J. nat. Rubb. Res., **1(3)**, 155–166

Mineral Nutrition and Reproduction in Hevea: *Effects of Nitrogen Fertilisation on Flowering and Fruiting in Immature Trees of Some Clones*

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A field investigation was undertaken to ascertain the influence of nitrogen manuring on flowering and fruiting of clones RRIM 600, PB 260 and PB 235, and flowering of PB 330. The study was conducted in existing fertiliser trials, on young trees of about three years old. Flowering and fruiting twigs, inflorescences and fruits were visually counted on the trees. Some fruits were also harvested.

Heavy nitrogen applications, at rates significantly higher than amounts hitherto recommended for growth, generally induced flowering in the young trees. Flowering intensity, measured in terms of frequency of trees in flower, number of flowering twigs per tree and number of inflorescences per tree was generally increased. This effect appeared more marked in a late-flowering clone like RRIM 600 than in PB 260, which has a natural propensity to initiate early flowering.

The large nitrogen dressings also increased the frequency of fruiting trees, number of fruiting twigs per tree and total number of fruits per tree. As with flowering, the positive influence of heavy nitrogen manuring on fruiting was more effective in the poor seeding clone RRIM 600, than in the profuse seeder PB 260.

Among the essential mineral nutrients, generally nitrogen is required in the largest quantity by green plants[1]. Regular and adequate nitrogen fertiliser applications improve significantly both vigour and yield in most crops, for example wheat[2], rice[3], oil palm[4], cocoa[5] and apple[6]. However, in these plants, the economically important yield or crop consists of reproductive parts, *viz.* fruits, seeds or grains, while in *Hevea brasiliensis,* it consists of latex, a secondary metabolite and its processed product, dry rubber. Nevertheless, nitrogen manuring of rubber trees does enhance vigour[7] and dry rubber yields[8].

Very few investigators have studied the effect of fertilisers on reproduction in the rubber tree[9,10]. Watson and Narayanan[9] showed that nitrogen applications to mature rubber trees can increase seed production. However, the mode of action of nitrogen on seed yield was not clearly unravelled, although a high leaf nitrogen-potassium ratio was recognised to be essential for better seed production[10].

In the present investigation, an attempt is made to study the effect of heavy nitrogen dressings on flowering and fruiting of immature *Hevea* trees.

EXPERIMENTAL

The study was conducted in four existing fertiliser experiments in which treatments were begun soon after planting. Each trial covered approximately 3.5 ha and they were sited on contrasting soils (Munchong, Prang, Gajah Mati series and alluvial soil) and clones (PB 235, PB 260, PB 330, RRIM 600). Four nitrogen application rates, ranging between zero and eight times the normal recommended rates[11], were tested while P, K and Mg fertilisers were applied uniformly at

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normal rates. Experimental details are shown in *Table 1*.

Flowering and Fruiting Observations

The study commenced when trees flowered for the first time, except in *Experiment SE 145/2* where observations began some months later. Flowering observations were carried out only when flowering had reached its zenith for the season as judged by casual visual inspection.

The ten to twelve central trees in each plot were recorded. All flowering twigs and inflorescences on the twigs were counted on each flowering tree, by observation from the ground.

Similarly, fruit yields were obtained by counting all mature and less than mature fruits on a tree before the commencement of seed dispersal. The earlier reported methods of measuring dispersed seed yields[9], from prepositioned wire cages and quadrats on the ground, were not attempted in the present study, in view of possible inter-plot seed contamination, because the plots were small. Instead, seeds were obtained from harvested mature fruits.

The direct counting of inflorescences and fruits was feasible, though tedious, because the immature trees were relatively short (approximately 10 m) and their adjacent canopies were yet to meet along the interrows. This direct counting method is more accurate for immature stands having distinct canopies than in mature stands where the canopies by becoming interlocked, render counting more difficult. In view of this, scoring was done only once in all the clones, except in PB 260 where a second count was possible three months later.

In all four trials only a proportion of the trees began to flower during the third year of field planting. Therefore, all flowering and fruiting data were calculated and expressed in terms of the total number of observed recording trees in the plot.

RESULTS

Flowering Intensity

Nitrogen manuring generally enhanced flowering intensity, in terms of the proportion of flowering trees and the numbers of flowering

TABLE 1. DETAILS OF FIELD EXPERIMENTS

Details	Experiment			
	SE 145/1	SE 145/2	SE 146	SE 148
Clone	PB 260	PB 235	RRIM 600	PB 330
Planted	Sep. 1979	Sep. 1979	Nov. 1979	Apr. 1980
Commenced (Expt.)	Apr. 1980	Apr. 1980	Aug. 1980	Sep. 1980
Soil series	Munchong/Prang	Munchong	Gajah Mati	Deep alluvial sandy clay loam
Plot size (trees)	35	35	30	30
Total nitrogen (g/tree)				
First level[a] (1 × normal)	1 145	1 145	896	863
Fourth level (4 × normal)	4 580	4 580	3 584	3 452
Eighth level (8 × normal)	9 160	9 160	7 168	6 904

Four levels of nitrogen fertiliser treatments: 0 (nil), first level, fourth level and eighth level.

