil (Experiment L):—Expressed with the same degree of confidence (95%) the magnitudes of the effects of the different nutrients are:

Nitrogen	— between	— 0.66	and	0.17	inches
phosphate	— *between*	*0.02*	*and*	*0.85*	*inches (significant)*
potash	— between	— 0.88	and	— 0.04	inches (significant)

SECTION II **2 x 2 x 2 SERIES**

This series includes five experiments

Key Letter	Estate	Planting date	Budding date	Soil
A	Voules, Johore	Nov/Dec. 1937	April & Oct. 1939	Inland
B	North Labis, Johore	October 1937	August 1939	,,
BA	Batu Anam, Johore	Oct/Dec. 1937	Budded stumps	,,
C	Banir, Perak	November 1937	Nov/Dec. 1938	Inland *alluvium*
K	Huntly, Perak	Oct/Nov. 1937	May/June 1939	Coastal alluvium

Experiments A, B and BA are situated on gently undulating land where the soils derived from the underlying rocks are of average fertility. Each represents a soil type which covers large areas of rubber land in all parts of Malaya.

Experiment K is situated on the western coastal flats where the soil is a heavy silty clay. On this type of land artificial drainage is essential to ensure successful growth of *crops, particularly rubber.*

The soil in experiment C is also of alluvial origin but falls within the group classified as inland alluvium. Inland alluvial soils exhibit a much greater variation in texture and in general morphological characteristics than the coastal alluvial soils. They are generally lighter in texture and more pervious; drainage is often necessary but not to the extent required in the heavier soils of the coastal flats.

The experiments of this series have the standard factorial arrangement, four of them with five randomized blocks of 8 treatments, and one (K) with 8 blocks of 4 plots each, with N. P and K confounded. Plot size was approximately one acre at A, B, BA and C, and one and a half acre at K.

Four of these experimental areas were opened up from jungle land, the felled jungle being burnt before the rubber was planted. Experiment C is on land previously covered with lalang (*Imperata arudinacae*). At A, B, K and C planting was done in the usual way with ordinary unselected seeds, and the young seedlings were budded later in the field. Experiment BA was planted with budded stumps, with only partial success initially, and much supplying was necessary during the first six months. In all areas planting was done in straight rows with a stand of 180 trees to the acre. Cover crops were established according to the procedure already described for the experiments of the six treatment series.

Manuring Treatments

The eight treatments, replicated four or five times in each experiment, are:—*o, n, p, k, np, nk, pk* and *npk*.

The nitrogen was supplied as sulphate of ammonia, phosphate as a mixture containing equal parts of superphosphate (18% P_2O_5) and Christmas Island rock phosphate, and potash as sulphate of potash.

Unit application (i.e. application at time of planting) was at the rate of 2.4 ozs. sulphate of ammonia, 2.9 ozs. of the phosphate mixture and 0.7 ozs. of sulphate of potash per planting point.

As in other experiments, the fertilisers were first applied in the planting hole immediately before planting, and the number of subsequent applications prior to budding varied according to rate of growth. The rates of applications after budding increased progressively with age.

Particulars of manuring are summarised in Table II.

TABLE II.

Relative Dressings in Fertiliser Units

Expt.	Years from planting				Years from budding						
	0	½	1	1½	½	1	1½	2	2½	3	3½
A.	1	1	1	—	1	1½	2	3	—	—	—
B.	1	1	1	1	1	1½	2	3	—	—	—
BA.	1	Budded stumps			1	1	1½	—	3	—	?
C.	1	1	—	—	1	1½	2	3	—	—	—
K.	1	1	1	—	1	1½	2	3	—	4	—

