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# FERTILIZER RESPONSES IN MATURE *HEVEA* UNDER SRI LANKAN CONDITIONS

*by*

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## ABSTRACT

*The results of three out of a series of eight experiments that have been in progress (most of them) since 1976, are discussed. Yield increases in the existing plantations could be obtained with increased applications of nitrogen fertilizers in the form of urea. The level of application could be increased to double that of the currently recommended rate. Some yield increases were also obtained with applications of potassium.*

*It has also been shown that application of rock phosphate to mature rubber trees is not always beneficial. Similarly, applications of magnesium containing fertilizers to mature rubber should not also be made indiscriminately.*

*Although the leaf K concentration showed K deficiency in one experiment, application of potassium has increased the K level without increasing yield suggesting that the critical levels for leaf K may have to be clone specific and at least for the clone RRIC 45, the leaf K levels may have to be revised.*

*In general, fertilizer application to mature rubber with complete NPKMg mixtures, may not be economically justified, particularly in the present context of fertilizer and rubber prices. The results reported have covered only parts of the planting cycles following fertilizer application. The experiments are still in progress and will be continued at least until the responses have stabilized. A detailed economic analysis at the end of this period would then give a more realistic picture on the economics of fertilizer application for mature rubber under Sri Lankan agro-climatic conditions.*

Many reports on fertilizer response from mature rubber have been published. Lord (1929) found evidence in Sri Lanka of cumilative yield increase attaining about 150 kg/ha/annum from 14 years of N application. In subsequent investigations, the main response had been, to phosphate fertilizers with a smaller response to nitrogen but little to potassium (Bolton, 1960) and to applications of nitrogen only with certain combinations of K, in Malaysia (Pushparajah, 1969) and / or phosphorus in Liberia (Guha, 1975). More recently, Sivanadiyan (1983) did not obtain statistically significant yield responses to applications of either N, P, K or Mg in a number of trials covering a large number of soil types in Malaysia, over periods up to 10 years.

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A series of experiments have been in progress, most of them since 1976, to investigate some of the possible reasons for these variable and contradicting results and to further ascertain and quantify nutrient requirements of mature rubber under Sri Lankan conditions.

## MATERIALS AND METHODS

Eight field experiments varying in duration from 5 to 22 years have been in progress in rubber plantations in Sri Lanka. Only three experiments are discussed in detail.

### Experiment 1

This experiment started in 1976, was designed to compare the effects of three levels of nitrogen, phosphorus, potassium and magnesium on growth and yield of mature rubber. The experimental trees were RRIC 45 planted in May/June 1967 at 6×3m and grown with a mixed leguminous cover of *Pueraria Phaseoloides* and *Desmodium ovalifolium* in the Kalutara District receiving an average annual rainfall of 3125 — 3750 mm.

The soil, classified as Agalawatta series (Silva, 1964), is one on which rubber is commonly grown in Sri Lanka. Soils are of variable depth, often shallow, and frequently strewn with boulders and outcrops of the granitic rock, from which they are derived. They are silty clay loam in texture and strong brown to yellowish red in colour.

The three levels of nutrients tested were: Nitrogen — 0, 105 and 210 g N as urea, phosphorus — 0, 50 and 100 P as rock phosphate, potassium — 0, 95 and 190 g K as potassium chloride (muriate of potash) and magnesium — 0, 21 and 42 g Mg as kieserites per tree per year. The fertilizer treatments were applied to experimental plots in a $3^4$ factorial confounded design with single replication. In all experiments: (a) each plot consisted of 30 to 40 measuring trees surrounded in all sides by one row of guard trees. (b) All fertilizers were forked into the soil at depths varying from 5 to 10 cm and tapping was done on the ½ S d/2 system.

### Experiment 2

This experiment was started in 1976 in the Kegalle District to test the effects of three levels of nitrogen and magnesium and two levels of phosphorus and potassium on growth and yield of rubber, on clone PB 86 planted in 1964. The ground cover conditions were similar to those in Experiment 1 and annual average rainfall varied from 2250 to 2500 mm.

Parambe series soil, another common rubber growing soil, was chosen for this experiment in view of its contrasting physico-chemical characteristics. These soils are deep, silty in texture and brown to reddish brown in colour derived from micaceous parent material, the most common such parent material being a biotte gneiss.

The experimental design was a $3\times2\times2\times3$ factorial combination in single replication with levels 0, 1 and 2 for N and Mg and 0 and 1 for P and K. The unit levels for the nutrients and other experimental details were approximately same as in Experiment 1.

### Experiment 3

There are only a few reports of long term fertilizer experiments on *Hevea*, established and monitored from planting into renewed panel stage. This experiment which was started in the Ratnapura District was designed to compare the effects of two levels of N, P and K on the performance of clone PB 86 since planting in 1961. Ground cover management practices and rainfall pattern were similar to those in Experiment 1.

The soil is Boralu series, is shallow, gravelly loam brown to reddish yellow in colour and overlying cabook. It is characterised by the presence of iron concretions which occur thoroughout the soil mass.

The nutrients N, P and K each at levels 0 and 1 were compared in a $2^3$ factorial design, with four replicates. The unit levels of nutrients were approximately, 250 kg/ha of N as ammonium sulphate 132 kg/ha of P rock phosphate and 250 kg/ha of K as potassium chloride, during the immature period of 6 years. Thereafter, the rates were the same as in Experiment 1 and 2. All plants received uniform applications of Mg as kieserite.

### Records and sampling

Yield recording were made once a month from all central, measuring trees in each plot. This was done by measuring the total volume of latex and then coagulating 50 ml. samples to obtain the dry rubber content in the usual manner. All the yield data were expressed as g dry rubber per tree per tapping per year.

Growth assessments were made by measuring trunk girths annually at a constant height of 150 cm above the union on all effective trees.

Sampling of leaves in the low shade position in July/August annually and soils whenever necessary, were done for chemical analyses by accepted procedures.

## RESULTS

Pre-treatment yields were recorded for 6 months totalling 12 recordings in Experiments 1 and 2. Where post-treatment yields were affected by pre-treatment differences, as revealed in co-variance analysis, they were accordingly adjusted. A similar approach was adopted with trunk girth recordings. All post-treatment data were subjected to analysis of variance and where necessary partitioned into linear and quadratic components. Characterisation of soils by pre-treatment analysis (Table 1) indicated that in all experimental areas total N and P appeared to be satisfactory. K, Mg and cation exchange capacity (CEC) values were, however, comparatively much higher in Experiment 2.

