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RESPONSE OF *HEVEA* TO FERTILIZERS IN NORTHERN WEST BENGAL

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An experiment was conducted at the Regional Experiment Station of Rubber Research Institute of India at Nagrakata from 1989 to find out the nutritional requirement of *Hevea* in northern West Bengal. Treatments included four levels of nitrogen (N) and three levels each of P_2O_5 and K_2O in factorial randomised block design. Nitrogen significantly influenced girth, girth increment (GI) and percent tappability while P and K failed to show any direct effect. Application of 40 kg N per ha recorded significantly higher girth, GI and percent tappability over no N. Soil and leaf nutrient status was not influenced by N application. However, P and K application significantly influenced the respective leaf nutrient status. DRIS indices for different nutrients indicated the order of limiting nutrient as K>N>P. Interaction between N and K significantly influenced the percent tappability. Significant linear increase in percent tappability with K levels was observed only in the absence of N but with the N percent tappability did not increase significantly with K levels. Phosphorus and interaction between N, P and K significantly influenced the average yield (g/tree/tap) and estimated annual yield (kg/ha). Phosphorus showed significant negative effect on yield. The control ($N_0P_0K_0$) recorded significantly higher average yield (32.7 g/t/t) compared to other treatment combinations except N_{40}:P_0:K_{40}, N_{20}:P_0:K_{20}, N_{40}:P_0:K_0, N_0:P_{20}:K_{40} and N_0:P_{20}:K_{20}. However, estimated annual yield taking into account the percent tappability was significantly higher with N_{40}:P_0:K_{40} (1223 kg/ha) compared to control (764.2 kg/ha). Hence fertilizer mainly helped in better growth resulting in reduced immaturity period and higher percent tappability. Bark thickness and yield components like dry rubber content were also significantly influenced by fertilizer application.

Key words: Bark thickness, DRC, DRIS, Fertilizer, *Hevea*, Tappability.

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INTRODUCTION

Rubber (*Hevea brasiliensis*) is newly introduced into the northern part of West Bengal, which has been found to be marginally suitable for its cultivation (Rao *et al.*, 1993). Soil and climatic conditions of this area are entirely different from those of the traditional rubber growing tract. Northern West Bengal comes under the sub-Himalayan region with well-drained sandy loam soil. Average annual rainfall is 3200 mm, distributed mainly during June to September (Fig. 1). Unlike the traditional region, northern West Bengal receives only southwest monsoon and winter sets in by October/November. Winter temperature goes as low as 5°C during December/January. For successful cultivation of any crop in an area having agroclimate different from traditional regions, there is a need to develop and standardise agronomic practices. Among different agronomic practices, nutrition is a very important aspect. In view of the differences in agroclimate, the fertilizer doses recommended for the traditional region cannot be adopted as such. Hence study of the nutritional requirement of *Hevea* in the northern part of West Bengal was undertaken.

MATERIALS AND METHODS

The study was conducted at the Regional Research Station of Rubber Research Institute of India (RRII) at Nagrakata, located at 26° 54′ N latitude, 88° 25′ E longitude and an altitude of 69 m above MSL.

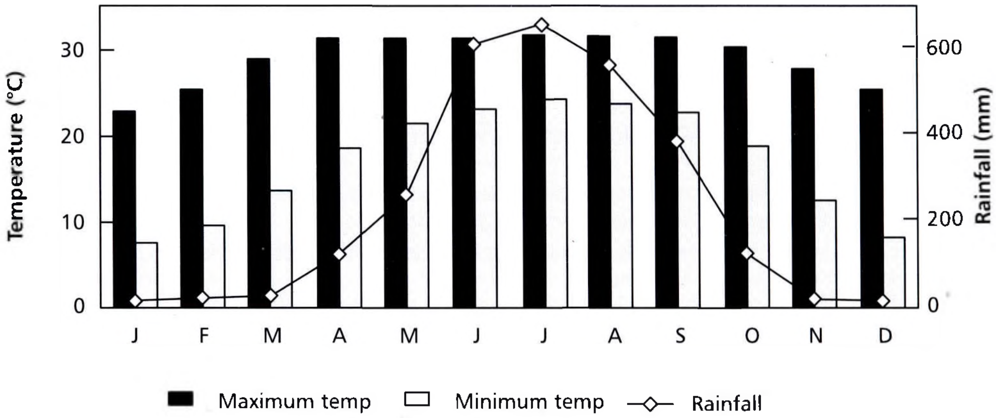

Fig. 1. Mean weather parameters at Nagrakata (1991-92)