Uniform P, K and Mg fertilisers applied to all plots in proportions as present in RRIM Mixture Mag.X, following recommended Immature Manuring Schedule[11,12].

Total nitrogen applied as ammonium sulphate until commencement of study.

[a]Amount as present in RRIM Mixture Mag.X, when applied at rate following Immature Manuring Schedule[11,12].

twigs and inflorescences per tree. These 'per tree' values were obtained by dividing the total number of flowering twigs, inflorescences, *etc.* in each plot by the total number of observed trees in the plot, and then calculating the mean value for each treatment from all the replicate plots.

Percentage flowering trees. There was a general tendency for more trees to flower with increased nitrogen applications *(Figure 1)*. The effect was most pronounced in RRIM 600, where the percentage of trees which flowered increased from 6% for nil nitrogen treatment to 58% where nitrogen was applied at eight times the normal recommended rate. However, this enhancing effect was smaller or only marginal in the case of the other clones.

Flowering twigs per tree. Significant increases in flowering twig production were apparent with heavier nitrogen dressings *(Figure 2)*. The highest number of flowering twigs per tree was obtained with the maximum application (8 × normal) except in clone PB 260 in which the fourth level (4 × normal) ranked the best. Responses were again more marked in RRIM 600, with values ranging from 0.16 twigs to 2.68 twigs per tree, approximately amounting to a seventeen-fold increase.

Inflorescences per tree. Higher dressings of nitrogen significantly enhanced the number of inflorescences per tree in all four clones *(Figure 3)*. The best nitrogen treatment for inflorescence production was the eighth level (8 × normal) except in PB 260 in which the fourth level yielded the highest. Again among the four clones the response was most marked in RRIM 600, although the magnitude of production was low. For instance, inflorescence production was increased seventeen times, from 0.31 inflorescence per tree in the control to 5.31 inflorescences per tree at the eighth level of nitrogen treatment while in PB 260, a significant but smaller increase of 156%, ranging between 139.7 inflorescences per tree for control (nil nitrogen) and 358.1 inflorescences per tree for 4 × normal nitrogen application, was recorded during February 1983. The best treatment (the eighth level) in PB 235 and PB 330 increased inflorescence production over the control, by 166% and 129% respectively, the corresponding values for inflorescence numbers being: 23.0 to 61.2 (PB 235) and 64.3 to 147.5 (PB 330).

Fruiting Intensity

The percentage of fruiting trees, the numbers of fruiting twigs per tree and fruits per tree, also responded positively to increased nitrogen applications, possibly resulting, at least partly, from the increased flowering intensity.

Percentage fruiting trees. The proportion of trees bearing fruits increased with higher nitrogen dressings. Applications at four times the normal recommended rate generally gave the highest percentage of fruiting trees in the three clones studied *(Figure 4)*. In RRIM 600, no fruiting was detected on trees which had not received any nitrogen, and only 1.4% of the stand bore any fruits when normal nitrogen fertiliser rate was used. However, with applications at four times the normal level (the fourth level), the proportion of fruiting trees increased to 22%. In the case of clone PB 235, fruiting was absent both in the control and normal nitrogen-treated trees. The effect of nitrogen on percentage of fruiting trees was less marked in clone PB 260, where heavy fruiting was also recorded in the control.

Fruiting twigs per tree. An increase in the number of fruit-bearing twigs was recorded with heavier nitrogen manuring. The effect was apparently curvi-linear in all clones, the best response being always obtained at the fourth level or 4 × normal nitrogen rate *(Figure 5)*. A decline in the quantity of fruiting twigs resulted at the highest nitrogen level (8 × normal), to values either lower, (PB 260) or higher, (PB 235 and RRIM 600) than those obtained with normal nitrogen.

In RRIM 600, the fourth level of nitrogen increased the production of fruiting twigs by a factor of forty-five, over the normal level though only from 0.014 to 0.63 fruiting twigs per tree *(Figure 5)*. The response in PB 260 was less marked, amounting to about 38%, during