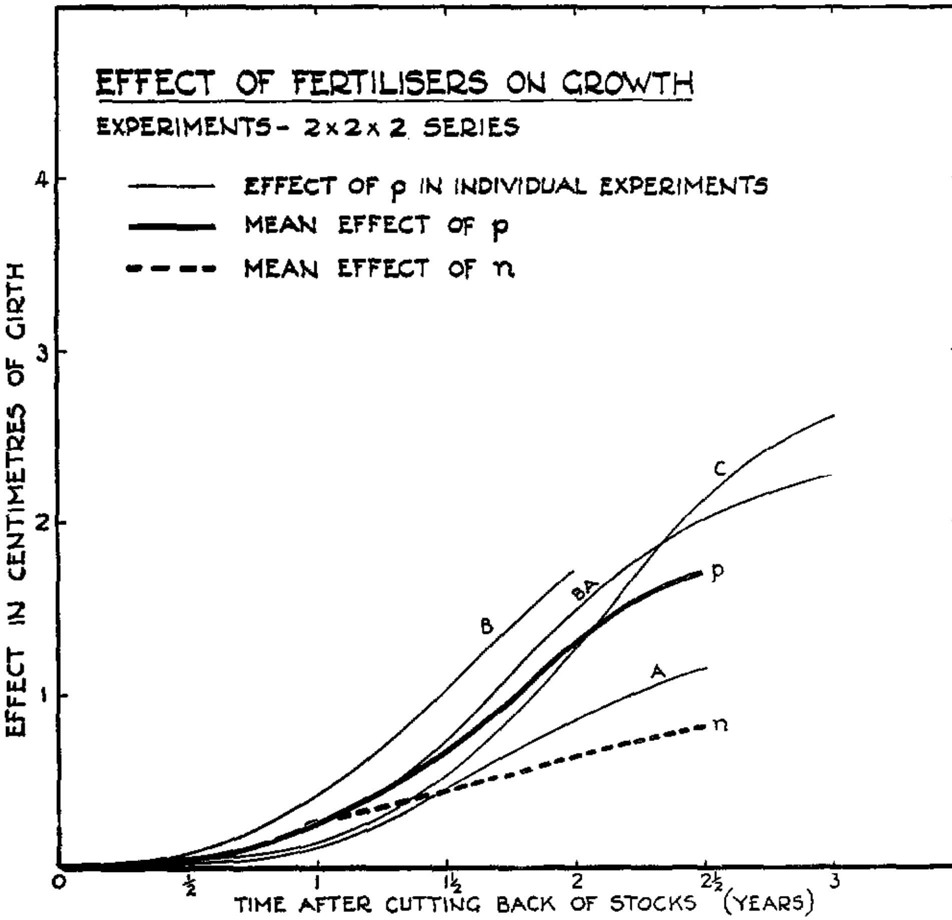

FIG. 2. SHOWING EFFECT OF p AND OF n AT DIFFERENT TIMES IN THE 2 x 2 x 2 SERIES OF EXPERIMENTS.

Planting Material

All experiments in this series have two clones except K which has four clones. In all areas each clone was confined to a complete block of plots. Clone distribution was as follows:—

A	Tj.1 (3 blocks) Pil.B.84 (2 blocks)
B	Tj.1 (3 blocks) P.B.86 (2 blocks)
BA & C	Tj.1 (2 blocks) P.B.86 (3 blocks)
K	Tj.1 (2 blocks) P.B.86 (2 blocks) Pil.B.84 (2 blocks) G.1 (2 blocks)

Effect of fertilisers on early growth

On the coastal alluvial soil (experiment K) no effect due to fertilisers was detected during the first four years after planting. On the inland alluvium, however, as well as on the three inland sedentary soil types in this series, the beneficial effect of phosphate became apparent during the first year of growth and this effect was maintained throughout the period up to 1941. At 18 months after budding the mean girth of plants which received phosphate was from 7 to 25 per cent greater than the girth of plants in the control plots. Maximum growth was obtained in the *np* and *npk* plots, the difference between the effect of these two mixtures being very small and obviously not significant, indicating that potash contributed little or nothing to the improvement in vigour. The trend of the mean values for height and girth of plants during the first three to four years after planting is sufficiently consistent to justify drawing the conclusion that in this series of experiments also the application of nitrogen has resulted in a small increase in the rate of growth of young rubber on inland soil types, addition of phosphate has had a marked beneficial effect, while added potash again has produced no detectable improvement. The effects of nitrogen and of phosphate are shown graphically in Fig. 2.

Effect of fertilisers based on post-war-measurements

The first post-war girth measurements were recorded in 1946. The data showed that in the three experimental areas on inland sedentary soils the improvement due to treatment with nitrogen and phosphate, which was apparent during the early period when fertilisers were applied regularly, was maintained during subsequent years when the areas concerned were neither manured nor properly upkept. On the inland alluvium however (experiment C), the initial gain was lost, no effect due to manuring treatment being detectable at this stage.

The increments in girth during the period 1946-1947 show that the rate of growth during this period, in all five experiments, was not affected by the early pre-war treatments with fertilisers and, moreover, the more backward trees in the no-phosphate plots are tending to catch up with the larger ones in the phosphate plots.

No response to nitrogen or potash was demonstrated at this stage in this series of experiments on inland soil types. On the coastal alluvial soils however (Experiment K) a harmful or retarding effect on growth due to added potash was demonstrated. The results showed that the chances were nineteen to one (95% confidence) that the effect of potash in this particular experiment was harmful and the magnitude of the effect lies between —0.94 and —0.27 inches in girth.

When the data for this group of experiments are examined collectively we may summarise the conclusions by stating that the chances are nineteen to one that the true values of the effects of the different plant nutrients, estimated at 7 to 9 years after budding, lie between the following limits.

	Inland sedentary soils (Expts. A. B and BA)	Inland Alluvium (Expt. C)	Coastal Alluvium (Expt. K).
N	—0.13 and 0.34 ins.	—0.19 and 0.59 ins.	—0.52 and 0.12 ins.
P	1.12 and 1.59 ins.	—0.68 and 0.66 ins.	—0.23 and 0.41 ins.
K.	—0.02 and 0.54 ins.	—0.95 and 0.40 ins.	—0.94 and —0.27 ins.

Obviously only the effects of phosphate on inland sedentary soils and of potash on the coastal alluvium are statistically significant. The former is a beneficial effect and the latter slightly harmul.

The magnitude of the effect of phosphate varies between estates. At B the phosphate added has resulted in nearly twice as much increase in girth of trees as on A, while the improvement at BA was still greater. The chances are nineteen to one that, at 7 to 9 years after budding, the increase in girth of trees in each of the three experimental areas on inland soils due to application of phosphate lies between the following limits.

Expt	*95% Confidence Limits.*
A.	0.30 and 1.10 inches
B.	0.95 and 1.72 ,,
BA.	1.70 and 2.55 ,,

SECTION III. **3 x 3 x 3 SERIES**

This includes only two experiments.

Key Letter	Estate	Planting date	Budding date	Soil
M	Juasseh, Negri Sembilan	October 1938	Clonal Seeds	Inland
O	Ratanui, Perak	January 1938	June 1939	Coastal alluvium

The choice of site for experiment M was rather unfortunate because of soil variation. There are two distinct soil types in this area, one a reddish brown friable heavy loam and the other a grey clay loam largely confined to the lower parts of the gently undulating terrain. The former is the more fertile soil and this was reflected in the growth of the rubber plants.

In experiment O the ground is flat and the soil, a brownish grey silty clay loam of alluvial origin, is uniform over the whole area.