The experiment was laid out in 1989 over an area of 4.3 ha with four levels of nitrogen (N) (0, 20, 40 and 60 kg/ha) and three levels each of P_2O_5 and K_2O (0, 20 and 40 kg/ha). There were 36 treatment combinations laid out in factorial randomised block design with two replications. Polybag plants of RRIM 600 were planted at a spacing of 4.9 x 4.9 m. Gross plot size was 25 plants and net plot, nine plants. Soil was acidic (pH 4.4) with high organic carbon (OC) (2.3%), very low available P (0.2 mg/100 g) and low available K (4.2 mg/100 g) (Table 1). Cover crop (*Pueraria phaseoloides*) was established in the inter-row. All the cultural practices recommended for rubber were followed. Treatment-wise fertilizer was given through urea, rock phosphate and muriate of potash and applied in circular bands around the plants up to five years and afterwards in rectangular patches between rows servicing every four trees. For the first two years, half of the phosphorus dose was supplied in the form of single super phosphate and the remaining as rock phosphate. Fertilizer was applied in two equal splits as pre- and post-monsoon dose. Pre-treatment composite soil samples were collected at 0-30 cm and 30-60 cm depths for nutrient analysis. Post-treatment soil and leaf samples were collected during 1996. Soil and leaf samples were analysed following the standard analytical procedures (Morgan, 1941; Bray and Kurtz, 1945; Jackson, 1973). Leaf and soil nutrient status was assessed using sufficiency / critical range values (Karthika kuttyamma *et al.*, 2000). Using the leaf N, P and K nutrient content and DRIS norms values reported by Joseph *et al.* (1993), nutrient index values were calculated following the procedure reported by Beaufils (1973). Nutrient sufficiency or deficiency was interpreted using the N, P and K index values. Bark thickness was assessed using bark-measuring gauge, during 1996. Observations on girth at 150 cm height were recorded at half yearly intervals during June and December and annual girth increment (GI) was calculated. Per cent GI over control ($N_0P_0K_0$) was calculated during the fourth and seventh year after planting.

Table 1. **Initial soil nutrient status**

Depth (cm)	Organic Carbon (%)	Available P (mg/100 g)	Available K (mg/100g)	pH
0-30	2.3	0.2	4.2	4.4
30-60	1.7	Trace	3.1	4.3

Tapping was started in 1998 under the 1/2S d/2 system. Regular yield recording was started in 1999 at monthly intervals. Plot-wise cup lump yield was recorded during 1999 and the annual mean yield (g/tree/

tap) was calculated. Dry rubber content (DRC) was recorded during July 1999. Using mean yield, the annual yield (kg/ha) was estimated by multiplying with plant population (420 trees/ha), respective per cent tappability and number of tapping days (115 days). Unlike the conventional formula for calculating the annual yield, the per cent tappability of respective treatments was used to delineate the treatment having beneficial effect on tappability.

All the data were subjected to the analysis of variance. Group comparison methods like trend comparison and factorial comparison were used for further partitioning of the main and interaction effects using the orthogonal polynomial contrast method to understand the functional relationship between treatment level and variable and the nature of interaction between treatments (Gomez and Gomez, 1984).

RESULTS

Effect of fertilizer on growth

Nitrogen has significant influence on girth during different years (Table 2). Application of 20 kg N per ha resulted in significantly higher girth over control but this was on par with other levels. It is interesting to note that over the years the effect of N application over control slowly narrowed and faded out by the 10th year. Unlike in the immaturity period, treatments comprising application of 40 and 60 kg N per ha during first year of tapping (9th year) showed significant effect on girth compared to 0 kg N per ha. The effect of P and K as well as the interaction of N, P and K was not significant in any of the years.

Application of N showed significant positive effect on annual GI during third and fourth years only (Table 3). During later years of immaturity period occasionally higher doses of N showed less GI. The effect of P and K as well as the interaction of N, P and K on girth increment was not significant. Annual GI over control was calculated during fourth and seventh years to study the effect of fertilizer application, over control. Among the nutrients studied, only N showed significant effect on GI, over control. During fourth year 60 kg N per ha recorded 17.3 per cent more GI over control but it reduced to 8.7 per cent during the seventh year. However, among the N levels no significant difference was observed.