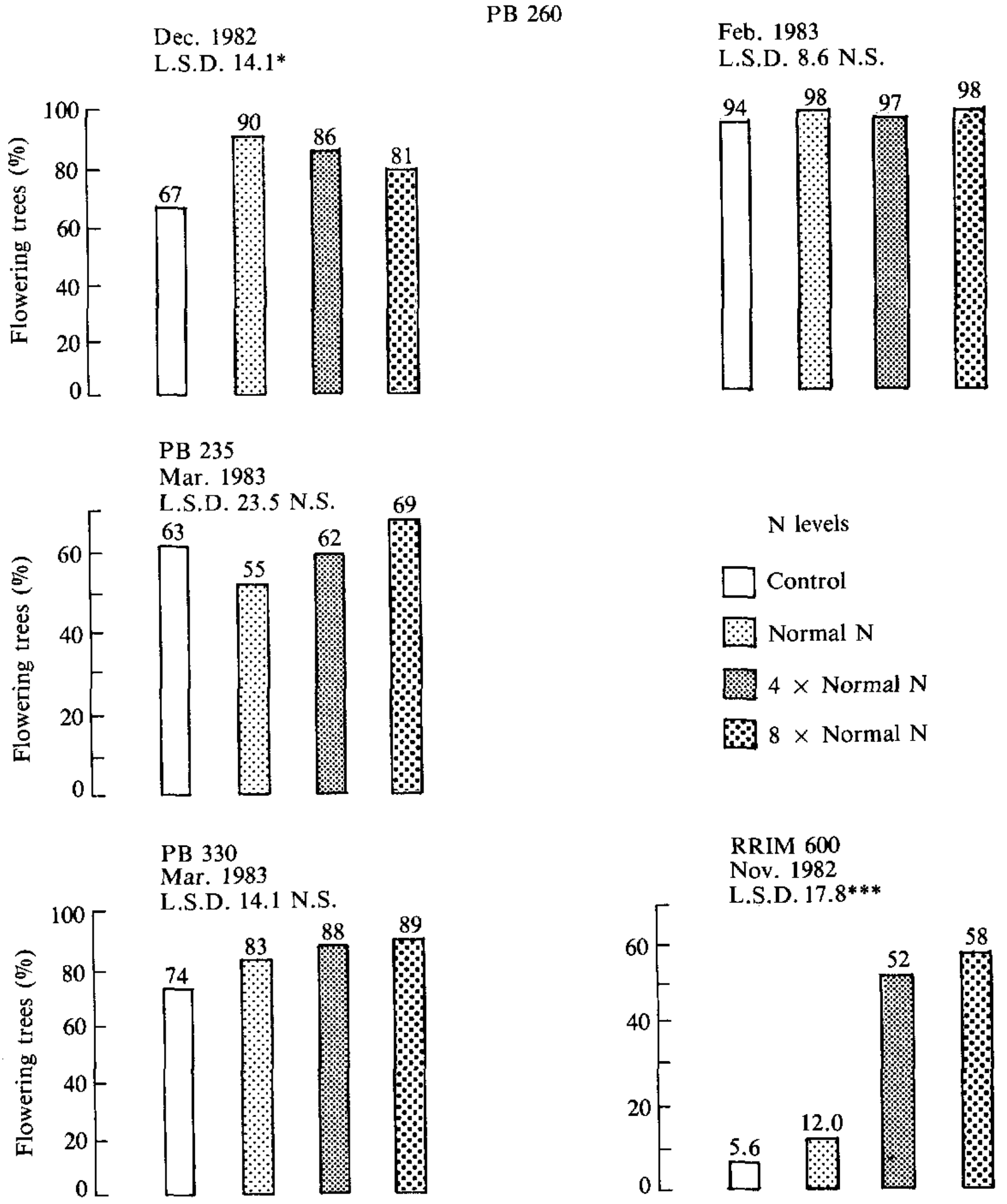

Figure 1. Nitrogen manuring on percentage of trees undergoing flowering for clones PB 260, PB 235, PB 330 and RRIM 600.