Both experiments consist of 27 plots, having the standard 3 x 3 x 3 factorial arrangement in three blocks of 9 plots each and using the fertilisers providing nitrogen, phosphorus, and potash, in all combinations of each at three levels of application. In experiment M each plot covers an area of approximately one half acre consisting of 9 rows of trees in two blocks and 8 rows in the other. Plots in experiment O are bigger, covering an area of one and one half acres consisting of 13 rows of 21 trees.

Both areas were previously covered with well grown jungle vegetation. The jungle growth was burnt after felling and the rubber plants were planted in straight rows. A creeping leguminous cover of *Centrosema pubescens* and *Pueraria javanica* (*Calopogonuim mucunoides* also in Expt. O) was established between the planting rows. Clean weeded strips, eight feet wide, were maintained along the planting rows throughout the early period of growth.

Manuring

The fertilisers applied include 3 levels (0, 1, 2) of sulphate of ammonia, 3 levels of a phosphate mixture consisting of 2 parts Christmas Island rock phosphate and 1 part concentrated superphosphate, and 3 levels of sulphate of potash.

Unit levels at time of planting (in ozs. per planting point) were:—

	Experiment M	*Experiment O*
Sulphate of Ammonia	0, ½, 1 oz.	0, 1¼, 2½ oz.
Phosphate mixture	0, 1, 2 oz.	0, ¾, 1½ oz.
Sulphate of potash	0, ⅓, ⅔ oz.	0, ½, 1 oz.

As for other experimental areas the quantities applied were increased progressively with time after planting (experiment M) or with time after budding (experiment O).

Planting Material

In experiment M planting was done with Prang Besar Isolated Garden seeds. Ordinary unselected seeds were planted in experiment O but the young seedlings were budgrafted 17 months later, budwood of three clones being used, namely P.B. 86, Pil.D.65 and Pil.B.84. Each plot in the experiment was subdivided into 3 sub-plots for the three different clones.

Effect of fertilisers on early growth.

Good growth was obtained in both areas during the period up to the end of 1941 but the fertilisers had no beneficial effect in the coastal alluvial clay area. In experiment M (inland soil), however, the beneficial effect of phosphate became apparent at an early date. The mean girths of trees at 50 inches above ground at different times after planting are shown in Table III.

TABLE III.

Mean Girth in Cms.

	Experiment M — Months after planting			Experiment O — 18 months after cutting back stocks.
	18	24	30	
n_0	7.36	11.98	16.99	13.95
n_1	7.11	11.71	16.53	13.80
n_2	7.44	11.95	16.77	13.89
p_0	6.10	10.07	14.45	14.03
p_1	7.80	12.52	17.46	13.91
p_2	8.01	13.05	18.37	13.71
k_0	7.35	12.03	17.06	14.00
k_1	7.26	11.74	16.52	13.75
k_2	7.29	11.88	16.71	13.90
s.e.	±.254	±.337	±.409	±.076
Linear response to p	1.91	2.98	3.92	
s.e.	±.334	±.445	±.538	
Curvature	−1.49	−1.92	−2.10	
s.e.	±.578	±.770	±.933	

(In analysing the data for experiment M adjustments have been made to allow for disturbing effects of incidental circumstances, in this instance soil variations and rat damage during the early stages of growth.)

It will be observed that phosphate has had an appreciable effect on growth in experiment M but no effect in experiment O. Neither nitrogen nor potash has had any detectable effect during the early period in either of the two experimental areas.

Effect of fertilisers based on post-war records.

By 1946 growth of trees in experiment M was more uniform and it became apparent that the disturbing effect of rat damage had disappeared and adjustment for this was no longer necessary. In analysing post-war records adjustments were made to allow only for the disturbing effect of soil variation.

In this area of inland soil the average girth at 50 inches above ground of trees treated with phosphate was still 1.8 inches greater than those which received no phosphate. The benefit, observed at 7½ and 8½ years after planting was obtained from fertiliser applications during the first 3 years of growth. At this stage however the rate of growth as determined by the increase in girth during the period 1946-47 was lower in the phosphate plots than in those which received no phosphate. In other words, about 5 years after the cessation of manuring the more backward trees are slowly catching up with the better grown trees which benefited during the early stages from applications of phosphate. This is a feature which has been observed in several experimental areas.

Phosphate was applied at two levels in these experiments. On the inland soil, an appreciable increase in girth of trees resulted from applications at unit level of phosphate, but the additional benefit obtained by doubling the quantity applied was very small in comparison, and it is doubtful if the advantage gained by increasing the rate of application beyond the unit level is economically worth-while. The effect of unit level of phosphate (P_1), evaluated in terms of increase in girth at 50 inches above ground, and the additional increase (P_2) obtained by doubling the quantity applied are shown in Table IV.

TABLE IV.

Effect of two levels of Phosphate (P_1, P_2) on girth (inches)

	Time after planting, in years			
	1½	2	2½	7½
P. 1.	0.67 (3½)	0.96 (5½)	1.19 (8½)	1.43 (12½)
P. 2.	0.08 (7)	0.21 (11)	0.36 (17)	0.41 (24)
s.e.	±0.130	±0.173	±0.213	±0.327

[Figures in brackets are the total amounts (in ozs.) of the phosphate mixture applied up to the time indicated.]

Growth data recorded during 1946-1948 still showed no benefit from early treatment with nitrogen or with potash. Interactions were also examined but all were found to be insignificant.

On the alluvial clay soil (Experiment O) no response to treatment with either nitrogen, phosphate or potash could be detected on examination of post-war girth records.

SECTION IV **PHOSPHATE SERIES**

This series consists of six experiments.