Table 2. **Effect of nutrient levels on girth**

Nutrient level (kg/ha)	Girth during different years (cm)								
	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
N0	8.1	15.1	24.3	33.6	40.3	43.7	47.3	51.1	54.3
N20	8.6	16.3	26.1	35.1	41.4	45.4	49.2	52.3	54.6
N40	8.7	16.7	26.7	35.9	42.3	46.2	49.8	53.1	54.6
N60	8.8	17.0	27.2	36.0	42.4	46.6	49.6	53.1	55.7
SE	0.1	0.3	0.5	0.5	0.4	0.5	0.7	0.5	0.5
CD (P<0.05)	0.3	0.9	1.5	1.4	1.2	1.4	1.4	1.3	NS
P0	8.5	16.3	26.0	35.1	41.1	45.4	48.9	52.6	54.2
P20	8.5	16.1	25.9	35.1	41.6	45.3	48.5	51.8	55.1
P40	8.6	16.4	26.3	35.3	41.9	45.7	49.5	52.7	55.0
SE	0.1	0.3	0.5	0.4	0.4	0.4	0.6	0.4	0.5
CD (P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
K0	8.2	15.8	25.6	34.7	41.0	45.0	48.3	51.6	54.8
K20	8.7	16.4	26.2	35.2	41.7	45.9	49.5	52.9	55.1
K40	8.6	16.6	26.4	35.6	42.2	45.5	49.2	52.6	54.5
SE	0.1	0.3	0.5	0.4	0.4	0.4	0.6	0.4	0.5
CD (P<0.05)	0.3	NS	NS	NS	NS	NS	NS	NS	NS

Table 3. **Effect of nutrient levels on girth increment**

Nutrient level (kg/ha)	Girth increment during different years (cm)								Percent over control	
	3rd	4th	5th	6th	7th	8th	9th	10th	4th year	7th year
N0	7.1	9.2	9.3	6.7	4.6	3.5	2.9	1.9	103.8	101.8
N20	7.8	9.8	9.0	6.3	4.5	3.7	2.1	1.7	112	106.1
N40	8.1	10.1	9.2	6.4	4.5	3.6	2.6	1.8	114.8	107.9
N60	8.2	10.2	8.8	6.4	4.8	3.0	2.4	1.9	117.3	108.7
SE	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.1	2.3	1.2
CD (P<0.05)	0.7	0.6	NS	NS	NS	NS	NS	NS	6.6	3.3
P0	7.8	9.7	9.1	6.3	4.9	3.3	2.5	1.8	111.3	105.9
P20	7.6	9.8	9.2	6.5	4.4	3.2	2.3	1.9	111.4	105.6
P40	7.9	9.9	9.0	6.6	4.4	3.8	2.7	1.8	113.3	106.9
SE	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.1	2.0	1.0
CD (P<0.05)	NS	NS	NS	NS	0.4	NS	NS	NS	NS	NS
K0	7.6	9.8	9.0	6.4	4.6	3.3	2.5	1.9	110	105
K20	7.7	9.8	9.0	6.5	4.8	3.7	2.8	1.8	112.8	107.1
K40	8.0	9.8	9.3	6.6	4.3	3.4	2.2	1.7	113.2	106.3
SE	0.2	0.2	0.1	0.1	0.2	0.2	0.2	0.1	2.0	1.0
CD (P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

In rubber, attainment of 50 cm girth at 125 cm height is the criterion for assessing the tappability. A minimum of 75 per cent trees should attain this girth for starting tapping. Only N and interaction between N and K showed significant effect on percent tappability (Table 4). Nitrogen application showed significant linear effect on percent tappability. Application of 60 kg N per ha recorded significantly higher percent tappability (80%) compared to no N (66.3%), which was on par with other levels. Only 40 and 60 kg N per ha recorded desired tappability (>75%) and both these treatments were on par. Existence of N x K interaction was mainly due to the significant linear response of N to K levels. Further partitioning of this response indicated that the significant linear response to K levels was shown by N_0 only. Nitrogen application failed to show any significant positive interaction with K levels.

