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VARIATION IN MINERAL COMPOSITION OF LEAVES AND ITS RELATIONSHIP WITH PHOTOSYNTHESIS AND TRANSPIRATION IN POLYCLONAL SEEDLINGS OF *HEVEA BRASILIENSIS*

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Polyclonal seedlings of *Hevea brasiliensis* were examined for differences in major nutrient contents of leaves, photosynthetic CO_2 exchange rate (CER) and associated characteristics and biomass production. In spite of the application of equal doses of N,P and K to all the plants, considerable variations were observed in leaf N,P and K contents indicating the genotypic variation in absorption of mineral nutrients. Leaf N,P and K per unit leaf area exhibited significant positive correlations with CER, stomatal conductance (gs) and transpiration rate. Leaf nutrient content showed positive relationship with the instantaneous water use efficiency of leaves. Leaves of the polyclonal seedlings also showed appreciable variation in mineral composition, photosynthetic rate and water use efficiency.

Key words: *Hevea brasiliensis*, Shoot biomass, Transpiration, Water use efficiency.

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INTRODUCTION

Though photosynthesis is mainly controlled by genetic characteristics, environmental factors also have significant influence. Differences in photosynthetic characteristics are related to light environment, leaf anatomy, physiology, and nutrient status of leaves (Nobel *et al.*, 1975; Boardman, 1977; Barker, 1979). Relationship between leaf nutrient content and leaf photosynthetic capacity has also been reported (Moss and Peaslee, 1965; Ozbun *et al.*, 1965; Bottrill *et al.*, 1970; Natr, 1972; Barker, 1979; Jacob *et al.*, 1990; Jacob and Lawlor, 1992). Significant positive correlation between leaf N content and photosynthetic rate has been well documented in many plant species (Ryle and Hesketh, 1969; Nevins and Loomis, 1970; Brown, 1978; 1981; DeJong, 1982; Sylversten, 1984; DeJong and Doyle, 1985). Most nutrient deficiencies ultimately depress net photosynthesis (Natr, 1972). In higher plants, deficiencies of essential elements often cause visual symptoms on leaves often involving chlorosis or necrosis. When symptoms of elemental deficiency or toxicity are evident, structure of the chloroplasts is usually altered which affects photosynthesis. Relationship of major nutrients (N, P and K) with photosynthesis has not yet been reported in *Hevea*. Polyclonal seedlings were used for the experiment to assess possible relationship of genotypic variation in mineral nutrient composition of the leaves with carbon dioxide exchange rate (CER) and associated characteristics.

MATERIALS AND METHODS

The experiment was conducted at the Rubber Research Institute of India, Kottayam. Seedlings used for the study were raised from polyclonal seeds of *Hevea brasiliensis* in cement pots filled with about 45 kg of soil and grown under well watered conditions and standard cultural practices. 10:10:4:1.5 N P K Mg mixture was applied to all the pots in equal doses. Seventy seedlings were selected for the experiment. All the observations were taken at the age of eighteen months. Carbon dioxide exchange rate and transpiration were measured by a closed system infra red gas analyser (Portable Photosynthesis System, LI 6200 LICOR, USA). The ambient CO_2 was 345±15 ppm and all the measurements were taken under natural sunlight as described elsewhere (Dey *et al.*, 1995). After gas exchange measurements leaves were harvested and leaf area was recorded using a leaf area meter (LI 3000, LICOR,USA). These leaves were dried in oven for 72 h at 80°C. After recording the dry weights the leaves were used for estimation of mineral elements. Nitrogen content was determined by micro-Kjeldahl method and phosphorus and potassium by using autoanalyser (Karthikakuttyamma, 1976). The mineral contents estimated from the dry leaf samples were later converted on leaf area basis from specific leaf weight. The above ground plant parts were cut and dried in oven at 80°C and total shoot biomass recorded.

RESULTS AND DISCUSSION

Considerable variation was observed in leaf N per unit leaf area (CV=12.9%) with a mean of 0.22 mg/cm^2 (Table 1). Leaf N per unit leaf area showed a significant positive correlation with CER (Table 2, Figure 2). It is well documented in other plants that leaf N deficiency decreases net photosynthesis (Natr,1975; Jacob *et al.*, 1990). Nitrogen and chlorophyll contents of leaves decreased in N deficient plants (Jones, 1966). However, chlorophyll loss is not the only cause of decreased photosynthetic rate in N deficient leaves. N deficiency decreases capacity of the mesophyll for photosynthesis (Jacob *et al.*, 1990).

Positive correlation between leaf N and specific leaf weight (SLW) (Table 2) indicates that thicker leaves maintain high N and thus high CER. The relationship between CER and SLW in *Hevea* was reported by Dey *et al.* (1995). Field gas exchange measurements on intact peach leaves indicated that leaf N content and leaf weight per unit leaf area are highly correlated with CO_2 assimilation rate and mesophyll conductance (DeJong and Doyle, 1985).