Key Letter	Estate	Planting date	Budding date	Soil
BL	North Labis, Johore	October 1937	April 1939	Inland
P	Malay Rompin, Negri Sembilan	December 1937	April 1939	"
R	Rengo Malay, Johore	October 1937	April 1939	"
T	Bradwall, Negri Sembilan	December 1937	October 1939	"
U	Muar River, Johore	December 1937	July 1939	"
V	Sepang, Selangor	November 1937	October 1939	Coastal alluvium (peaty)

The experiments are sited on a variety of soil types including brownish red, friable, clay loam derived from granite (Expt. BL), yellow silty clay derived from Triassic shale (P), reddish brown clay loam derived from Quartzite (R), brownish red clay and yellow silty clay loam derived from schists and shales of the Carboniferous group, with bands of lateritic fragments at varying depths below the surface (T and U) and finally a peaty loam over grey clay of alluvial origin (V). The experimental areas on the sedentary inland soils are gently undulating, while that on the coastal alluvial soil is flat.

All experiments consist of 40 plots arranged in 5 blocks of 8 treatments. Each plot covers an area of approximately 1¼ acres except in experiment T where plot size is 1 acre.

All these experimental areas were previously covered with well grown jungle vegetation. The jungle growth was burnt after felling and the rubber plants were planted in straight rows, the planting density being 180 to the acre. As in most other manuring experiments laid down during this period a creeping leguminous cover was established between the planting rows and subsequently controlled by maintaining clean weeded strips along the planting rows throughout the early period of growth up to 1941. Regular rounds of weeding were carried out to eradicate all undesirable plant species.

Manuring

The fertilisers applied include five levels (0, 1, 3, 5, 7) of phosphorus supplied as superphosphate (18%). The remaining three treatments are (*1*) lime (*2*) lime plus superphosphate (level 3), (*3*) sulphate of ammonia plus superphosphate (level 5) plus sulphate of potash. Thus five plots in each block received phosphate, two received lime and one received nitrogen and potash in addition to the phosphate. One plot in each block was a control receiving no fertiliser. The eight treatments are indicated briefly but perhaps more clearly as follows, o, p_1, p_3, p_5, p_7, CaO, p_3, np_5k.

Unit levels of fertilisers at time of planting were:—

Sulphate of ammonia	½ oz. per planting point
Superphosphate (18%)	½ oz. ,, ,, ,,
Sulphate of potash	¼ oz. ,, ,, ,,
Lime (CaO)	16 ozs. ,, ,, ,,

Growth during the first year was backward in all experiments in this series and at the end of 12 months the plants were not sufficiently large for budgrafting. Fertilisers were applied at planting also at 6 months after planting, but owing to the backward growth a third application at the same level was given at 12 months in all areas except experiment R. The quantities of fertilisers applied after budding were increased progressively with the age of the budgrafts. Particulars of manuring are summarised briefly in Table V.

TABLE V.

Relative Dressings in Ozs.

	Years from planting			Years from budding			
	0	½	1	½	1	1½	2
p_1	½	½	½	½	1	1½	2
CaO	16	16	16	16	32	48	0
nk	¾	¾	¾	¾	1½	2½	3

(Dressings for treatments p_3, p_5, and p_7 are 3, 5 and 7 times the dressing for treatment p_1).

All experiments in the series received treatments as indicated in the schedule except that experiment R did not receive the extra application at one year after planting, and experiment V did not receive the final dressing at two years after budding.

Planting Material

In all six experiments planting was done with ordinary unselected seeds and the young seedlings were budded in the field later. Budwood of two clones was used in each experimental area, budding being arranged so that three out of the five experimental blocks carry one clone and the remaining two blocks carry the other clone. The two clones selected were P.B. 86 and Pilmoor B.84, but in Experiment BL, clone P.B.186 was substituted for clone P.B.86.

Effect of fertilisers on early growth

A significant response to phosphate was demonstrated early at all centres situated on inland soils, but no response was detectable on the peaty alluvial soil (experiment V).

The effect was first observed in increased height of plants during the second 3 months interval after planting. At this time the response to p was significant at three centres (P, R and U) and although the effect was not proven on the other two inland soil areas (BL and T) there were indications that the effect observed may have been real.

Similar observations were made at 12 months after planting but the magnitude of the effect of p increased. During the first year of growth no curvature in response to different levels of phosphate was demonstrated, so it would appear that the optimum level was not reached in the range tested. There are indications that maximum response in growth during the first year would be reached at levels of application greater than 7 units, or $3\frac{1}{2}$ ozs. superphosphate at time of planting followed by $3\frac{1}{2}$ ozs. at 6 months after planting. The practical conclusion which may be derived from this observation is that the initial application of phosphate in the planting hole should be greater than the equivalent of $3\frac{1}{2}$ ozs. of superphosphate to ensure maximum growth rate during the first year, thus increasing the chances of having plants large enough to bud within a year from planting.

Girth measurements were recorded at intervals after budding. The magnitude of the response to phosphate varied between the different estates, but the differences reached significance only during the second year after budding. Up to the end of 1941 (2 years after budding) the phosphate fertilisers were developing a continuously larger effect and the differences in responses on the different estates were becoming more marked. Curvature in response to different levels of phosphate was more strongly developed at this period; the maximum dressing p_7 may have had a greater effect than p_5 at T, but elsewhere there was no significant differences between the effects of p_5 and p_7. The effect of the lower levels p_1 and p_3 was consistently less.

The estimated mean responses to two levels of phosphate and the total effect are shown in Table VI.

TABLE VI.