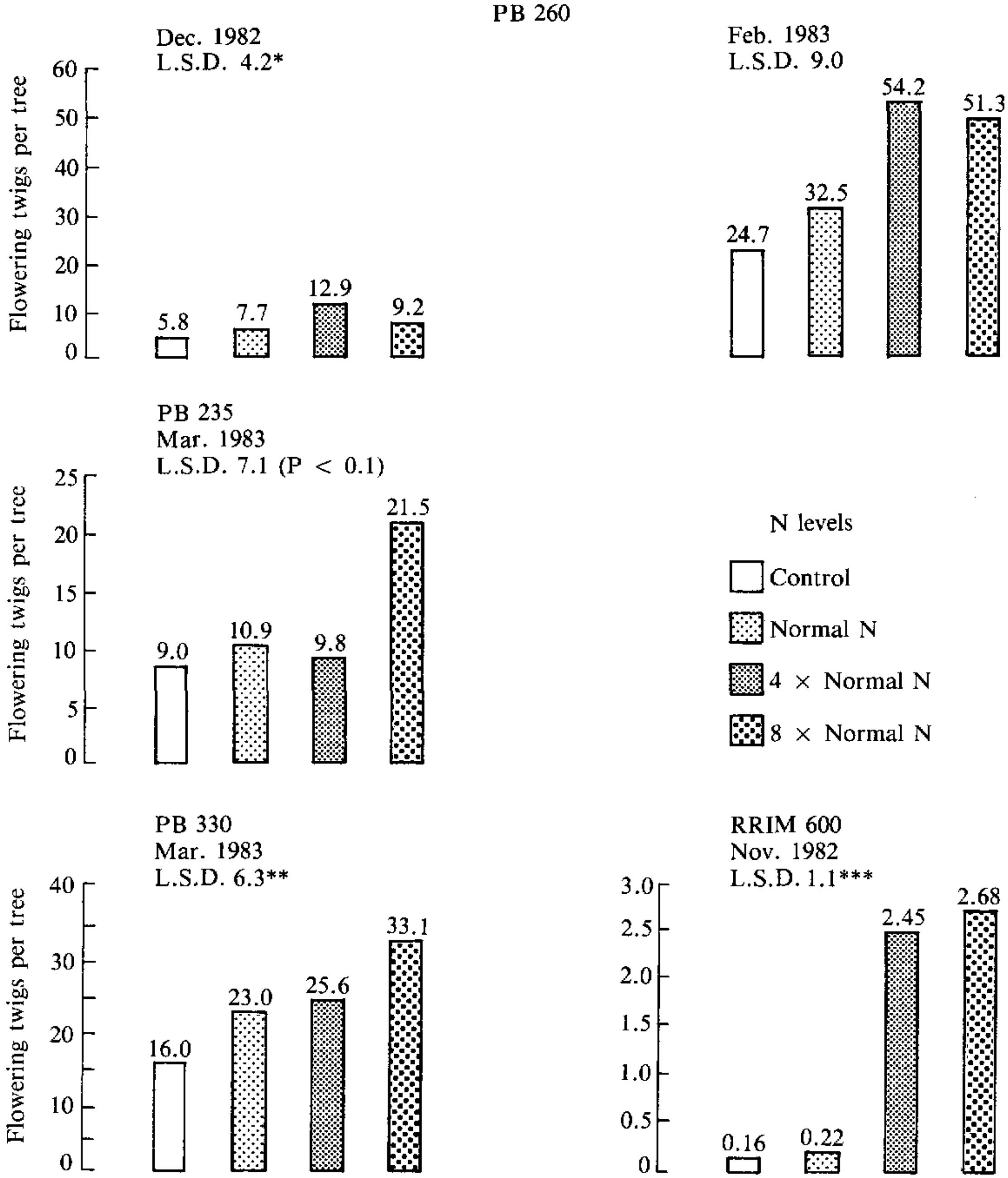

Figure 2. Nitrogen manuring on number of flowering twigs per observed tree for clones PB 260, PB 235, PB 330 and RRIM 600.