Table 4. **Effect of N and N x K interaction on tappability**

N level (kg/ha)	Potash level (kg/ha)			
	K0	K20	K40	Mean
N0	53.8	72.2	73.0	66.3
N20	77.7	72.2	71.5	73.8
N40	78.5	74.5	78.2	77.1
N60	80.8	76.0	83.2	80.0
Mean	72.7	73.7	76.5	74.3
		N	K	NK
S.E		2.5	2.2	4.4
CD (P<0.05)		7.15	NS	12.6

Effect of fertilizer on soil and leaf nutrient status

Application of N and K did not bring about significant change in soil fertility status, however, higher level of P significantly reduced the soil organic carbon (Table 5). In general, fertilizer application did not bring about significant change in soil N and K status compared to pre-treatment status but there was increase in soil P status with P application (Tables 1&5). Leaf N status was not significantly influenced by the application of different nutrient and their interaction (Table 5). Leaf P and K status were significantly influenced by application of respective nutrients. Even without phosphorus application the leaf P status (0.35%) was already high. With application of P it further increased significantly. Application

Table 5. **Effect of nutrient levels on post-treatment leaf and soil nutrient status and DRIS indices**

Nutrient level	Soil nutrient status (0-30cm)			Leaf nutrient status (%)			DRIS indices for different nutrients		
	OC %	P	K	N	P	K	Ni	Pi	Ki
N0	2.2	0.91	4.4	3.2	0.38	1.06	-19.4	43.1	-23.7
N20	2.2	0.41	3.9	3.2	0.35	1.08	-15.4	36.1	-20.7
N40	2.2	0.61	4.0	3.2	0.36	1.10	-15.9	36.6	-20.7
N60	2.1	0.67	4.1	3.2	0.37	1.19	-20.6	37.2	-16.7
SE	0.13	0.16	0.34	0.04	0.01	0.05	2.4	3.0	3.1
CD (P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
P0	2.3	0.46	3.8	3.2	0.35	1.11	-16.1	34.8	-18.7
P20	2.2	0.75	4.3	3.2	0.37	1.10	-17.2	37.9	-20.8
P40	1.9	0.73	4.1	3.2	0.38	1.12	-20.3	42.0	-21.8
SE	0.11	0.13	0.3	0.04	0.08	0.04	2.1	2.6	2.7
CD (P<0.05)	0.31	NS	NS	NS	0.02	NS	NS	NS	NS
K0	2.0	0.56	3.6	3.2	0.37	1.08	-19.0	40.6	-21.6
K20	2.3	0.62	4.1	3.3	0.36	1.03	-13.7	38.5	-24.9
K40	2.2	1.04	4.5	3.2	0.37	1.20	-20.8	35.7	-14.9
SE	0.11	0.13	0.3	0.04	0.08	0.04	2.1	2.6	2.7
CD (P<0.05)	NS	NS	NS	NS	NS	0.12	NS	NS	7.7

of 40 kg P_2O_5 per ha recorded significantly higher leaf P (0.38%) over no P_2O_5 but was on par with 20 kg P_2O_5 per ha. Application of 40 kg K_2O per ha recorded significantly higher leaf K compared to 20 kg K_2O per ha but this was on par with no K_2O. Nutrient interaction did not significantly influence the leaf nutrient status. In general, leaf N and K status was medium and P status was high according to the sufficiency levels.

DRIS indices for N (Ni), P (Pi) and K (Ki) broadly indicated the order of limiting nutrients K>N>P (Table 5). Nitrogen and phosphorus application failed to show any significant effect on Ki (Table 5). Application of 20 kg K_2O per ha showed significant imbalance in K compared to 40 kg but on par with no K_2O. Interaction between N, P and K did not significantly influence the DRIS indices. Since DRIS index value for single nutrient is meaningless, DRIS index value for other nutrients must be simultaneously looked into for interpretation. Hence among the treatment combinations, 40:40:40 kg N: P_2O_5:K_2O per ha recorded more balanced leaf nutrient status (Ni = -17.2, Pi = 22.1 and Ki = -4.8) compared to control (Ni = -21.1, Pi = 36.9 and Ki = -15.8) and other treatment combinations. In general, application of P caused imbalance between N and K. Better nutrient balance was observed with omission of P application.