*Table 1. Pre-treatment soil analyses*

| Characteristics | Experiment — Soil — Sampling depth<br>Experiment 1<br>Agalawatte<br>(granatic) | | Experiment 2<br>Parambe<br>(biotite geniss) | | Experiment 3<br>Boralu<br>(cabook) | |
|---|---|---|---|---|---|---|
| | 0—15 (cm) | 15—30 (cm) | 0—15 (cm) | 15—30 (cm) | 0—15 (cm) | 15—30 (cm) |
| pH (water) | 4.15 | 4.20 | 4.50 | 4.60 | 4.70 | 4.50 |
| C (%) | 1.86 | 0.97 | 1.40 | 0.54 | 2.12 | 0.76 |
| N (%) | 0.24 | 0.13 | 0.20 | 0.211 | 0.24 | 0.13 |
| Total — P (ppm) | 353 | 272 | 351 | 313 | 248 | 183 |
| Available — P (ppm) | 17.0 | 2.0 | 3.0 | 1.0 | 13.3 | 2.0 |
| Total — K (me/100g) | 3.33 | 3.21 | 5.76 | 6.07 | 2.43 | 3.46 |
| Total — Mg (me/100g) | 5.99 | 6.61 | 10.84 | 9.91 | 3.51 | 4.23 |
| Exchangeable — K (me./100g) | 0.12 | 0.04 | 0.27 | 0.21 | 0.07 | 0.02 |
| Exchangeable — Mg | 0.15 | 0.03 | 6.61 | 6.69 | 0.15 | 0.05 |
| CEC (me./100g) | 5.67 | 4.64 | 10.64 | 10.02 | 4.99 | 3.66 |

## NITROGEN

**Yield:** The post-treatment mean yields for the different levels of nitrogen are given in Figs. 1, 2 and Table 2.

*Table 2. Effect of nitrogen and potassium on yield*
*(Experiment 2)*

| Treatment | Yield (g/tree/tapping)<br>1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|
| $N_0$ | 25.77 | 34.50 | 32.32 | 20.88 | 25.83 | 29.60 | 32.20 |
| $N_1$ | 25.72 | 33.60 | 34.67 | 24.82 | 24.31 | 35.00 | 34.20 |
| $N_2$ | 24.41 | 34.10 | 34.64 | 24.46 | 24.88 | 33.80 | 32.70 |