Responses to two levels of Phosphate (inches of girth)

	Period	Units of p		Total 0—7
		0—3.5	3.5—7	
	1939 - 1940	0.14	0.14	0.28
	1940 - 1941	0.41	0.20	0.61
	1941 - 1946	1.02	0.38	1.40
Total	1939 - 1946	1.57	0.72	2.29

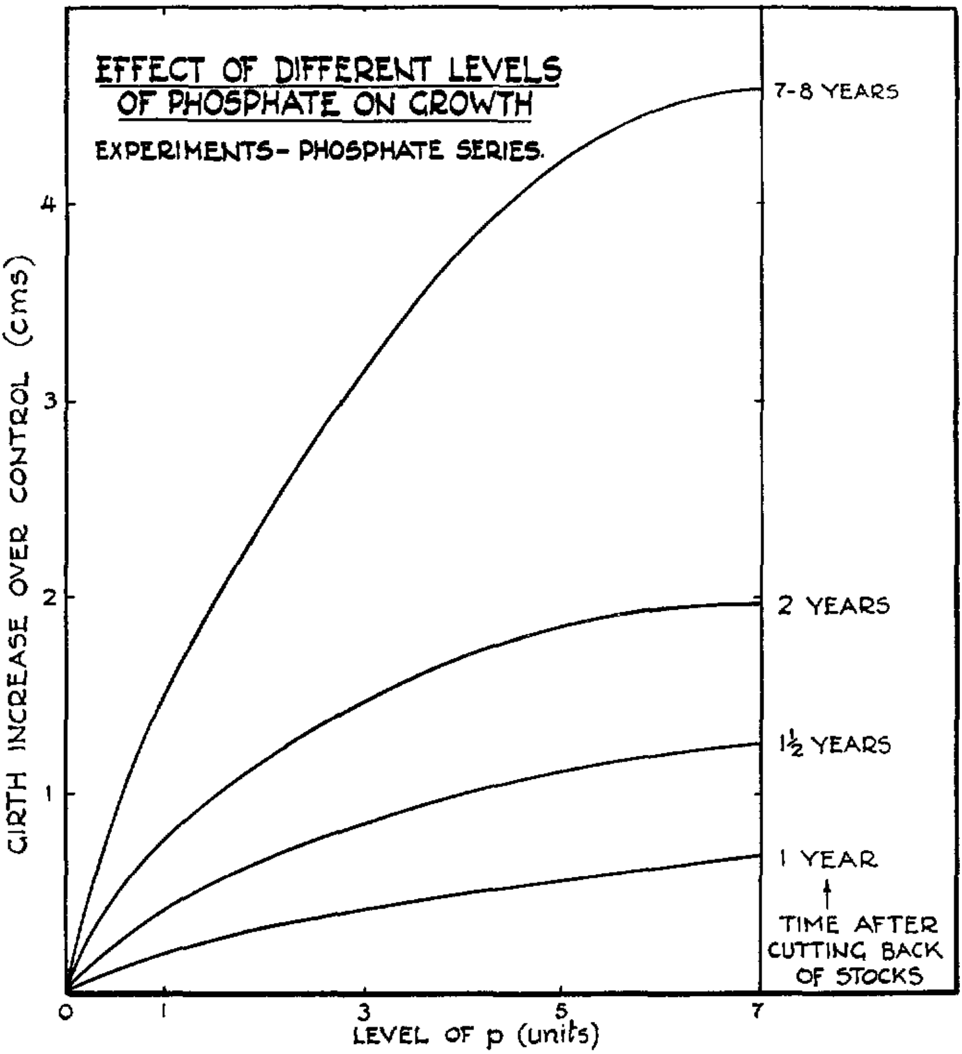

FIG. 3. SHOWING MEAN EFFECT OF p APPLIED AT DIFFERENT LEVELS.

It will be observed that if we consider an application of 7 units of phosphate in two dosages of 3.5 units, the second dosage produced an increase in girth during the first year after budding about equal to that produced by the first dosage. Subsequently, the benefit gained from the second dosage was appreciably less than that obtained from the first. Of the total benefit gained up to 1946 (7 years after budding), 66 per cent of this was produced by the first level of 3.5 units per application, the additional 3.5 units applied on each occasion producing only 33 per cent of the total gain.

The mean effect of the different levels of phosphate at 12, 18 and 24 months after completion of budding is shown graphically in Fig. 3.

It is shown that the response to phosphate increases steadily with increase in the quantity applied up to about 5 units. Quantities beyond this level give little additional benefit. Thus it appears that maximum growth rate up to about 2 years after budding will be obtained on most inland soil types if the total quantity of phosphate applied during that period is equivalent to from 33 to 46 ozs. of superphosphate. In practice this amount would be applied in gradually increasing dosages at intervals, but neither the optimum dosage at any particular stage in the life of the young plant, nor the optimum frequency of application has been determined. We consider that the most effective application of the fertiliser is the one applied at the time of planting when it is possible to mix the phosphate with the soil in the planting hole. The results of the experiments under consideration indicate that an initial application of phosphate equivalent to 3½ ozs. of superphosphate is not adequate to produce maximum growth during the first year. Levels at this stage should be increased well above the 7 units used in these experiments, and the total quantity applied up to two years after budding can be kept to the optimum limit indicated (33 to 46 ozs.) either by decreasing the rate of application or by cutting down on frequency of application during the post-budding stage.

The application of potash and nitrogen had no beneficial effect on early growth, and in the experiments of this series had a slightly harmful effect on later growth. On examining the girth increments for the period 1941 to 1946 it would appear that this harmful effect had not disappeared at seven years after budding.

The effect of lime was variable but on the whole harmful. Differences in response between estates were significant. A slightly harmful effect was proven at P and R during the first two years but its effect thereafter appears to diminish although it probably continued at least during the third year after budding. A slightly harmful effect was indicated (not proven) also at BL but no effect was detected at T and U.

Effect of fertilisers based on post-war measurements

In regard to the experimental area on peaty alluvial soil (V), growth records taken in 1946 and subsequently, further confirmed earlier observations to the effect that fertilisers had no effect on the growth of rubber trees on this soil type. Therefore we shall make no further reference to this particular experiment and the following remarks on the experiments in the "Phosphate series" refer only to those sited on inland soil types.