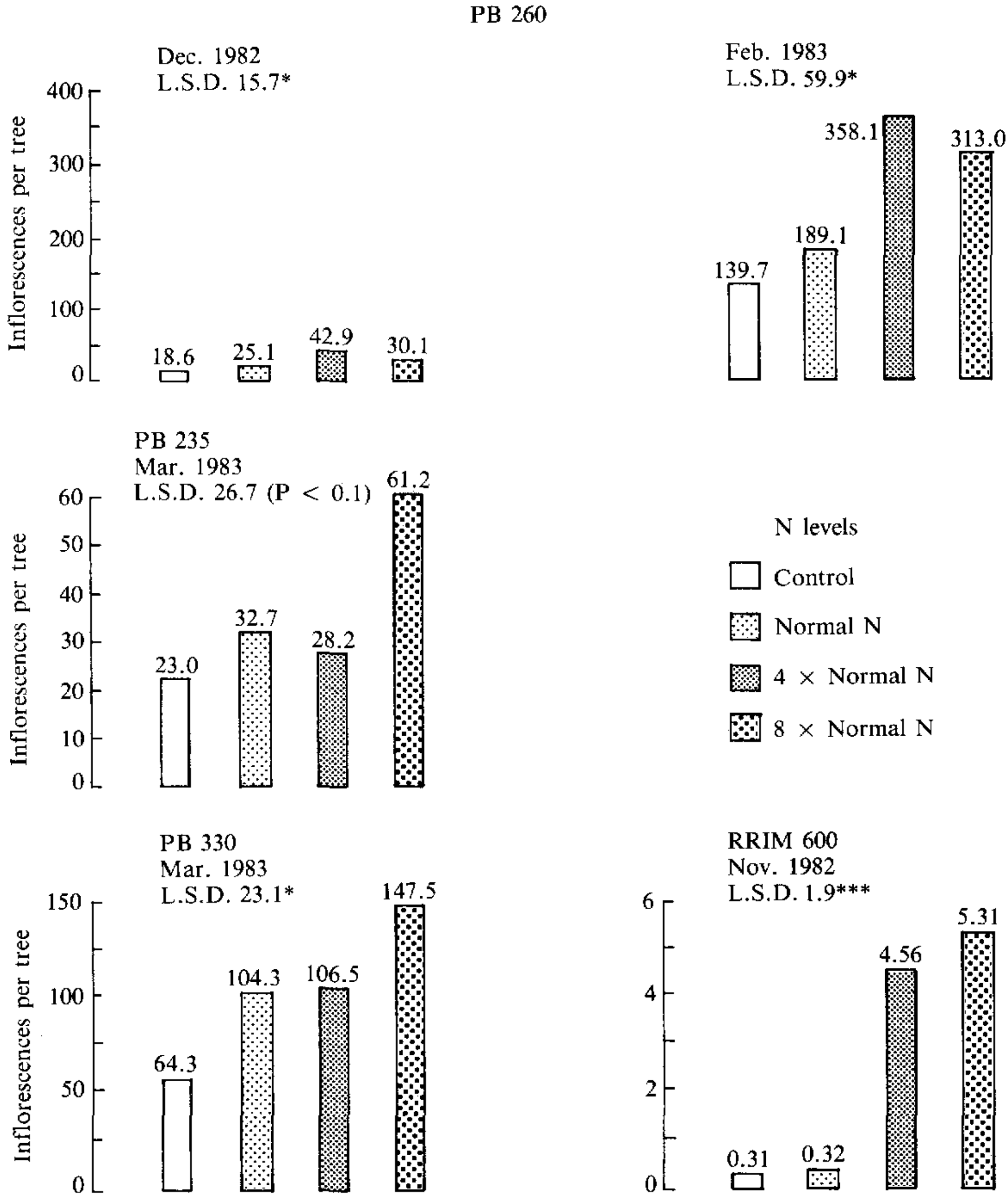

Figure 3. Nitrogen manuring on number of inflorescences per observed tree for clones PB 260, PB 235, PB 330 and RRIM 600.

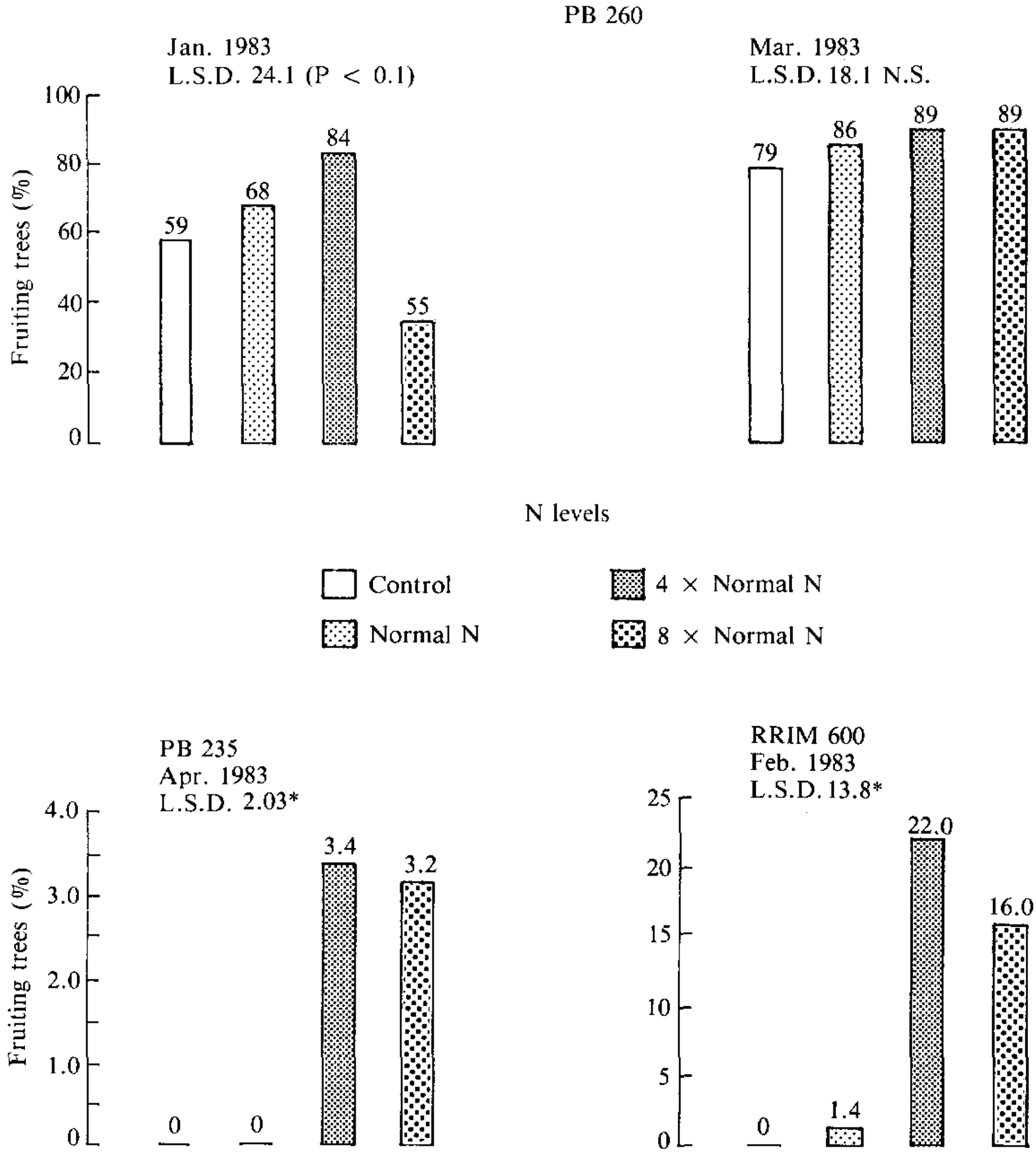

Figure 4. Nitrogen manuring on percentage of trees undergoing fruiting for clones PB 260, PB 235 and RRIM 600.