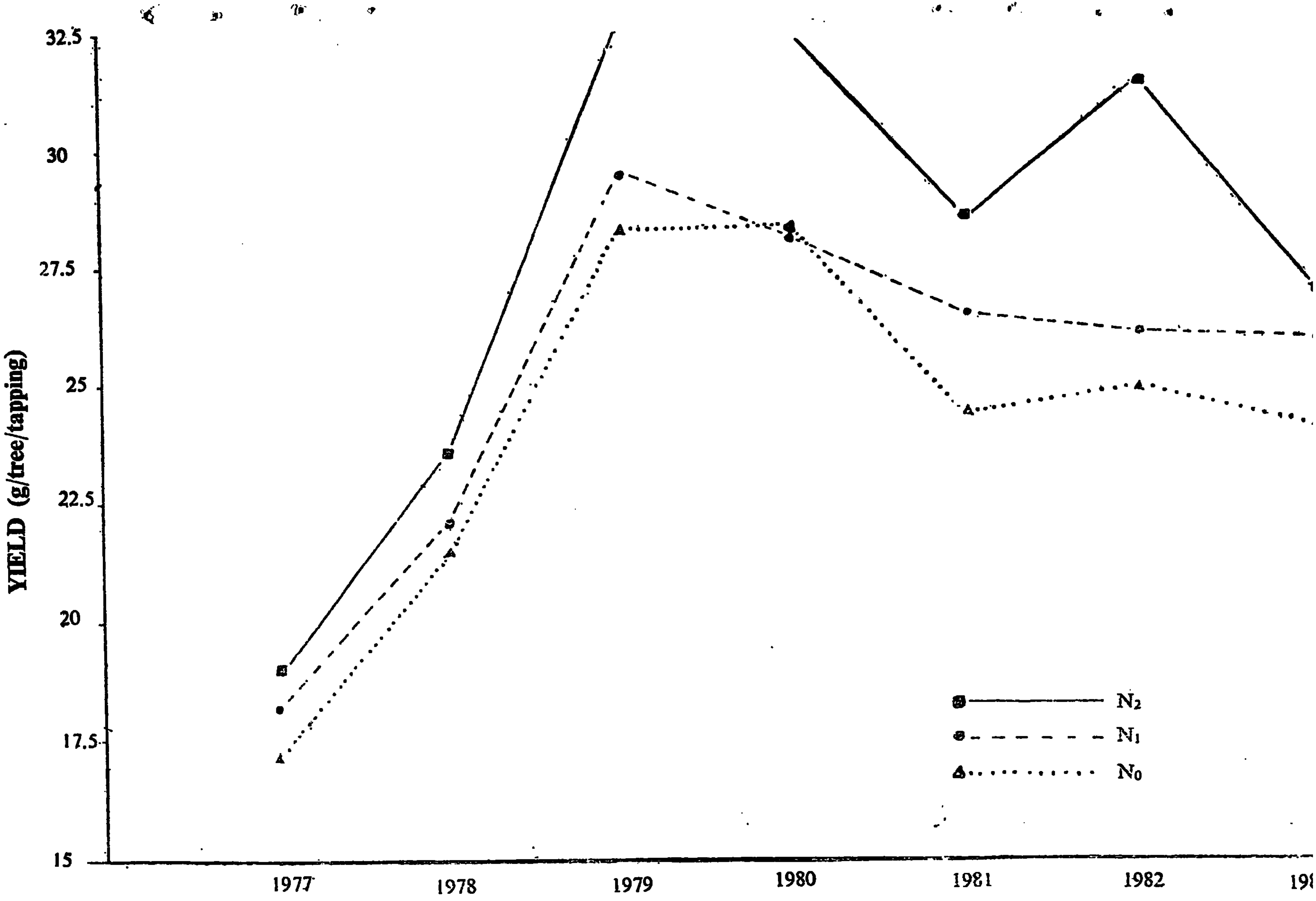

*Fig. 1:* EFFECT OF NITROGEN FERTILIZERS ON YEARLY MEAN YIELD — EXPERIMENT 1

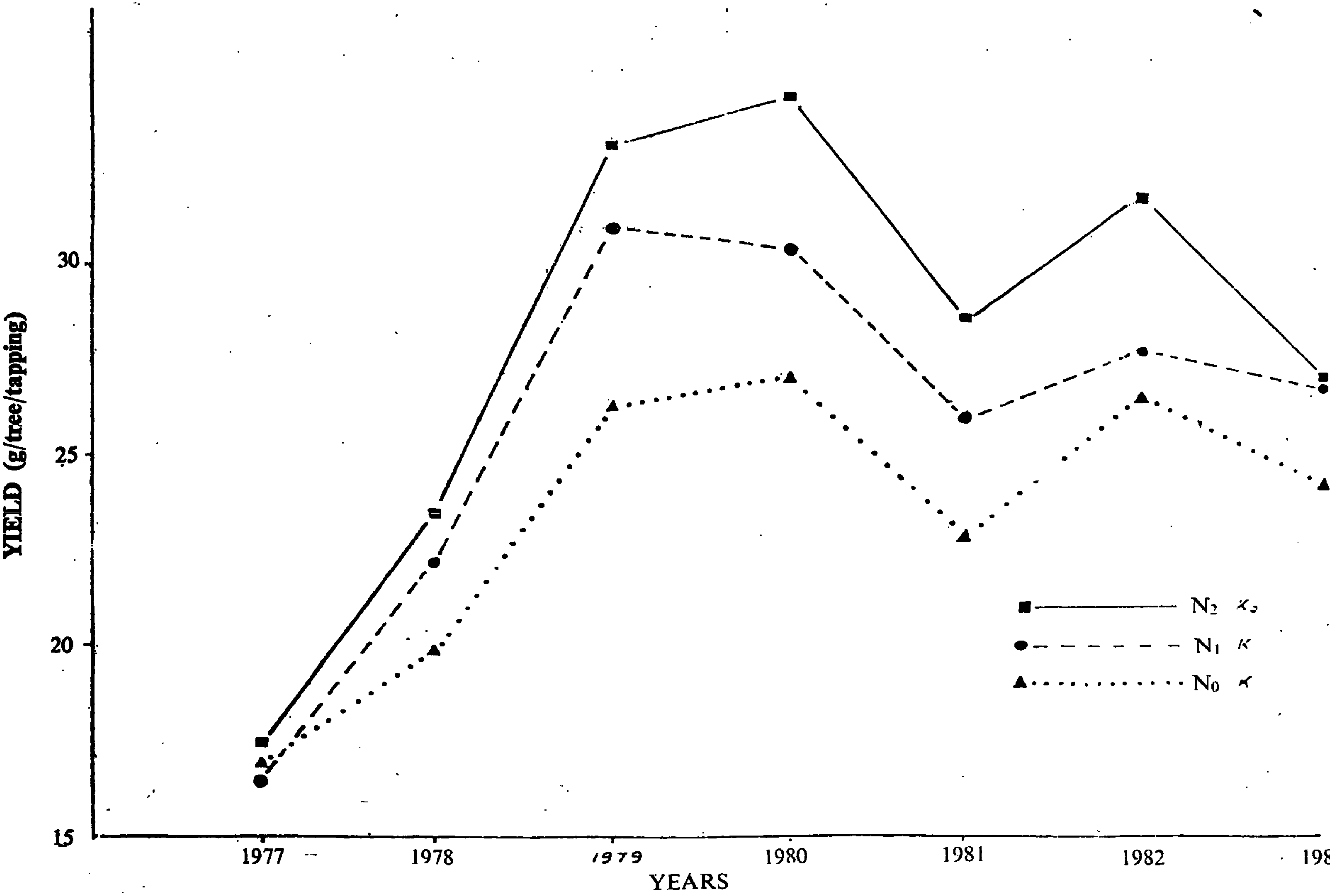

*Fig. 2:* EFFECT OF NITROGEN FERTILIZERS IN THE ABSENCE OF POTASSIUM ON YEARLY MEAN YIELD — EXPERIMENT 1

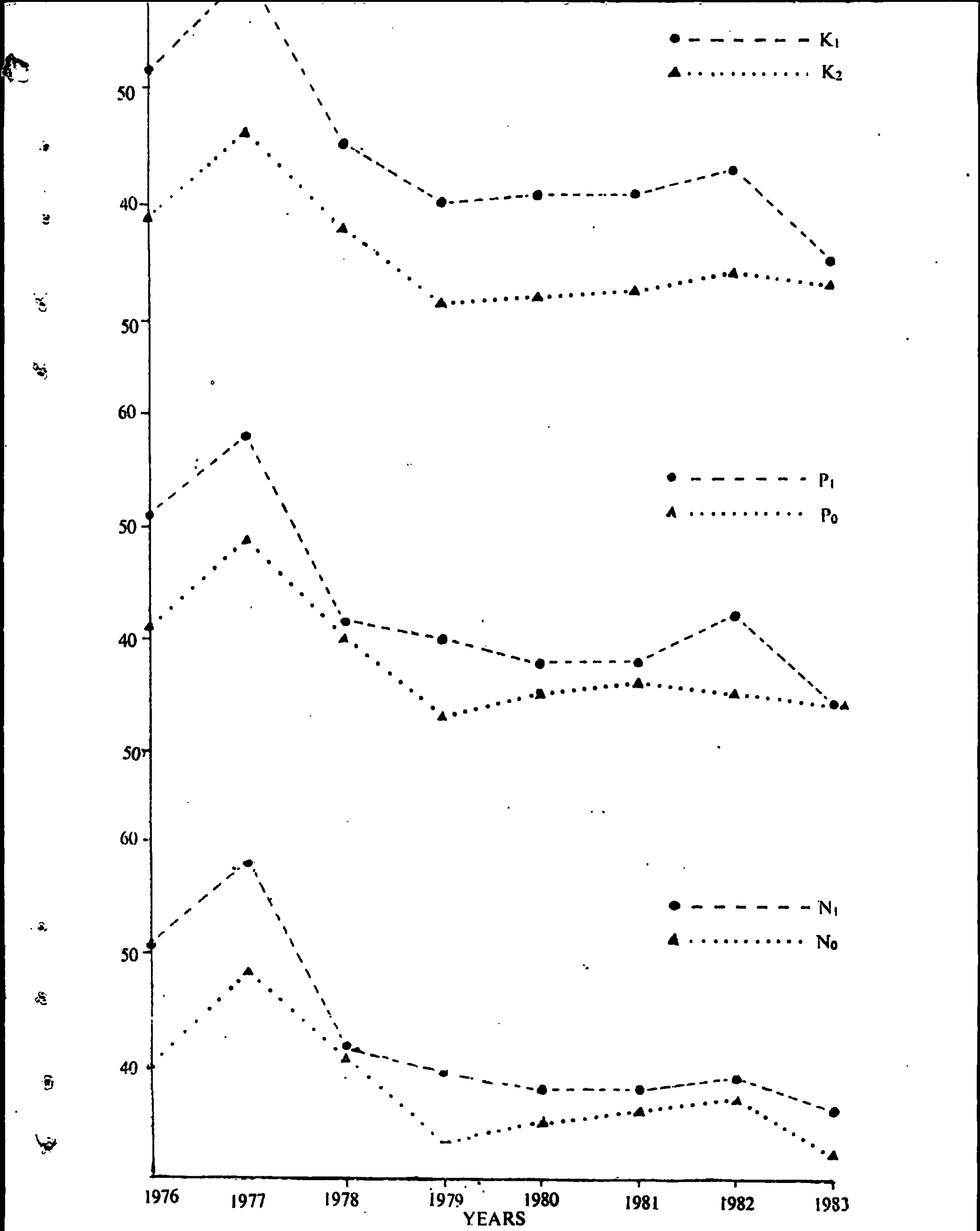

*Fig. 3:* EFFECT OF NITROGEN PHOSPHORUS AND POTASSIUM FERTILIZER ON YEARLY MEAN YIELD — EXPERIMENT 3

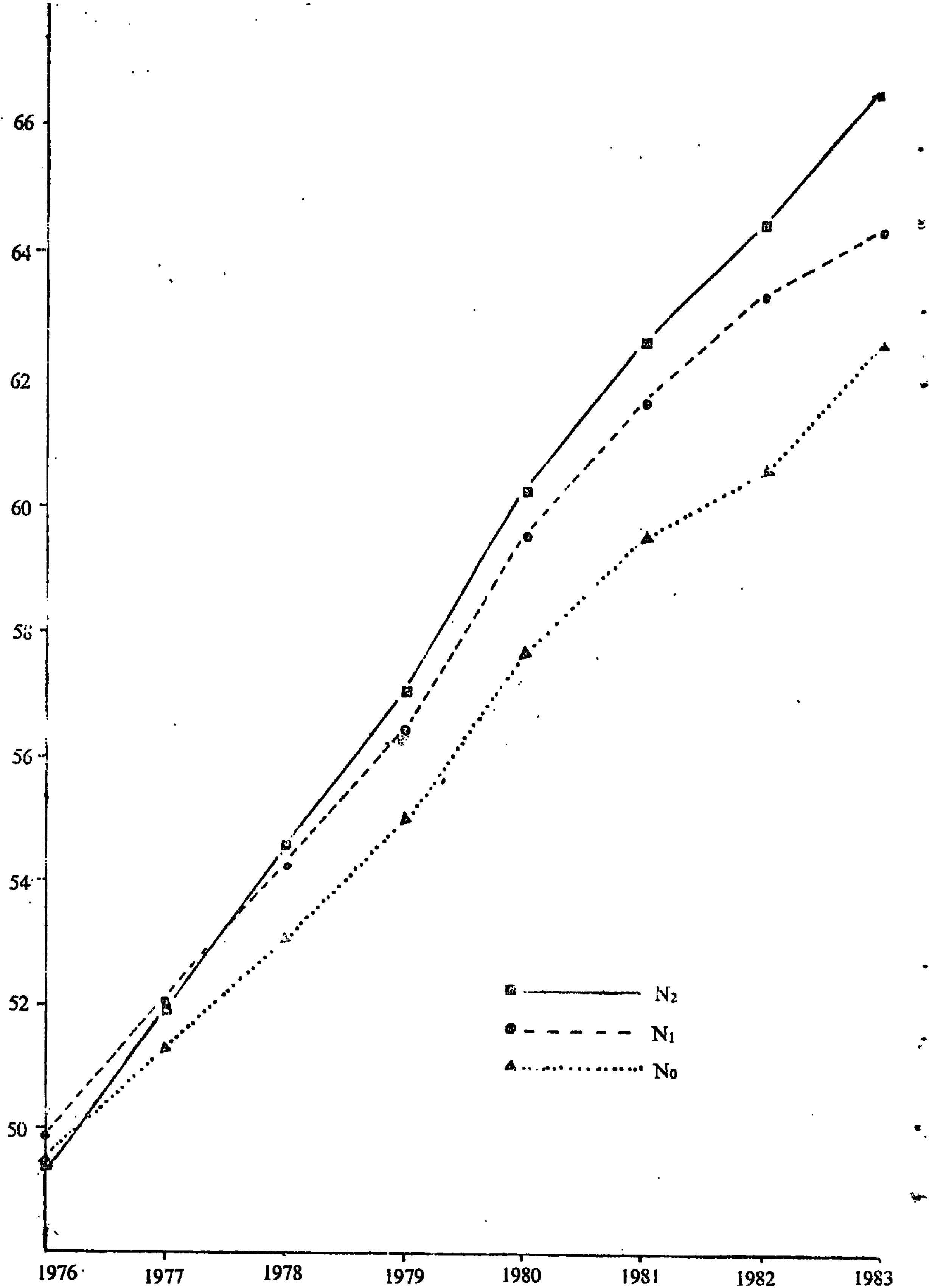

*Fig. 4:* EFFECT OF NITROGEN FERTILIZERS ON ANNUAL TRUNK GIRTH — EXPERIMENT 1

In Experiment 1 there was a small increase in yield (Fig. 1) during the second year itself due to application of nitrogen at level 1 and a further significant increase ($P<0.05$) when nitrogen application was increased to level 2. These increases were more marked and significant ($P<0.01$ and $P<0.001$) thereafter. Partitioning into linear and quadratic components showed that the effects were significantly linear throughout the study period ($P<0.05$ in 1977, 1978 and 1983) ($P<0.01$ in 1979, 1980 and 1981) and ($P<0.001$ in 1982).

As there had been no significant interaction of N with other nutrients, a closer scrutiny of the effects of N applied singly was made. Yield obtained with treatment combinations $N_0$ $K_0$, $N_1$ $K_0$ and $N_2$ $K_0$ were examined (Fig. 2) ignoring the effects of P and Mg as they were considered less important. This revealed the highest yield response of 28% in 1979, 1980 and 1981 with nitrogen at level 2 in the absence of K.

Analyses of annual yield data of Experiment 2, did not detect any statistically significant effects of N, P, K, or Mg on yield throughout the 8 year study period. However, a closer study (Table 2) as in Experiment 1 indicated small and inconsistent increases in yield to application of nitrogen.

In Experiment 3, only the last 8 year results, from 1976 to 1979 on the virgin panel and from 1980 to 1983 on renewed panel, are presented (Fig. 3). There had been consistently significant increases in yield (mostly at $P<0.01$) to applications of nitrogen, but the magnitude of the response appears to have declined. In 1978 and thereafter, except in 1979, application of nitrogen tended to produce only slight increases (not significant) in yield.