On inspection of the experimental areas after our return in 1946 it was found that the block of young rubber trees at Rengo Malay Estate (Expt. R) was no longer of any use for experimental purposes. At some time during the period of Japanese occupation, food crops were grown in the spaces between tree rows. In order to allow more light for successful growth of the food crops, the rubber trees over a large section of the area were pollarded. Some time later cultivation of food crops in this area was abandoned and the ubiquitous weed lalang (*Imperata arundinacae*) soon established itself. Apparently the lalang caught fire on one or more occasions for the trunks of many of the young trees were severely burnt.

The other four experiments in this series were in reasonably good condition, apart from the uncontrolled development of the indigenous cover (by this time the creeping leguminous cover had almost completely disappeared) and the loss of a few trees by storms or by disease. After the usual operations of cleaning up the areas, recording of girth measurements was resumed.

Post war records show that trees treated with phosphate are still significantly larger than those which received no phosphate. The magnitude of the effect of phosphate varied from place to place but it was consistently positive and highly significant statistically at all the four centres. The average gain in girth measured at 60 inches above ground during 1946 and 1947, at each of the four experimental areas under consideration, is as follows:—

				95% Confidence Limits.
BL.	...	2.57 inches	± .352	1.47 and 2.88 inches
P	...	1.66 ,,	± .278	1.11 and 2.22 ,,
U	...	1.72 ,,	± .376	0.97 and 2.47 ,,
T	...	3.31 ,,	± .448	2.41 and 4.20 ,,

These gains, estimated at 7 to 8 years after planting, were obtained as a result of applying, during the first four years after planting, amounts of phosphate equivalent to 46 ozs. of superphosphate at BL, P and U, and 32 ozs. at T. It should be noted however that applications of fertilisers ceased in 1941, five years before these measurements were taken, and it is probable that the response to phosphate would have been greater had it been possible to apply the fertilisers at intervals throughout the period of immaturity.

No response to lime could be detected nor was there any indication that phosphate was more effective in the presence of lime. The odd treatment (np_5k), which gives an estimate of the response to nitrogen and potash in the presence of phosphate, was slightly harmful causing a decrease of girth by about 0.6 inches at BL, T and U, but no effect was detectable at R. As this slight harmful effect was comparable to the response to potash shown in some other experiments it is suspected that the effect here also is due to potash. Although the evidence here is not sufficiently strong to state that the addition of potash has a harmful effect on growth of young rubber on inland soil it can be stated with confidence that it has had no beneficial effect in the experiments under discussion.

All three clones under test reacted to fertilisers in the same way. The rate of growth varied according to the natural vigour of the individual clone but the response to treatment with fertilisers in any one experimental area was the same throughout.

SECTION V — **REPLANTING**

Four experiments in replanted areas will be discussed.

Letter Key	Estate	Planting date	Budding date	Soil
N	Sungala, Negri Sembilan	October 1938	October 1939	Inland
SED.	Sedenak, Johore	November 1937	November 1939	,,
RW. 1.	Wardieburn, Selangor	November 1937	September 1938	,,
RW. 3.	Wardieburn, Selangor	December 1937	May 1939	,,

The experiments of this series are on inland soil types showing rather less variation in morphological characteristics than the soils on which the other series of experiments described above are situated. At N the soil is mainly a dark red, friable heavy loam with a distinct crumb structure, while the replanting experiment in Johore is sited on brownish red clay loam derived from granite. The soil at RW is a brownish yellow clay with a band of quartz fragments and iron concretions at varying depths below the surface. The parent material of this soil has not been identified. The general topography of the land in each of the four areas is gently undulating.

The four experiments have a factorial design, experiment N consisting of 32 plots, and treatments including four levels of nitrogen, four levels of phosphate and two levels of potash; experiment SED. also consists of 32 plots arranged in 4 blocks of 8 treatments. Experiment RW.1 has 50 plots arranged in 5 blocks of 10 treatments while experiment RW3 has 40 plots arranged in 5 blocks of 8 treatments. Plot size was approximately three quarters of an acre at N and one half acre in the other three experimental areas.

Each area previously carried a stand of old unselected seedling rubber trees. Replanting of these areas was carried out as part of the normal programme of replacement of old unselected low yielding trees with high yielding clones. The procedure followed was normal and need not be described here; suffice it to say that each area was planted in the usual way with unselected seeds and the young seedlings were budded later in the field. At N. and SED. planting was done in straight rows but at RW planting was done on prepared terraces following the contours. For certain reasons the stand per acre was rather low at SED. having only 132 planting points to the acre at time of planting. At N there were 180 plants per acre and in the other two experimental areas the initial planting density was about 200 per acre. A creeping leguminous cover was established between the planting rows or between the terraces, and subsequently controlled to reduce competition between cover and the rubber plants to a minimum consistent with the need for avoiding exposure of the soil.

Manuring

In the four experiments nitrogen was supplied as sulphate of ammonia, phosphate as a mixture containing equal parts of concentrated superphosphate and Christmas Island rock phosphate, and potash as sulphate of potash

Manuring treatments in each of the four experiments of this series are different. Particulars of treatments may be summarised briefly as follows:—

Exp. RW.1:—A basic dressing of potash was applied to all plots. The variable treatments include 3 levels (1, 2, 3) of nitrogen and three levels (1, 2, 3) of phosphate. There is also one treatment in which all the phosphate is supplied in the form of Christmas Island rock phosphate (corresponding to *n. p. k.* = 1:1:1:) Unit levels at time of planting were:— 1.3 ozs. sulphate of ammonia, 0.7 ozs. of the phosphate mixture and 0.5 ozs. of sulphate of potash per planting point. Quantities applied increased progressively with time after budding.