Effect of fertilizer on yield and yield components

Influence of fertilizer application on mean yield, DRC and bark thickness are presented in Tables 6 and 7. Average rubber yield (g/tree/tap) was significantly influenced by P and NxPxK interaction (Table 7). Application of P_2O_5 significantly reduced the yield at both 20 and 40 kg levels (Table 6). Among the treatment combinations, control ($N_0P_0K_0$) recorded significantly higher mean yield (32.7 g/t/t) over all other treatments, but was on par with $N_{40}P_0K_{40}$, $N_{20}P_0K_{20}$, $N_{40}P_0K_0$, $N_0P_{20}K_{40}$ and $N_0P_{20}K_{20}$ (Table 7). In general, treatment combinations without P showed higher yield compared to those with it. Annual yield (kg/ha) estimated by taking into account the respective treatments percent tappability and mean yield is presented in Table 8. Interaction between N and K significantly influenced estimated annual yield with N_0K_0 recording significantly lower yield (580.7 kg/ha) compared to all other treatments. Interaction between N, P and K also showed significant effect on estimated annual yield (Table 8). Among the treatment combinations, $N_{40}P_0K_{40}$ showed significantly higher yield (1223 kg/ha) over control (764.2 kg/ha) and other treatment combinations except $N_{20}P_0K_{20}$ (1059.5 kg/ha), $N_{40}P_0K_0$ (1019 kg/ha), $N_{60}P_0K_{40}$ (995.8 kg/ha), $N_0P_{20}K_{20}$ (945.2 kg/ha) and $N_{20}P_0K_{40.}$ $N_{20}P_4K_0$ (1004.kg/ha) and $N_0P_{40}K_{20}$ (961.6 kg/ha). Dry rubber content (DRC) was significantly influenced by K and PxK interaction (Table 9). Application of K_2O significantly increased DRC only up to the 20 kg per ha level beyond which there was a nominal decrease. The interaction effect of PxK does not appear to be complimentary. Application of 20 kg K_2O per ha with or without P gave higher DRC.

Bark thickness was significantly influenced by the main effect of N, P and K and PxK interaction (Tables 6 & 9). There was response to N at all levels of application, but between levels the differences were not significant. Application of P gave response only at 40 kg P_2O_5 per ha level. Application of K_2O also gave positive response at both lev-

Table 6. **Effect of nutrient levels on rubber yield, DRC and bark thickness**

Nutrient level	Mean rubber yield (g/tree/tap)	DRC (%)	Bark thickness (mm)
N0	23.8	35.2	5.20
N20	23.6	36.1	5.39
N40	23.7	34.8	5.40
N60	22.6	34.6	5.42
SE	0.8	0.6	0.08
CD (P<0.05)	NS	NS	0.16
P0	24.9	35.6	5.27
P20	22.6	34.3	5.35
P40	22.7	35.5	5.49
SE	0.7	0.5	0.07
CD (P<0.05)	1.9	NS	0.14
K0	22.9	34.0	5.20
K20	24.2	36.4	5.50
K40	23.1	35.1	5.40
SE	0.7	0.6	0.07
CD (P<0.05)	NS	1.6	0.14

Table 7. **Effect of N, P, K on mean rubber yield (g/tree /tap)**

N level	P0 (kg/ha)				P20 (kg/ha)				P40 (kg/ha)				N
(kg/ha)	K0	K20	K40	Mean	K0	K20	K40	Mean	K0	K20	K40	Mean	Mean
N0	32.7	23.4	23.2	26.4	15.7	26.1	26.5	22.8	19.9	25.1	22.0	22.4	23.8
N20	23.3	28.4	21.3	24.4	22.3	23.9	23.4	23.2	22.8	24.1	22.9	23.3	23.6
N40	27.1	22.8	30.5	26.8	23.6	22.7	19.6	21.9	23.5	24.4	19.2	22.4	23.7
N60	21.5	22.0	23.0	22.2	20.9	25.3	21.7	22.6	21.9	22.6	24.3	23.0	22.6
Mean	26.1	24.1	24.5	24.9	20.6	24.5	22.8	22.6	22.0	24.1	22.1	22.7	23.4
		N	P	K	NP	NK	PK	NPK					
SE		0.80	0.70	0.70	1.4	1.4	1.2	2.3					
CD(P=0.05)		NS	1.90	NS	NS	NS	NS	6.7					

Table 8. **Effect of N, P, K on mean rubber yield (g/ha)**

N level	K0 (kg/ha)				K20 (kg/ha)				K40 (kg/ha)				N
(kg/ha)	P0	P20	P40	Mean	P0	P20	P40	Mean	P0	P20	P40	Mean	Mean
N0	764.2	376.6	601.3	580.7	696.8	945.2	961.6	867.9	848.1	807.2	840.4	831.9	760.1
N20	783.6	790.8	1004.0	859.4	1059.5	795.4	809.0	888.0	673.2	781.5	897.6	784.1	843.8
N40	1019.0	871.5	917.5	936.0	802.1	817.6	881.0	833.6	1222.7	779.0	638.5	880.1	883.2
N60	802.3	801.7	895.9	833.3	829.8	892.8	820.1	847.6	995.8	894.7	868.9	919.8	866.9
Mean	842.2	847.0	934.9	802.3	710.1	862.7	815.6	859.2	854.7	867.9	811.3	853.9	838.5
		N	P	K	NP	NK	PK	NPK					
SE		33.4	28.9	28.9	57.8	57.8	50	100.1					
CD(P=0.05)		NS	NS	NS	NS	165.2	NS	286.1					