**Girth:** Positive girth responses to applications of N were evident only in Experiment 1. Nitrogen treatments showed significantly higher girths (Fig. 4) at both $N_1$ and $N_2$ levels since 1978. Girth increment over the 8 year period had been very marked ($P<0.001$) with increases of 12% and 24% for $N_1$ and $N_2$ levels, respectively. Partitioning of treatment effects showed significantly linear response ($P<0.05$ in 1978 and 1979, $P<0.01$ in 1980 and $P<0.001$ in 1981 and 1982) from the third year.

**Leaf nutrient contents:** Guided by the tentative critical range proposed by Yogaratnam and Silva (1977) pre-treatment leaf N contents were in general very low to low and leaf P and Mg in the medium to high range and in some cases very high. Leaf K levels were, however, considered low in Experiment 1 and medium in Experiment 2.

Application of nitrogen at level 1 increased the leaf nitrogen content in Experiment 1 (Table 3) from 3.07 to 3.21% and a further increase ($P<0.05$) to 3.32 at $N_2$ level in the second year itself. Thereafter, these differences were maintained fairly consistently, although the absolute values appeared to be below the suggested optimum range/ application of nitrogen was also found to decrease K content in leaves at $N_1$ level in 1977 ($P<0.05$), 1978 ($P<0.01$) and 1980 ($P<0.05$) and $N_2$ level in 1977 ($P<0.05$) 1978 ($P<0.001$)and 1980 (P 0.01).

In Experiment 2, application of nitrogen showed a tendency to increase leaf N (Table 4). But in Experiment 3, leaf N content (Table 5) had been consistently higher in plots that received N regularly although the absolute value in the control and treated plots were much below the sufficiency levels.

Total P by per chloric/sulphuric acid, available P by $NH_4$ F/Hcl, total K and Mg by 6 N Hcl and exchangeable K and Mg and CEC by ammonium acetate — pH 7.

*Table 3. Effect of nitrogen fertilizers on leaf nutrient content*

*(Experiment 1)*

| Treatment | Pre-treatment | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|---|---|---|
| | | | | *Nitrogen (%)* | | | | |
| $N_0$ | 2.97 | 3.07 | 3.27 | 2.78 | 2.97 | 2.75 | 2.82 | 3.06 |
| $N_1$ | 3.01 | 3.21 | 3.35 | 2.90 | 3.08 | 2.92 | 2.80 | 3.09 |
| $N_2$ | 2.99 | 3.32* | 3.47* | 2.82 | 3.08 | 2.96* | 2.95 | 3.23 |
| $N_0K_0$ | 3.12 | 3.34 | 3.34 | 2.76 | 2.89 | 2.92 | 3.00 | 3.07 |
| $N_1K_0$ | 2.94 | 3.27 | 3.27 | 2.84 | 3.92 | 2.97 | 2.77 | 3.23 |
| $N_2K_0$ | 3.05 | 3.48 | 3.48 | 2.72 | 3.24 | 3.21 | 3.04 | 3.41 |
| | | | | *Potassium (%)* | | | | |
| $N_0$ | 1.11 | 1.09 | 1.10 | 1.01 | 1.25 | 0.98 | 1.17 | |
| $N_1$ | 1.04 | 1.02 | 1.03** | 0.98 | 1.16 | 0.93 | 1.22 | |
| $N_2$ | 1.08 | 1.03 | 1.01*** | 0.99 | 1.14 | 0.95 | 1.21 | |

In this and all other tables, *, ** and *** indicate those treatments differing from the control (zero level) at $P = 0.05$, 0.01 and 0.001, respectively.