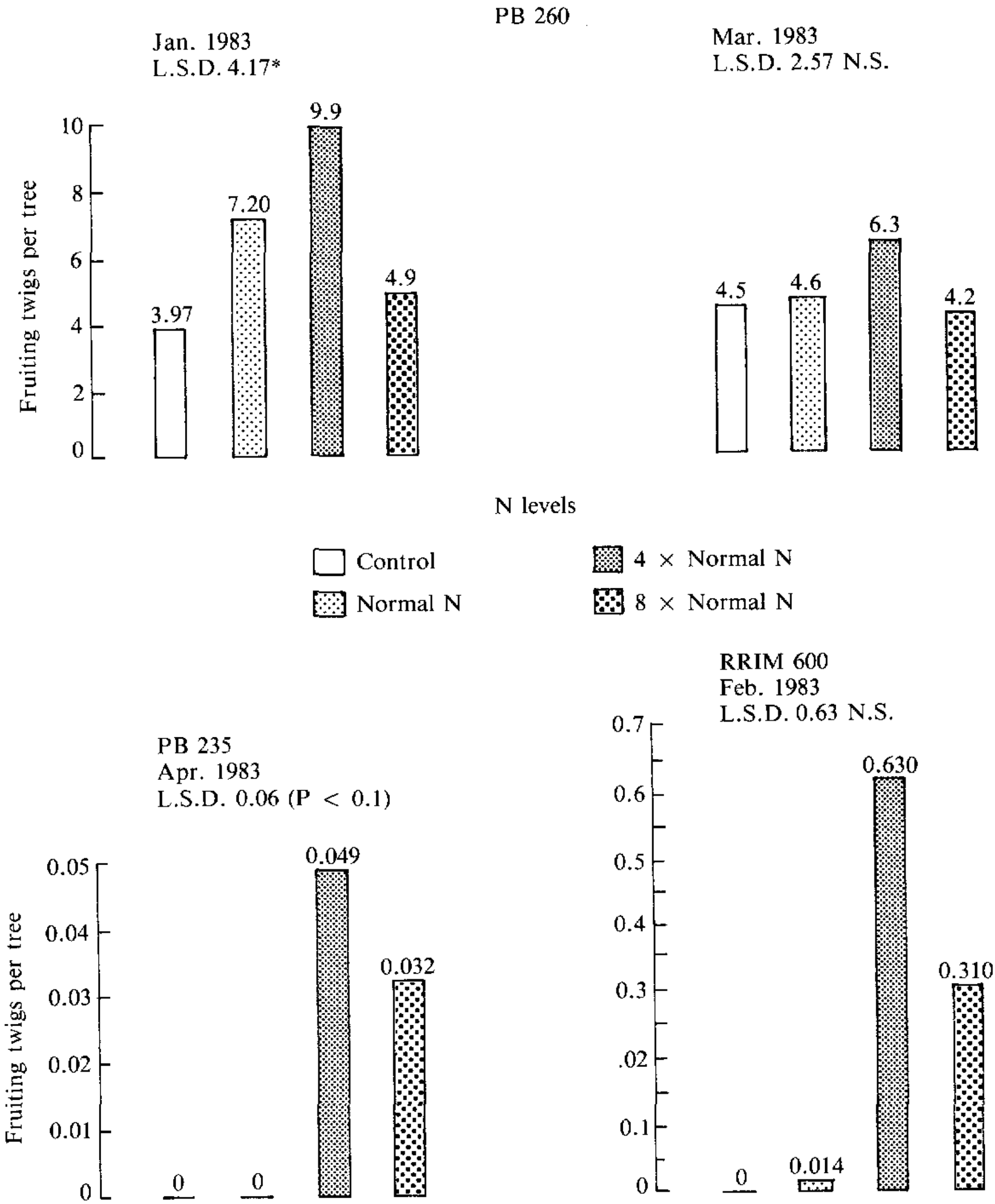

Figure 5. Nitrogen manuring on number of fruiting twigs per observed tree for clones PB 260, PB 235 and RRIM 600.

two flowering seasons. The corresponding increases were from 7.2 to 9.9 fruiting twigs (January 1983) and from 4.6 to 6.3 (March 1983) fruiting twigs per tree.

Fruits per tree. As in the case of fruiting twigs, increased nitrogen manuring apparently gave a curvi-linear response effect on fruit production. The best responses were consistently obtained with the fourth level.

No fruits were produced in the absence of nitrogen manuring in RRIM 600 and PB 235. In addition, PB 235 did not fruit with normal nitrogen applications *(Figure 6)*. Clone RRIM 600 responded to nitrogen by exhibiting a fifty-five-fold increase in fruit production over the first or normal level, though the increase was only from 0.014 to 0.77 fruits per tree. In PB 260 these increases were 39% (January 1983) — from 15.4 to 21.4 fruits per tree — and 25% (March 1983) — from 7.2 to 9.0 fruits per tree.