Table 9. **Effect of P x K on DRC and bark thickness**

P level	DRC (%)				Bark thickness (mm)			
(kg/ha)	K0	K20	K40	Mean	K0	K20	K40	Mean
P0	32.3	37.8	36.8	35.60	4.96	5.40	5.48	5.27
P20	33.8	35.0	34.2	34.30	5.16	5.49	5.40	5.35
P40	35.9	36.4	34.4	35.50	5.49	5.55	5.42	5.49
Mean	34.0	36.4	35.1	35.13	5.20	5.50	5.40	5.37
		P	K	PK		P	K	PK
SE		0.56	0.56	0.97		0.07	0.07	0.12
CD (P=0.05)		NS	1.6	2.8		0.14	0.14	0.24

els significantly and maximum DRC was obtained at the 20 kg per ha level.

DISCUSSION

During immaturity period, N significantly influenced the growth and bark thickness but P and K failed to show any effect. Nitrogen plays a key role in biomass production and accumulation and hence N application significantly increased the girth and GI and ultimately percent tappable plants. Many workers also reported the effect of N on growth of *Hevea* during immaturity period (Ananth *et al.*, 1966; Potty *et al.*, 1974; Kalam *et al.*, 1974). Significant effect of N on GI was noticed up to fourth year only. This period coincided with active growth period of rubber and hence significant response was noticed. During later years of immaturity period, GI declined and occasionally the higher doses of N showed lower GI. Earlier many workers like Potty *et al.* (1974) and Ananth *et al.* (1966) also reported negative response to higher doses of N and attributed this partly to release of N from the cover crop, which die during later years of immaturity. During immaturity period, 20 kg N significantly increased the girth of trees compared to control but during tapping (9th year), 40 kg N was required for significant effect. This may be attributed to the fact that tapping usually leads to slowing down in growth and hence higher N dose is required for better growth. Percent tappability is the cumulative effect of growth over the years. Nitrogen significantly influenced girth and thereby, the percent tappability. Desired tappability (>75%) was attained with application of 40 kg and not 20 kg N. As expected, for getting more number of plants to tappable girth higher does of N is required.

Response to added fertilizer depends on nutrient supplying capacity of the soil. Major source of soil-N is soil organic matter. The high organic C content (2.3%) in the soil enables it to supply a major portion of N requirement of rubber. According to one estimate, mineralising of 1.5 per cent of organic matter in soil having organic matter content of 4 per cent would release 70 kg per ha (Donhue *et al.*, 1990). Hence significant response was noticed only up to 20 kg N and at higher level no such response was noticed. Rubber being a deciduous tree adds an average of about six tonnes leaf litter (Krishnakumar and Potty, 1992). Because of the addition of huge litter biomass regularly, the soil organic C was maintained and the difference in growth between no N plot and N applied plot diminished over the years.

Phosphorus application failed to show any effect on growth despite low available soil P status. It is well known that soil P test does not take into account the organic P content. Often nearly half of the total P in soil occurs in organic form, most of which is derived from plant tissue. Amount of organic P in Indian soil varies from 2.6 to 75 per cent of total P (Mukherjee *et al.*, 1979).

Soil being rich in organic matter content, P released from organic matter decomposition was sufficient to meet plant demand. Addition of P resulted in further increase in leaf P status to excess level. This created imbalance in plant nutrient status and hence omission of P showed more balanced leaf nutrient status and better response in terms of yield, DRC and bark thickness. Similar result of poor growth response, increase in leaf P and build up in soil P were reported by Kalam *et al.* (1974) Ananth *et al.* (1966), Pushparajah *et al.* (1974) and Poliniere and Brandt (1969). Guha (1975) also reported depression in yield due to P application in acid igneous soils of Liberia in West Africa.