*Table 4. Effect of nitrogen on potassium fertilizers on leaf nutrient content*

*(Experiment 2)*

| Treatment | Pre-treatment | 1978 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|
| | | | *Nitrogen (%)* | | |
| $N_0$ | 2.76 | 2.76 | 2.76 | 2.94 | 2.39 |
| $N_1$ | 2.61 | 2.82 | 2.87 | 2.84 | 2.53 |
| $N_2$ | 2.74 | 2.83 | 2.82 | 2.92 | 2.53 |
| | | | *Potassium (%)* | | |
| $K_0$ | 1.58 | 1.56 | 1.61 | 2.74 | 2.68 |
| $K_1$ | 1.53 | 1.57 | 1.70 | 2.59 | 2.63 |

*Table 5. Effect of nitrogen, phosphorus and potassium fertilizers on leaf nutrient content*

*(Experiment 3)*

| Treatment | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|
| | | | | *Nitrogen* (%) | | | |
| $N_0$ | 2.65 | 2.71 | 2.42 | 2.39 | 3.15 | 2.56 | 2.34 |
| $N^1$ | 2.85* | 2.94 | 2.71** | 2.51 | 3.33 | 2.75 | 2.54* |
| | | | | *Phosphorus* (%) | | | |
| $P_0$ | 0.19 | 0.17 | 0.18 | 0.20 | 0.18 | 0.21 | 0.17 |
| $P_1$ | 0.21* | 0.20* | 0.22** | 0.24** | 0.20 | 0.23 | 0.20 |
| | | | | *Potassium* (%) | | | |
| $K_0$ | 0.96 | 0.76 | 0.88 | 0.66 | 0.85 | 0.68 | 0.67 |
| $K_1$ | 1.28** | 1.04 | 1.01 | 0.97** | 1.02 | 0.96 | 0.97 |
| | | | | *Magnesium* (%) | | | |
| $K_0$ | 0.25 | 0.31 | 0.29 | 0.35 | 0.33 | 0.30 | 0.29 |
| $K_1$ | 0.25 | 0.25** | 0.28 | 0.29** | 0.28* | 0.24* | 0.25 |

## POTASSIUM

**Yield :** Application of K in Experiment 1 gave small yield increases (Fig.5) when applied singly at the first level. The lag period between commencement of experimental fertilizer treatment and response was about 4 years. The magnitude of the response over the control was only 7 and 8% in 1981 and 1982 respectively. However in 1983 significant interaction ($P<0.05$) between K and P on yield was evident. Partitioning of PK interaction effect revealed a linear response to K ($P<0.01$) with the slope of this response varying with the level of P in a linear manner (Fig. 6).

Significant yield increases were observed with application of K in Experiment 3 (Fig. 3) but not in Experiment 2. The magnitude of this response was higher in the virgin panel, ranging from 17 to 33% in comparison with 13 to 28% in the renewed panel.

**Girth:** Significant interaction between K and Mg on girth increase over the 7 year period from 1976, was observed in Experiment 1, this effect was significantly quadratic (Fig. 7). It therefore follows that the quadratic response in girthing with application of Mg varied the levels of K.

**Leaf nutrient contents:** According to deficiency/sufficiency criteria, all experimental trees in Experiment 1 and 3 exhibited very low K content at the onset but the values in Experiment 2 appeared to be very high.

Potassium content of leaves (Table 6) were significantly increased ($P<0.05$) by application of K at both $K_1$ and $K_2$ levels in Experiment 1, within 1 year. The responses became more marked in subsequent years attaining statistical significance at 0.1% level except in 1981 (at 5% level). Inspite of these marked increases leaf K levels never reached the sufficiency levels suggested for optimum performances of the tree.

*Table 6. Effect of potassium fertilizer on leaf K content*

*(Experiment 1)*

| | | *Potassium (%)* | | | | |
|---|---|---|---|---|---|---|
| Treatment | Pre-treatment | 1977 | 1978 | 1980 | 1981 | 1982 |
| $K_0$ | 1.04 | 0.97 | 0.96 | 0.99 | 0.78 | 1.00 |
| $K_1$ | 0.99 | 1.04* | 1.06*** | 1.26*** | 0.93* | 1.14** |
| $K_2$ | 1.01 | 1.07 | 1.10*** | 1.31*** | 0.95* | 1.21** |

Leaf P contents were significantly decreased with application of K in 1980 ($P<0.01$) and 1981 ($P<0.05$) and similar tendencies in other years. Application of potassium at $K_2$ level tended to decrease the Mg content in leaves which was significant ($P<0.05$) in 1980 and 1982 (results not presented). In Experiment 2, potassium fertilizers had no effect on the K content in the leaves (Table 4).

## PHOSPHORUS

**Yield :** Application of phosphorus significantly increase yield ($P<0.01$) only in Experiment 3 (Fig. 3 and 8). Yield increases ranging from 19 to 22% were obtained from the virgin panel except in 1978. Response from renewed panels has been mostly below 10% except in 1982 when a 20% increase was obtained.

**Leaf Nutrient content:** Phosphate application tended to increase leaf P content in Experiment 1 (Table 7), these increases were significant ($P<0.05$) in 1978, 1980 and 1983. Similar increases were observed in Experiment 3 (Table 5).