Interestingly, the flowering and fruiting intensities did not peak at the same high nitrogen treatments, the former being at the eighth level and the latter at the fourth level.

DISCUSSION

Flowering data for the four clones suggest that heavy nitrogen dressings, besides enhancing flower production in young trees *(Figures 2* and *3)*, can also accelerate their transformation from the vegetative to the reproductive phase. This is apparent from the relatively large proportion of trees in the high nitrogen treatments which flowered during the third year *(Figure 1)*, in comparison with trees subjected to normal manuring. This inducing ability of nitrogen for early flowering, is shown to be effective in the late and poorly flowering clones like RRIM 600 *(Figure 1)*. Such nitrogen-induced early flowering will facilitate, in particular, *Hevea* breeding. For example, the appearance of flowers in younger and smaller trees will involve less tree climbing for hand pollination. In comparison with the existing girdling method of inducing flowering in young *Hevea*[13,14], induction through judicious fertiliser application would appear preferable: apart from being simpler than girdling, manuring, unlike girdling, does not decrease tree vigour, but on the contrary generally increases it[15]. If seedlings also respond similarly to nitrogen, as do immature buddings, then the breeding cycle might be considerably shortened. This is likely to benefit the breeding programme, for instance with the imported *Hevea* germplasm, for the early release of new clones with desirable genes. Possibly, girdling combined with manuring could give the best results.

Besides inducing flowering, extra nitrogen also increased fruit production *(Figure 6)*, the effect again being more pronounced in the infertile clone RRIM 600. These results are in accordance with earlier findings on mature trees[9,10]. It is apparent from the current study that, although an increased flowering intensity is followed by an increased fruiting intensity to an extent, yet a direct quantitative relationship does not appear to exist between flowering and fruiting intensities: inflorescence production was generally highest at the eighth level of nitrogen, in all clones except PB 260, while fruiting consistently peaked at the fourth level *(Figure 6)*. Computations of fruit to inflorescence ratios, with preliminary data for RRIM 600 *(Table 2)* indicate an increase in the number of fruits per inflorescence with heavier nitrogen manuring, peaking at the fourth level. This, together with other data from related investigations[16] indicate that enhancement in fruit yields, with heavy nitrogen application, is a result of both increased flowering intensity and an improvement in the quality of flowers produced.

The earlier reported findings of a rise in seed germination success with high nitrogen manuring[9] was also apparent in the present study *(Table 3)*, although, statistically, only small quantities of seeds were employed for our tests. The germination percentages obtained were fairly comparable to the earlier published values[9], thus allaying any doubts on the viability and quality of seeds from young trees.

Fertiliser programmes for *Hevea* are primarily formulated for improving vigour, growth and dry rubber yields. The positive effect of nitrogen manuring on growth and reproduction