High variation was observed in rate of CO_2 exchange per unit of N (CERN) among the genotypes. CERN showed highly significant positive correlation with CER indicating the influence of leaf N in the variation of CER among the genotypes. CERN showed significant coefficient of variation (23.5%). Considerable variation in CER in *Hevea* genotypes was reported earlier (Samsuddin and Impens, 1978b; Ceulemans *et al.*, 1984; Samsuddin, 1986; Dey *et al.*, 1995).

High values of CV were observed for conductance (37.4%) and transpiration rate (30.4%) (Table 1). The gs ranged from 0.04 to 0.2 mol/m^2/s and transpiration from 2.1 to 11.6 mmol/m^2/s with an average of 0.11 mol/m^2/s and 5.05 m mol/m^2/s respectively (Table 1). Shoot biomass exhibited the highest CV (43.6%) among the parameters observed followed by total leaf N (38.9%).

Significant positive correlations were observed between leaf N per unit area with gs and transpiration (Table 2). Earlier works indicated decrease in gs to CO_2

Table 1. **Mean, range and covariance of shoot biomass, leaf nutrient contents, CER and associated characteristics**

Variables	Mean	SE	CV (%)	Range
CO_2 exchange rate (μ moles m^2/s)	8.82	0.26	24.7	4.1-14.3
Specific leaf weight (mg/cm^2)	6.17	0.09	11.4	4.4- 8.5
Stomatal conductance (mol/m^2/s)	0.11	0.01	37.4	0.04-0.24
Transpiration (m mol/m^2/s)	5.05	0.18	30.4	2.10-11.55
Leaf N per unit area (mg N/cm^2)	0.22	0.003	12.9	0.17-0.29
Leaf K per unit area (mg K/cm^2)	0.08	0.002	18.4	0.05-0.11
Leaf P per unit area (mg P/cm^2)	0.01	0.00	18.18	0.01-0.02
CERN (μ mol CO_2 g/N/s)	4.08	0.11	23.5	2.10-6.54
Total leaf N per plant (g)	2.93	0.14	38.87	1.07-6.72
Total leaf K per plant (g)	1.00	0.05	38.67	0.46-2.00
Total leaf P per plant (g)	0.15	0.01	35.81	0.05-0.26
Total biomass (g)	200.7	10.46	43.59	47.90-429.3

exchange in N-deficient leaves of sugar beet (Nevins and Loomis,1970), maize, cotton and beans (Ryle and Hesketh, 1969). Maintenance of critical protein content in leaves is important for high CER (Lugg and Sinclair, 1981). Moreover, N being a constituent of proteins, could have many general effects on photosynthesis through its effects on protein synthesis.

Carbon dioxide exchange rate showed significant positive correlation with transpiration and gs (Figure 1). Significant positive correlations between gs and transpiration with CER and leaf N per unit area showed further evidence for the influence of leaf N on photosynthetic rate through effect on gs. The relationship of CER with gs and tran-

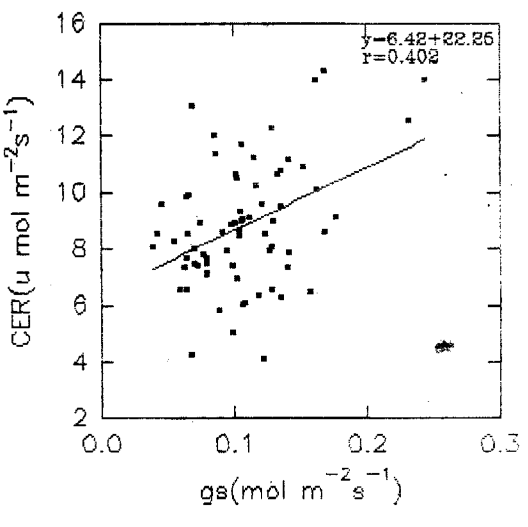

Fig. 1. Relationship between gs and CER

Table 2. **Correlation coefficient of shoot biomass, leaf mineral contents, CER and associated characteristics**

	CER	SLW	Condu ctance	Trans piration	Leaf N/ unit area	CERN	Total leaf N	Leaf K/ unit area	Total leaf K	Leaf P/ unit area	Total leaf P
Biomass	-0.11	0.08	-0.40**	-0.38**	0.001	-0.12	0.55**	0.10	0.51**	-0.003	0.57**
CER		0.25*	0.40**	0.34**	0.40**	0.85**	-0.07	0.40**	-0.03	0.33*	-0.10
SLW			0.10	0.002	0.42**	0.03	-0.004	0.58**	0.15	0.35**	-0.02
gs				0.82**	0.35**	0.21	-0.29*	0.10	-0.38**	0.27*	-0.32*
Transpiration					0.30*	0.15	-0.13	-0.021	-0.29*	0.29*	-0.13
Leaf N/unit area						-0.14	0.18	0.33*	0.01	0.61**	0.05
CERN							-0.19	0.24*	-0.05	-0.04	-0.16
Total leaf N								-0.18	0.85**	-0.09	0.94**
Leaf K/unit area									0.23*	0.31*	-0.19
Total leaf K										-0.14	0.84*
Leaf P/unit area											0.04