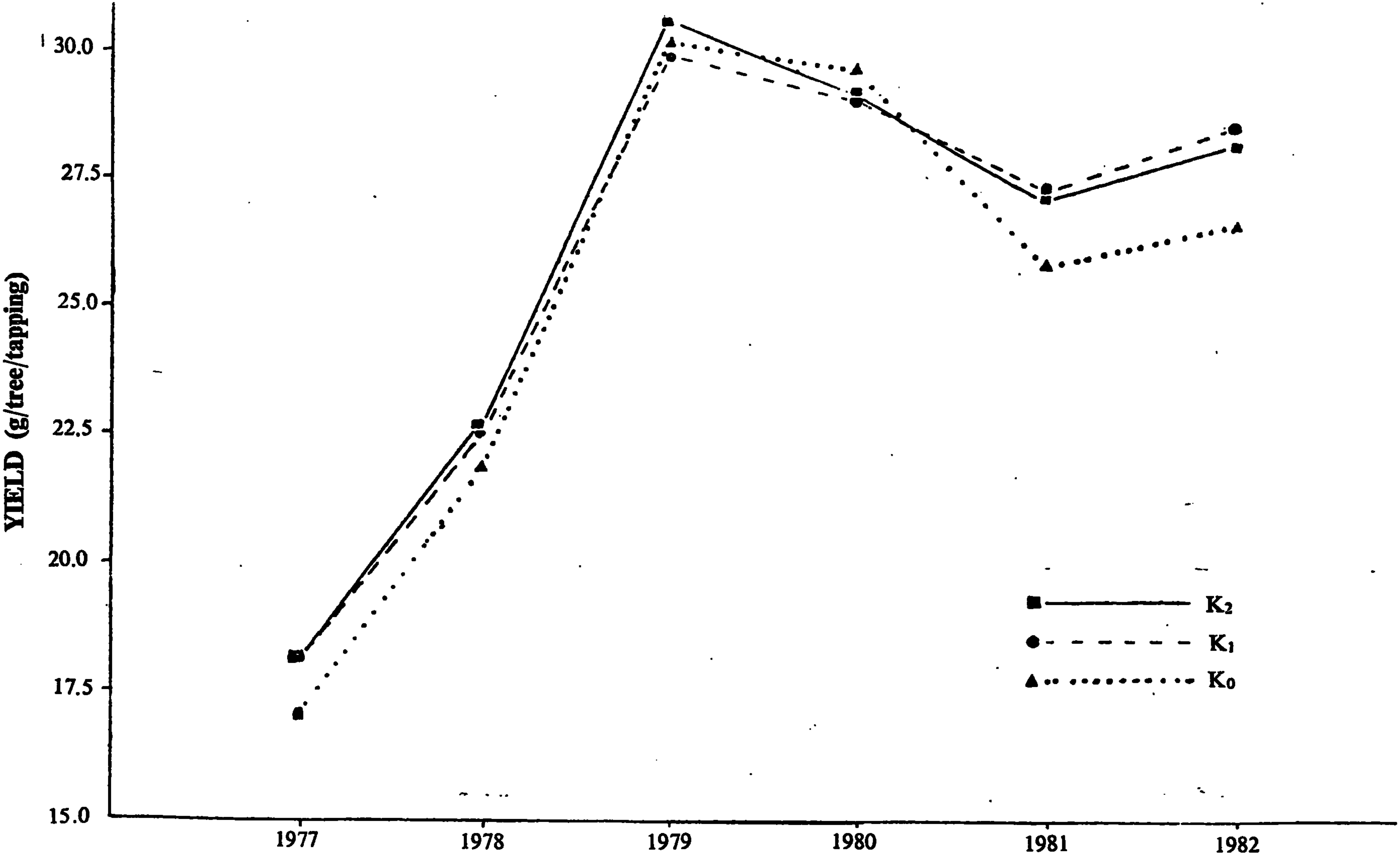

*Fig. 5:* EFFECT OF POTASSIUM FERTILIZERS ON YEARLY MEAN YIELD — EXPERIMENT *1*

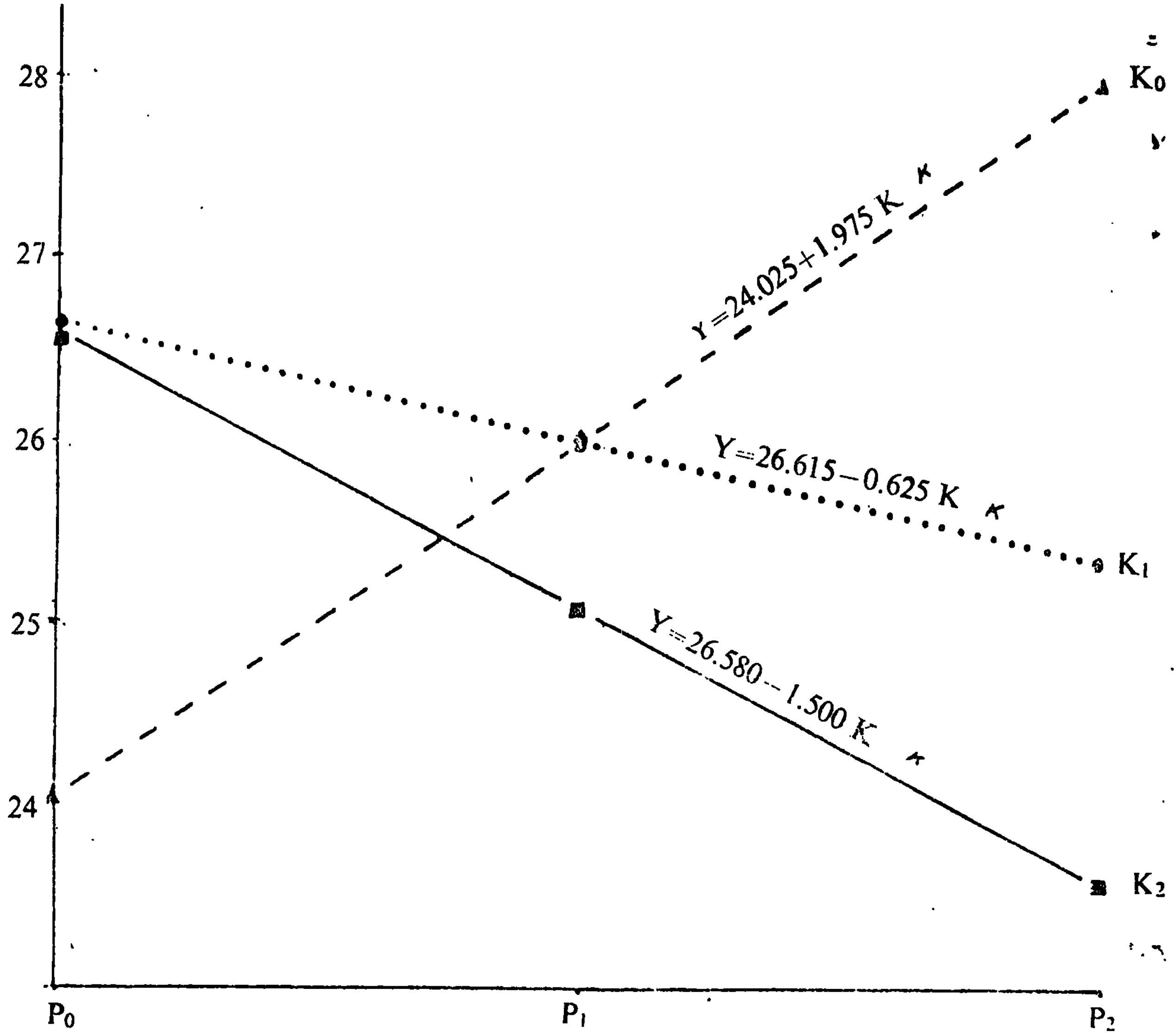

*Fig. 6:* EFFECT OF POTASSIUM AND PHOSPHORUS FERTILIZERS ON MEAN YIELD IN 1983 — EXPERIMENT 1

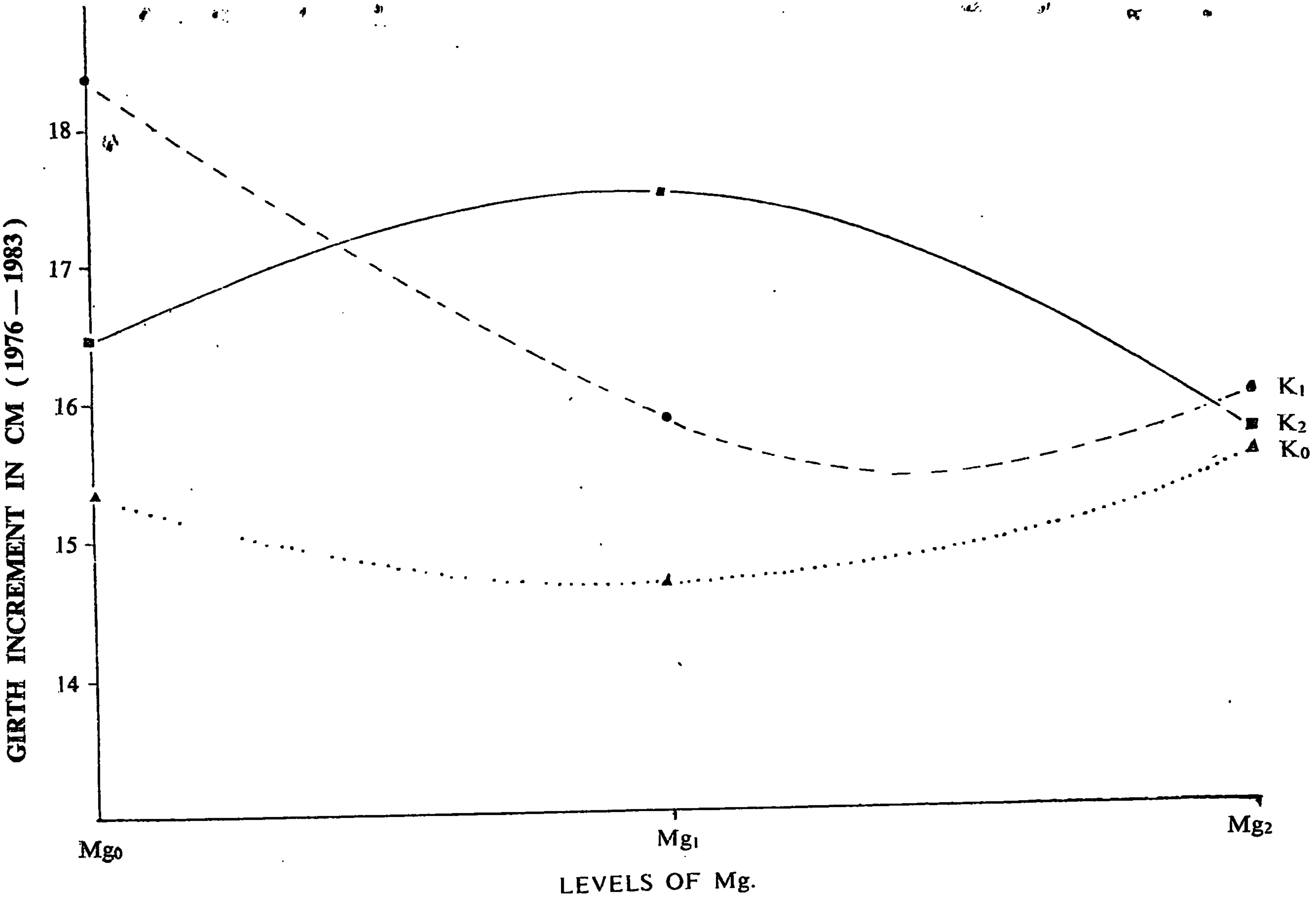

*Fig. 7:* EFFECT OF POTASSIUM AND MAGNESIUM FERTILIZERS ON GIRTH INCREMENT FROM 1976 TO 1983 — EXPERIMENT 1

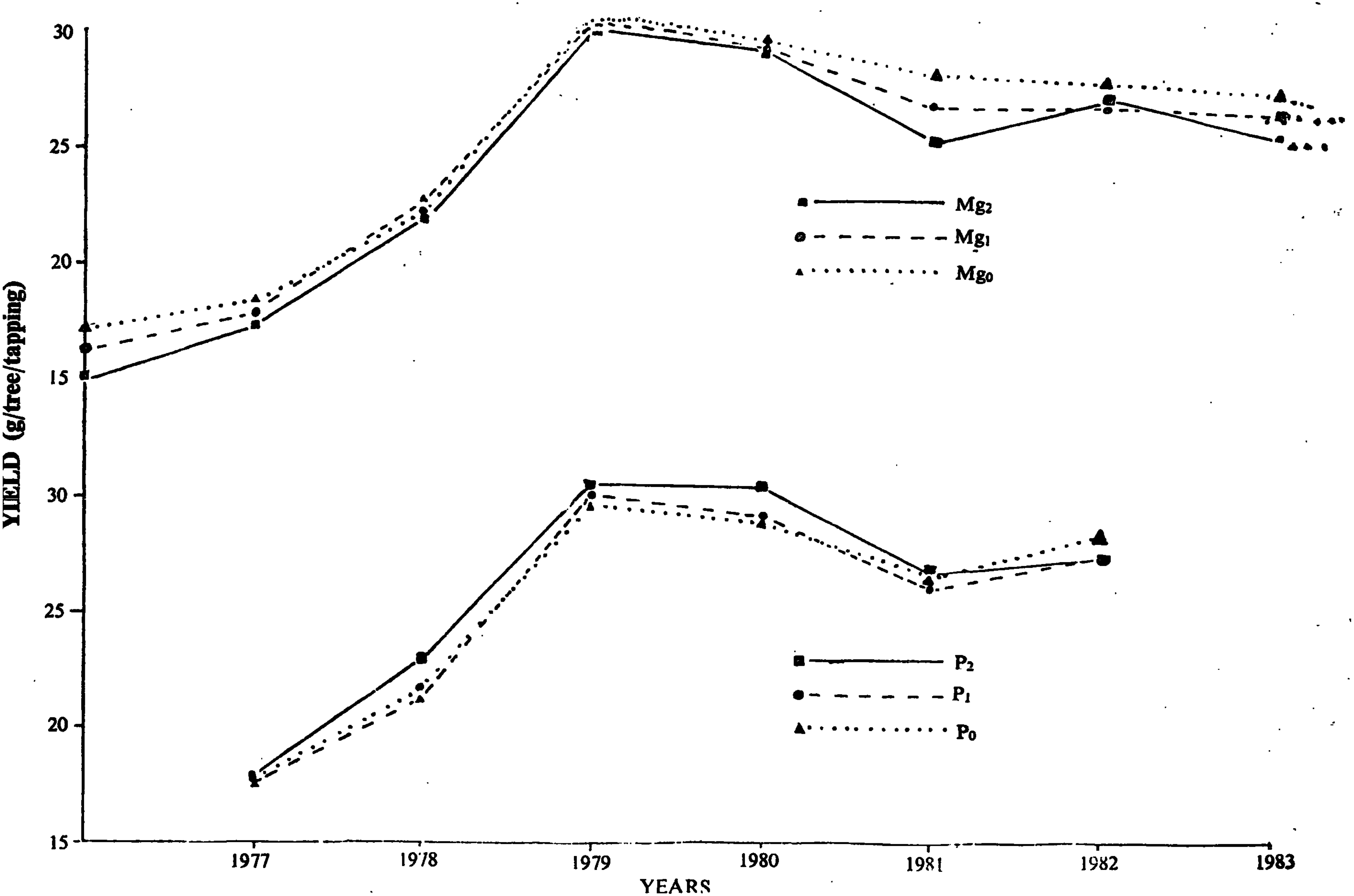

*Fig. 8:* EFFECT OF MAGNESIUM AND PHOSPHORUS FERTILIZERS ON YEARLY MEAN YIELD — EXPERIMENT

*Table 7. Effect of phosphorus fertilizers on leaf P content*

*(Experiment 1)*

| Treatment | Pre-treatment | Phosphorus (%) 1977 | 1978 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|
| $P_0$ | 0.20 | 0.19 | 0.19 | 0.24 | 0.19 | 0.24 |
| $P_1$ | 0.21 | 0.19 | 0.20 | 0.25 | 0.22 | 0.25 |
| $P_2$ | 0.20 | 0.21 | 0.21* | 0.26* | 0.20 | 0.25 |

## MAGNESIUM

**Yield :** Magnesium fertilizers at level 2 tended to show depressive effects on yield in Experiment 1 (Fig.8) attaining statistical significance ($P<0.05$) in 1976, 1981 and 1983.