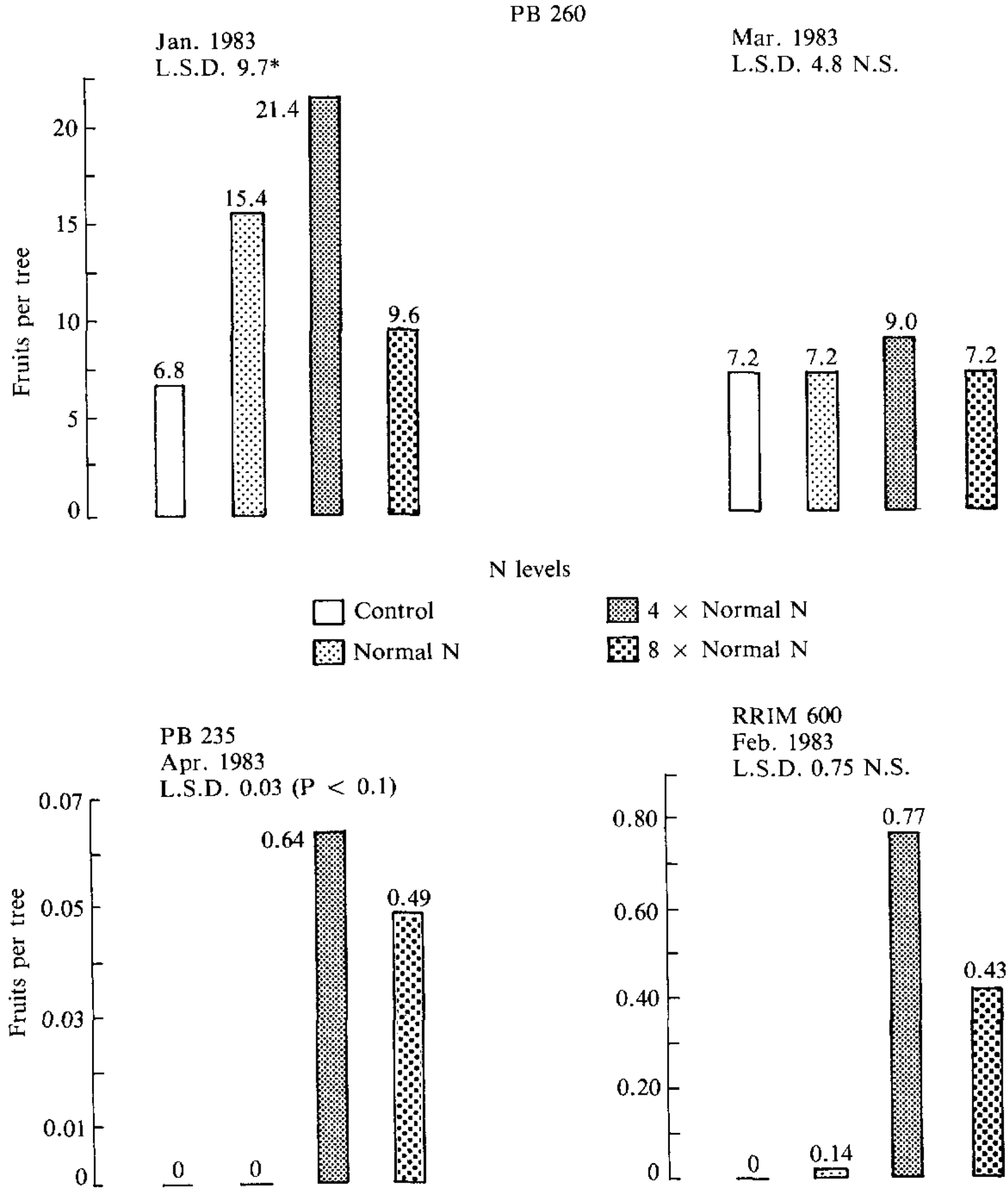

Figure 6. Nitrogen manuring on number of fruits per observed tree for clones PB 260, PB 235 and RRIM 600.

TABLE 2. NITROGEN MANURING ON FRUITS PER INFLORESCENCE RATIO FOR RRIM 600

Nitrogen level	Fruits per inflorescence
Control	0
Normal	0.021
Normal × 4	0.180
Normal × 8	0.072
S.E.	0.00402

TABLE 3. NITROGEN MANURING ON GERMINATION RATES FOR CLONE PB 260

Nitrogen treatment	Germination (%)
Control	37 (51)
Normal	57 (72)
Normal × 4	54 (39)
Normal × 8	77 (100)
S.E.	8.2

Figures within brackets indicate the total number of seeds used for the germination test.

has been described elsewhere[15]. Significant flowering and fruiting responses were obtained with high nitrogen levels in all clones, in the present study. From the present investigations, it is apparent that the amount of nitrogen in the recommended fertiliser formulations is not sufficient for maximising flowering and fruiting intensities. In the case of mature trees, Watson and Narayanan[9] showed that annual applications of 1.8 kg ammonium sulphate per tree gave the best seed yields, but they did not test levels higher than this. This level amounts to approximately three to three-and-a-half times the annual nitrogen dressings recommended for the normal maintenance of mature trees[17,18].

The enhancement in flowering and fruiting intensities, with high nitrogen manuring (fourth and eighth levels), is probably not the result of an osmotic effect caused by ammonium sulphate, because the trees did not exhibit any direct or indirect symptoms of a moisture stress response to treatment. In addition, the quantities of ammonium sulphate applied at the higher levels were considered small relative to the high buffering ability of the soil. The role of heavy nitrogen dressings is therefore assumed to be purely a nutritive one. Hence *it is seen from the current investigation that* in situations where seed production is to be enhanced, the supply of nitrogen at four times the maintenance dosage plus adequate supplies of other nutrients must be ensured from the outset.

CONCLUSION

From a systematic field study in existing immature manuring experiments it is apparent that heavy nitrogen applications, at rates far in excess of the normal, will: improve the vigour of trees; induce young trees to start flowering at an early age (three years); significantly increase the numbers of flowering twigs and inflorescences; improve fruit set and fruit yields. The seeds obtained from harvested fruits were of comparable viability to seeds collected from mature stands, as reported by Watson and Narayanan[9].

The induction and enhancement of flowering should benefit the breeding programme, as discussed above. From the present data, it can be concluded that for this purpose, the *application of nitrogen fertiliser at four times* the currently recommended level, is suitable.

The increased fruit set observed in the present work, together with other published data[9] indicate that seed gardens and fields designated for seed collection should also be fertilised with more nitrogen than the normal recommended levels.

Thus, in situations where earlier and enhanced flowering and fruiting are desired, nitrogen must be applied at about four times the currently recommended level.

It must be emphasised that it will be most beneficial to commence the extra nitrogen manuring soon after planting.

ACKNOWLEDGEMENT

The authors extend their grateful thanks to the field staff of the Soils and Crop Management Division, who were actively involved in this study, in particular Encik-Encik V. Balakrishnan, Leong Khai Hoong, Mokhtar Bujang, Ariffin Othman and Encik R. Ayathurai of Plant Science Division. The kind support from Dr E. Pushparajah, Assistant Director, Department of Biology, Dr Yoon Pooi Kong, Head, Plant Science Division, Dr J.B. Gomez and Dr Wan Abdul Rahman is deeply acknowledged.

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