Potassium, the third major plant nutrient, failed to show any significant effect on growth and yield. Omont (1980) and Pushparajah *et al.* (1983) also reported the same in young rubber. Tappability was significantly influenced by NxK interaction. With no N the tappability increased linearly with K levels, but with N application significant increase was not observed. This indicates that for the applied K levels N level of native soil is sufficient for obtaining significant increase in tappability. Significant positive effect of N x K on rubber growth has been emphasised earlier by Pushparajah *et al.* (1969), Owen, *et al.* (1957) and Bataglia and Santos (1999). Potassium significantly influenced the DRC and bark thickness. In *Hevea*, latex is produced in bark and K is known to improve the bark quality and DRC significantly (Pushparajah, 1969; Hamzah *et al.*, 1975; Pushparajah *et al.*, 1974). Significant effect of K on DRC and bark thickness in the absence of P and non-significant effect in the presence of P indicates that native soil P is sufficient to give significant response to applied K levels.

DRIS approach, which assess the sufficiency/deficiency of a nutrient in relation to other nutrient, identified K>N>P as the order of nutrients limiting rubber growth under the northern part of West Bengal. Imbalance in leaf nutrient content was observed with control plot. Balancing of leaf nutrient status with application of different combination of N and K was observed only with the omission of P. This indicates that the soil P status is adequate for balanced plant nutrition.

Mean yield significantly declined with P application due to the fact that P application increased the leaf P status to excess levels, which resulted in imbalance in the leaf nutrient status. Guha (1975) also reported yield depression due to P application in acid igneous soil of Liberia. Poliniere and Brandt (1969) reported positive growth reaction from omission of P in Podozolic soil. No treatment combination showed significantly higher mean yield (g/tree/tap) over control, however, estimated yield (kg/ha) was significantly higher with fertilizer application compared to control. Application of N and K at 40 kg per ha with omission of P gave a mean (g/tree/tap) yield on par with control but the estimated yield per ha was significantly higher over control. This is because mean yield in control plot was not that low to get any significant increase in yield with fertilizer application. The application of N and K at 40 kg per ha mainly resulted in better growth performance in terms of percent tappability, bark thickness and DRC compared to control. Thus, it showed significantly higher estimated yield over control. Moreover, this is the preliminary yield trend and prolonged tapping may drain out nutrients mainly N and K through latex (Pushparajah *et al.*, 1971). Hence, over the years, higher mean yield shown by control plot may not be sustainable. There is a need to gauge the yield trend for some more years to draw precise conclusions.

CONCLUSION

Rubber growth was significantly influenced by fertilizer application particularly

N while P and K failed to show any effect. During immaturity period, N significantly increased the girth over control but it slowly faded over the years. Nitrogen significantly increased the GI but up to the fourth year only. Percent tappability was significantly influenced by N and NxK interaction. Fertilizer application did not significantly change the soil nutrient status. However, P application resulted in build up of soil P. The leaf nutrient status was significantly influenced by P and K application. Leaf P status in control plot itself was high and it became excess with P application resulting in nutrient imbalance. Fertilizer application did not bring about any significant increase in mean yield (g/tree/tap) over control. But the estimated yield (kg/ha) was significantly higher in fertilised plots than in the control plot due to the significant effect shown by the fertilizer on the growth, leaf nutrient status and to some extent on DRC and bark thickness. Among the treatment combinations 40:0:40 kg $N:P_2O_5:K_2O$ per ha showed significantly higher estimated yield (1223 kg/ha). Owing to the loss of nutrients through latex exploitation, the better preliminary mean yield (g/tree/tap) shown by the control may not be sustainable in the long run and hence the trend needs to be gauged for some more years. Considering the better balance in leaf nutrient status, tappability, mean yield and estimated annual yield, 40:0:40 kg of $N:P_2O_5:K_2O$ per ha was found optimum during the initial years of tapping.

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REFERENCES

Ananth, K. C., George, C. M., Mathew, M. and Unni, R. G. (1966). The report of the result of fertilizer experiment with young rubber in south India. *Rubber Board Bulletin*, 9: 30-42.

Bataglia, O. C. and Santos, W. R. (1999). NPK fertilization effect on soil fertility, mineral nutrition and growth of rubber trees. *Revista Brasileira de Ciencia do Solo*, 23(4): 881-890.

Beaufils, E. R. (1973). Diagnosis and Recommendation Integrated System (DRIS): A general scheme for experimentation and calibration based on principles developed from research in plant nutrition. *Soil Science Bulletin*, 1: 120.

Bray, R. H. and Kurtz, L. T. (1945). Determination of total, organic and available forms of phosphorus in soils. *Soil Science*, 59: 39-45.

Donhue, R. L., Raymond, W. M. and John, C. S. (1990). An introduction to soils and plant growth, Prentice Hall of India, New Delhi, 666 p.