Exp. RW.3:—Eight treatments which may be indicated briefly as follows:—*o, n, p, k, np, nk, pk, npk*. Unit levels at time of planting were *n* = 2.4 ozs. sulphate of ammonia. *p* = 2.9 ozs. of the phosphate mixture and *k* = 0.7 ozs. of sulphate of potash per planting point. As in all other experiments quantities applied increased progressively with time after budding.

Exp. SED:—Treatments are the same as those for experiment RW. 3. Owing to loss of records during the period of Japanese occupation we are unable to state with certainty that the levels of application were identical.

N:—Treatments include 4 levels of nitrogen (0,1,2,3), 4 levels of phosphate (0,1,2,3) and 2 levels of potash (0.1). All early records relating to this experiment (apart from records of mean growth per plot) have been lost, so the levels of application are not known. They may be assumed to be comparable with levels in the other experiments.

Records of dates of application are incomplete but it is recollected that we endeavoured to follow a standard frequency of application in all experimental areas. The few records that are available are sufficient to indicate that the same procedure was followed in replanting experiments and it may be accepted that in each experimental area fertilisers were applied at planting, 6 months after planting, 6 months after cutting back of stocks and subsequently at 6 monthly intervals up to 3 years after cutting back. Records are not sufficiently complete, however, to enable us to state with certainty the exact number of applications for each experimental area.

Planting Material

Each experimental area was budded with one clone, but the clone differs for each estate. N — clone PB.86, SED. — clone Pil.B.84. RW.1 and 3 — clone Tj.1

Effect of fertilisers on early growth

Little can be said about the effect of fertilisers on early growth in these replanting experiments other than that there was a marked response to phosphate, and the beneficial effect of this nutrient was readily apparent on examination of height measurements at 6 months after planting. The increase due to phosphate was maintained throughout the early period up to 1941.

At RW1, where all plots received some phosphate, growth was fairly uniform over the whole area during the pre-budding stage. Detailed growth records for the pre-war period were lost but, in so far as it is possible to judge from plot means, it would appear that improved growth rate due to the higher levels of phosphate began to develop about 18 months after budding and thereafter, increased gradually.

Records of mean height and mean girth per plot in experiment N allow for statistical analysis and here it is proven that the effect of phosphate is highly significant. The first level of phosphate produced a girth increase of 10%, and the same relative increase was maintained throughout the early period. The second level produced a greater beneficial effect but it was not twice as effective as the first level. There was no significant difference between the effect of the second level and that of the third level.

No response to either nitrogen or potash could be detected in these replanting experiments during the early period up to about 3 years after budding.

Effect of fertilisers based on post-war records.

Perhaps the most interesting fact revealed on examination and analysis of the data is the similarity of responses to treatment with fertilisers in replanted areas and in newly planted areas on virgin soils. Analysis of post-war data shows that in these replanting experiments there has been a marked response to treatment with phosphate, but the other two major nutrients had little or no effect on the growth of the rubber plants. It is of interest to note, however, that, as in several of the other experiments, the effect of the potash as determined by girth measurements, is consistently negative in this series but the values just fail to reach statistical significance. Again, as in other experiments, the effect of nitrogen is consistently positive but is small and fails to satisfy the requirements for stating with confidence that the effect is real.

In regard to treatment with phosphate in replanted areas we can state with confidence that a marked beneficial effect can be expected in replantings on most inland soils. In the experimental areas under discussion, an increase in girth of trees due to treatment with phosphate has been obtained in each experiment, the magnitude of which lies between the following limits.

			95% Confidence Limits.
N.	...	...	1.69 and 3.00 inches
SED.	...	...	0.12 and 2.76 ,,
RW.3	...	...	0.92 and 1.99 ,,

The mean effect for all experiments of this series is an increase in girth of 1.75 $\pm$ 0.300 inches, but it should be noted that this gain, estimated at 7 to 8 years after planting, was obtained as a result of applying fertilisers for only a limited period of about 4 years after planting. Under normal circumstances fertilisers would be applied regularly at intervals during the whole of the period of immaturity and it is expected that the final effect on girth at maturity would usually be greater than the mean effect given herein.

Interactions were also examined but all were found to be insignificant.

Discussion and Conclusions

In Communication 266 the measurements considered are those taken in 1946 and 1947, and the effects of fertilisers are measured by the difference in girth of trees at the age of six to eight years from planting. A similar analysis of earlier growth records has not been possible because of the loss of many of the detailed measurements. Summaries which have survived the war of early height and girth measurements give the average effect of fertilisers in each experiment, and these effects are similar to those given by the girths of the older trees, viz. the main response was to phosphate fertilisers, with a small but positive benefit from nitrogen manuring in most instances, but no response to potash manuring. The heights obtained in the Six Treatment Series experiments at one year from planting showed a much greater response to phosphate manuring than appeared in the girths taken at a later date, but ultimately it is girth which is the criterion of tappability. It would appear, therefore, that impressions of fertiliser effects on young rubber which are based on height measurements may give an exaggerated estimate of the benefits likely to be obtained, and that the earliest available girth measurements, and not the heights of plants, should be used for this purpose.

The variations, between the different series of experiments, of the quantities used of different fertiliser ingredients has been noted by Fairfield Smith, and these variations are not considered to be important for potash and nitrogen because their effects on growth have been negligible or very small. Direct comparisons of varying levels of application of phosphate manures were made in the Phosphate Series experiments, and as a result some indication of the optimum level of application of phosphate has been obtained (see discussion under Section IV). The practical manuring recommendations which are implied have been incorporated in Replanting Manuring Schedule (1950), Advisory Leaflet S.AL. 11/50.