**Leaf nutrient content:** Leaf Mg contents were significantly increased with application of Mg at both $Mg_1$ and $Mg_2$ levels (Table 8). These increases have been obtained inspite of the very high leaf Mg levels of over 0.25% at the onset.

**Sulphur:** In view of the present practise of using urea as the source of nitrogen in rubber plantations, the $SO_4$ contents of the leaf and soil were also monitored. The $SO_4$ content in leaves was decreased from 2600 to 2520mg/kg with the application of urea at $N_1$ level and a further significant decrease ($P<0.01$) to 2422mg/kg was obtained at $N_2$ level. Similar decrease in soil $SO_4$ content from 340 to 308mg/kg was also observed when nitrogen level was increased from $N_0$ to $N_2$.

*Table 8. Effect of magnesium fertilizers in leaf Mg content*

*(Experiment 1)*

| Treatment | Pre-treatment | Magnesium (%) 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|
| $Mg_0$ | 0.30 | 0.29 | 0.33 | 0.28 | 0.32 | 0.27 | 0.25 |
| $Mg_1$ | 0.31 | 0.32* | 0.32 | 0.30 | 0.34* | 0.30** | 0.29*** |
| $Mg_2$ | 0.29 | 0.33* | 0.34 | 0.31* | 0.36*** | 0.31** | 0.30*** |

## DISCUSSION

Application of nitrogen to mature rubber under Sri Lankan conditions has been proved to be beneficial even in areas with good agronomic management history. Yield responses to nitrogen in Experiment 1 closely followed the response of girth but have been more marked suggesting a quadratic relationship (Paardekooper, 1970) of yield on girth. It is possible that either larger trees, as a consequence of increased nitrogen application, may have thicker bark, although this had not been proved in another study (Yogaratnam, 1980 and 1981) and greater length of the tapping cut or larger trees yield more per inch of the tapping cut than the smaller trees.

The general belief that nitrogen application may not be required during the early mature period (Pushparajah and Chellapah, 1969; Guha, 1975 and Sivanadiyam, 1983) may not be acceptable under local conditions, where the beneficial effects of legume covers do not persist as long under Sri Lankan agro-climatic conditions especially in view of our higher rainfall conditions. Yogaratnam and Perera (1981) reported a declining response to application of nitrogen from 4 years after planting. It therefore, appears that the beneficial effects of legumes may not have gone beyond 1975 *i.e.* 8 years from planting in Experiment 1. This has been suggested by the low pre-treatment leaf nitrogen content (Table 3). Indeed even with $N_2$ level of nitrogen which is double the currently recommended rate, it was not possible to raise the nitrogen content to the optimum levels, consistantly. The importance of nitrogen on the performance of tree crops has been emphasised by several workers, Yogaratnam and Perera (1981) and Peries and Yogaratnam (1982) in *Hevea*, Bavanathan and Sundaralingam (1969) and Peries and Yogaratnam (1982) in tea, Loganathan (1978) and Peries and Yogaratnam (1982) in coconut, Ng (1979) in oil palm and Yogaratnam and Greenham (1982) in apple.

The absence of other nutrients in particular K on N responses, in contradiction with the reports of other workers (Guha, 1975), suggests that these nutrients were present at low levels but adequate for optimum performance of the trees. On the contrary, application of K singly had also been found to increase yields, of course with a time lag of 4 years from the time of application. It may be that trees adapted to poor environment of inherently low exchnageable K (0.04 m = equiv/100 g), would exhibit optimum performance even under low leaf K contents (Table 6). Moreover, these trees are believed to be less sensitive to environmental changes hence the delayed development of yield responses to K fertilizers. Further, although it appears difficult to explain the quadratic pattern of the K — Mg interaction (Fig. 7) yet, it is evident that the beneficial effect of K on girth increase over the 8 year period had been eliminated by high levels of Mg fertilizers. A similar antagonism existed between K and P at the highest levels, on yield in 1983 (Fig. 8). It now appears that the leaf K deficiency/sufficiency levels for diagnostic purposes may have to be revised for the low — K areas. A leaf potassium content of 1.05% would perhaps be adequate, while a value of 0.85% or below would perhaps be deficient. It would be beneficial if P and Mg fertilizers are also kept within reasonable limits.

Discontinuation of N application at a later stage of the cycle, probably in the second virgin panel or even later may be considered based on the results from Experiment 2 on Parambe soils. Adequate fertilization with other sound agronomic practices, during the early immature period, as evident from field records, would have provided a continuous but steady supply of large amounts of nutrients in particular N, from legume covers that mineralise rapidly with its nutrient content becoming quickly available again for uptake by *Hevea* (Yogaratnam *et al*, 1976). This followed by more nitrogenous fertilizers during the early mature phase would have enabled a steady build up of nutrient reserves within the whole tree system (Tan, 1975). This may possibly sustain the nitrogen needs of mature trees during the later stages.

This importance of N, P and K application during the immature period has also been amply emphasised in Experiment 3 on Boralu soils as reported earlier by Jeevaratnam (1969). Diminished responses to applications of NPK fertilizers during the latter stages of the cycle (renewed panel) may have been due to the absence of well balanced nutrition. This could not be avoided in this experiment as the treatments were arranged in a factorial combination where the inclusion of a control (zero level) for each nutrient would have caused severe nutritional stress on some experimental trees thus restricting normal physiological activities in the tree. This would have been further enhanced by regular uniform applications of Mg applications of Mg fertilizers, as reflected by the very high leaf Mg contents (Table 5). High levels of Mg application were also found to depress yields in Experiment 1. supporting earlier reports (Law and Tan. 1977).

Although leaf and soil $SO_4$ contents were reduced by the continuous use of urea at both $N_1$ and $N_2$ levels in Experiment 1, yet the absolute values were much above the normal range of $SO_4$ content for agricultural soils in other countries (Muller and Sissingh, 1980). The use of sulphur for disease control in rubber plantations may have also contributed to the high levels of $SO_4$ in rubber soils.

Mature rubber plantations with agro-forestry systems of cultivation are likely to conserve and utilize the reserve of nutrients more stringently than other agricultural systems. Nutrient re-cycling is very efficient with relatively small less of nutrients through the latex (Sivanadiyan, *et al*, 1972). Further, the fertilizer requirements of trees under tapping are also expected to diminish in view of the reduction in tree biomass, resulting from intensified self-pruning and thining off of canopy.

To sum up, experiments done under Sri Lankan agro-climatic conditions, demonstrate that judicious fertilizer application is required for proper economic benefit to be derived. However, unlike in other countries N application should be continued uninterrupted during the initial period of tapping at least in the virgin panels. Thereafter, soil and leaf analysis could be used as a guide. On the other hand, discontinuation of K fertilizers may be considered in areas with K content (6N HCI extractable K), ranging from 5 to 6 me per 100g soils, such as the soils derived from biotite gneiss (micaceous parent material). Similarly, P and Mg application may also be discontinued for several years, particularly Mg application, in areas with Mg levels ranging from 5 to 6 m equiv. such as the granite derived and the cabook type soils.

It should however, be appreciated that the recommendations suggested in this paper would apply only to replanted areas which received high standards of agronomic management, including adequate manuring and legume covers, during the immature phase.

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