Gomez, K. A. and Gomez, A. A. (1984). Statistical procedures for agricultural research. John Willey and Sons New York, 680 p.

Guha, M. M. (1975). Fertilizer response from mature rubber in Liberia. *Proceedings of International Rubber Conference*, 1975, Kuala Lumpur, Malaysia, pp. 108 - 121.

Hamzah, Mahmod, A. A., Sivanadyan, K. and Gomez, J. B. (1975). Effect of mineral fertilizer on bark anatomy of *Hevea brasiliensis*. *Proceedings of International Rubber Conference*, 1975, Kuala Lumpur, Malaysia.

Jackson, M. L. (1973). Soil chemical analysis, Prentice Hall Inc., New York, 498p.

Joseph, M., Mathew, M., Sethuraj, M. R. and Ranganathan, C. R. (1993). Diagnosis and Recommendation Integrated System: 1. Formulation of DRIS norms for *Hevea brasiliensis*. *Indian Journal of Natural Rubber Research*, 6(1&2): 111-116.

Kalam, M.A., Karthikakuttyamma, M. Punnoose, K. I. and Potty, S.N. (1980). Effect of fertlizer application on growth and leaf nutrient content of some important *Hevea* clones. *Rubber Board Bulletin*, 16(1) : 19-30.

Karthikakuttyamma, M., Joseph, M. and Nair, A.N.S.

(2000). Soils and nutrition. In: *Natural Rubber: Agromanagement and Crop Processing* (Eds. P.J. George and C. Kuruvilla Jacob), Rubber Research Institute of India, Kottayam, pp. 171-214.

Krishnakumar, A. K. and Potty, S. N. (1992). Nutrition of *Hevea*. In: *Natural Rubber: Biology, Cultivation and Technology* (Eds. M. R. Sethuraj and N. M. Mathew). Elsevier, Amsterdam, pp. 239-262.

Morgan, M. F. (1941). Chemical diagnosis by universal soil testing system. *Bulletin of the Connecticut Agricultural Experiment Station*, 450p.

Mukherjee, S. K., Sudhansu, K. Gosh and Kunal Gosh (1979). Mineralogy and chemistry of P in soil. In: *Phosphorus in Soils, Crops and Fertilizer*. Indian Society of Soil Science Publication, New Delhi, Bulletin No. 12: 9-22.

Omont, H. (1980). Effect of fertilizer application on growth of immature *Hevea* and nutrient content of soil and leaf. *International Rubber Research and Development Board Symposium*, 1980, Kottayam, India.

Owen, G., Westgarth, D. R. and Iyer, G. C. (1957). Manuring *Hevea*: Effect of fertilizer on growth and yield of mature rubber trees. *Journal of the Rubber Research Institute of Malaya*, **15**(1): 29-52.

Poliniere, J. P. and Brandt, V. H. (1969). Pot culture technique for study of *Hevea* nutrition. *Journal of the Rubber Research Institute of Malaya*, **21**(2): 250 - 257.

Potty, S. N., Abdulkalam, M., Punnoose, K. I. and George, C. M. (1974). Response of *Hevea* to fertilizer application in relation to soil fertility characteristics. *International Rubber Research and Development Board Symposium*, 1974, Cochin, India, pp. 39/1 - 39/15.

Pushparajah, E. (1969). Response on growth and yield of *Hevea* to fertilizer on Rengam series soil. *Journal of the Rubber Research Institute of Malaya*, **21**(2): 165-174.

Pushparajah, E., Chan, H. Y. and Sivanadyan, K. (1983). Recent developments for reduced fertilizer application for *Hevea*. *Proceedings of the Rubber Research Institute of Malaya Planters Conference*, 1983, Kuala Lumpur, Malaysia, pp. 313-327.

Pushparajah, E., Sivanadyan, K., Png, T. C. and Ng, E. K. (1971). Nutrient requirement of *Hevea* in relation to stimulation. *Proceedings of the Rubber Research Institute of Malaya Planters Conference*, 1971, Kuala Lumpur, Malaysia, pp. 189-200.

Puspharajah, E., Sivanadyan, K. and Yen, F. K. (1974). Efficient use of fertilizer. *Proceedings of The Rubber Research Institute of Malaya Planters Conference*, 1974, Kuala Lumpur, Malaysia, pp. 102- 114.

Rao, P.S., Jayaratnam, K. and Sethuraj, M.R. (1993). An index to assess the areas hydrothermally suitable for rubber cultivation. *Indian Journal of Natural Rubber Research*, **6**(1&2): 80-91.