Interaction effects either between fertilisers or between clones and fertilisers have not been revealed in the girth measurements. This means that the effects of two individual fertiliser ingredients have not been enhanced or reduced when they are applied together, and that all clones react in approximately the same way to fertilisers (see Communication 266, tables C, D, 3 & 7).

In one or two instances apparent two-factor fertiliser interactions have occurred i.e. interaction between two ingredients, such as phosphate and potash, but Fairfield Smith concludes that such instances are more likely to be due to quality differences between the fertilisers used in the Six Treatment Series experiments. This hypothesis has yet to be confirmed. In spite of this hypothesis, differences in fertiliser effect on growth due to different qualities of fertiliser ingredients are probably negligible, certainly in relation to the main effects which these experiments demonstrate, and can generally be ignored. The results of the experiments are deemed to be applicable when using sulphate of ammonia, rock phosphate and muriate of potash as the sources of nitrogen, phosphate and potash, respectively. These fertilisers are now generally available and they have been used in all post war experimental manuring.

The occurrence, in the post-war girth increments from some experiments, among the smaller trees of a greater rate of girthing than in the larger trees, cannot readily be explained. It seems unlikely that the smaller trees in unmanured plots are in some way obtaining extra food, which could only arise as a "poaching" effect by the border trees, or through fertilisers applied since the war being washed on to the unmanured plots. As rubber trees mature, their rate of girth increase falls off appreciably, and it is possible that the larger manured trees have reached this stage earlier than the smaller trees, and therefore show a slightly reduced rate of girth increase.

The real point of interest and the practical issue which arises from the whole series of experiments is, of course, how should a young rubber tree be manured in order to attain maturity as early as possible?

The conclusions which may be drawn from the results of the experiments have been clearly and concisely stated and summarised in Communication 266. They emphasize the major role played by phosphate added to the soil in improving the growth of young rubber trees during their years of immaturity until they become tappable. This result has occurred on all types of inland soils on which the experiments are sited, but on coastal alluvium soils the response to phosphate manuring has been negligible. There is a consistent, but small, positive benefit from nitrogen manuring on all inland soil types, but not on the coastal soils. Potash manuring has not improved growth; on inland soils there has been a tendency for potash to retard growth slightly, and on alluvial soils this harmful tendency becomes much more pronounced.

Very sandy soils (containing over 80% sand) which can usually be expected to be deficient in potash, were not included among those on which the manuring experiments were carried out; this probably accounts for the absence of marked benefits from potash manuring such as have been obtained on the sandy flats at the R.R.I. Experiment Station.

Although the majority of the manuring experiments now reported were laid down on "jungle" soils, i.e. soils previously uncultivated and still having their original stand of jungle trees, the same type of growth responses to fertiliser treatments have been obtained in the "replanting" experiments, which only cover a small range of soils. It is expected that similar responses will be obtained from the average type of inland soil in replanted areas. Replanting in the middle and late thirties was carried out, not on the worst soils of an estate, because to do so entailed a probable risk of failure, nor on the best soils, because here were the best trees and therefore the chief source of revenue. In most instances areas were chosen which promised an average chance of success, in the absence of any information on replanting well founded on experiments, and hence the more eroded steeper slopes and hill tops, the gritty and more sandy soils, and the thin soils which showed laterite gravel and rock material close to the surface, were avoided in favour of the more 'average' soil. Such obviously less fertile and more degraded soils may be expected to require more intensive manuring than the ones we have been considering, depending on their degree of exhaustion and on the plant foods of which they have been depleted.

Whilst the present discussions are concerned only with the effects of fertilisers on growth, ultimately it is their effect on the yielding capacity of the tree and how they influence the economics of rubber cultivation which will be of special interest to the rubber planter. Data on yield records are being collected and will be presented in a further Communication as soon as sufficient have been obtained on which to base conclusions. Until this information is available it is not unreasonable, as Fairfield Smith points out, to expect from uniform planting material some degree of proportionality to exist between the size of the tree and its yield; that is to say, where fertilisers have increased the size of the tree larger yields may be expected than from the smaller trees in the less successful fertiliser treatments. With unselected seedling trees the larger ones are not always the best yielders, but this necessarily follows because of the very mixed genetical characteristics that are to be found in the rubber trees of this type.

From practical and economic points of view the most important fact demonstrated in the experiments that have been discussed is the marked effect of phosphate in advancing maturity of young rubber planted in both virgin and previously cultivated inland soils. The effect is remarkably consistent, for the benefit has been observed quite distinctly in all experiments sited on inland soil types, not only in those described in this report but also in other miscellaneous manuring experiments which were in progress over a corresponding period but do not fall within the groups of experiments discussed herein. The magnitude of the effect may vary from one place to another but the trend is always in the same direction and it is estimated that the benefit obtained from regular applications of phosphate during the early stages of growth will amount to an advance in maturity by at least one year and often more. The economic value of such an effect is clearly apparent; the cost of treatment with the optimum quantity of phosphate is but a fraction of the value of a year's crop. Obviously expenditure on manuring of young immature rubber trees with phosphate on inland soil types may be regarded as a very safe investment, even should there be no correlation between the size and its subsequent yielding capacity. The precise value to be placed on nitrogen and potash manuring, which have relatively little effect on girth, can only be decided when their effect, if any, on yields in these experiments has been assessed. In replantings, if it can be decided that nitrogen and potash are deficient in the soil, then the fertilisers used should include these ingredients as well as the phosphate for at least the first few years.

Acknowledgments

The authors wish to acknowledge the very willing assistance and co-operation which at all times has been offered by Managers and Staffs of estates where the experiments are sited. Without this help it would not have been possible to carry out the experiments. The careful recording of measurements by the Field Assistant Staff of the Soils Division is also very gratefully acknowledged.