* Significant at 1% level ** Significant at 0.01 1% level

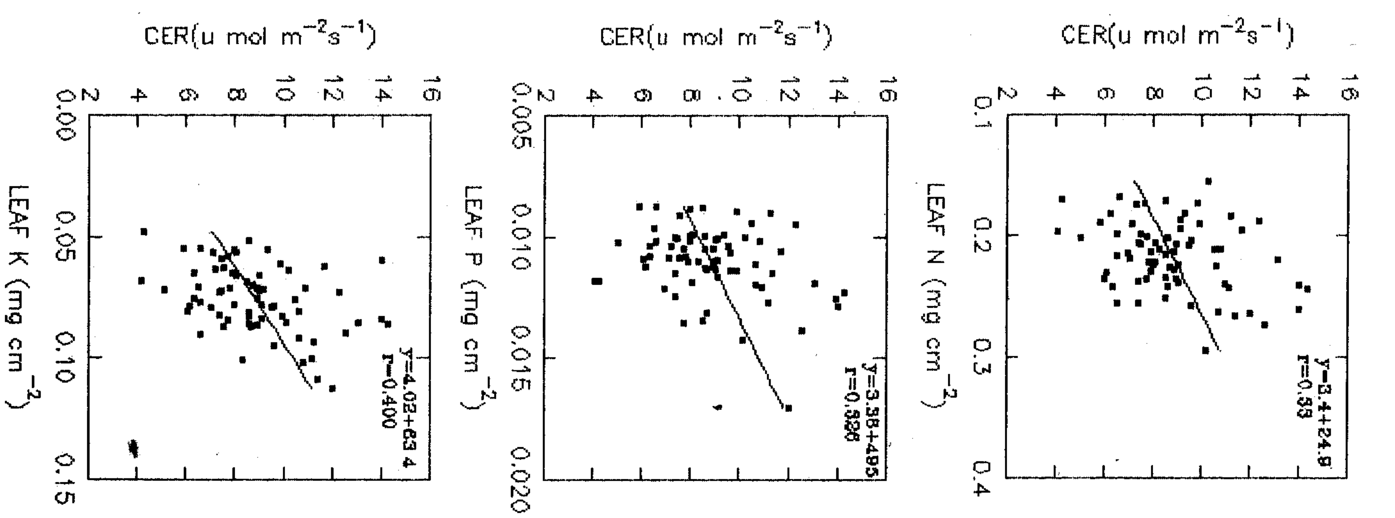

Fig. 2. Relationship between leaf N, P and K with CER

spiration was reported earlier in *Hevea* by Samsuddin and Impens (1978a).

Considerable variation was observed in leaf K per unit area (CV 18.4%) and total leaf K per plant (CV 38.6%)(Table1). Total leaf K showed variation among the genotypes (0.46 to 2.0 g). In the present observations K per unit leaf area also showed significant positive correlation with CER (Table 2, Figure 2). Significantly high positive correlation was found between leaf K per unit area and specific leaf weight which indicates that thicker leaves have high K content per unit area which in turn is related to high CER. K deficiency decreases stomatal aperture and affects CO_2 exchange rates of leaves (Barker,1979). In this study there was no significant correlation between leaf K per unit area with gs and transpiration. According to Natr (1975) K deficiency decreased diffusion resistance of stomata. Samarappuli (1992) suggested that K sufficient rubber plants appear to close stomata and reduce transpiration more rapidly than K deficient ones. Under moisture stress conditions, adequate supply of K was reported to impart tolerance to moisture stress by influencing the rate of transpiration , CER and expansive growth (Hsiao and Lauchli, 1985).

Leaf P per unit leaf area showed a CV of 18.18% (Table 1). The leaf P level also showed significant positive correlation with CER (Table 2, Figure 2) though not as pronounced as leaf N and K per unit leaf area. Leaf P per unit area also exhibited a positive correlation with gs (Figure 3) and transpiration rate. It is reported that the effect of P deficiency on rate of photosynthesis is substantially less pronounced than N and only a strong decrease in leaf P depressed photosynthesis (Natr, 1975).

Instantaneous water use efficiency, defined as the ratio of A/gs, was calculated and the seedlings were classified into three

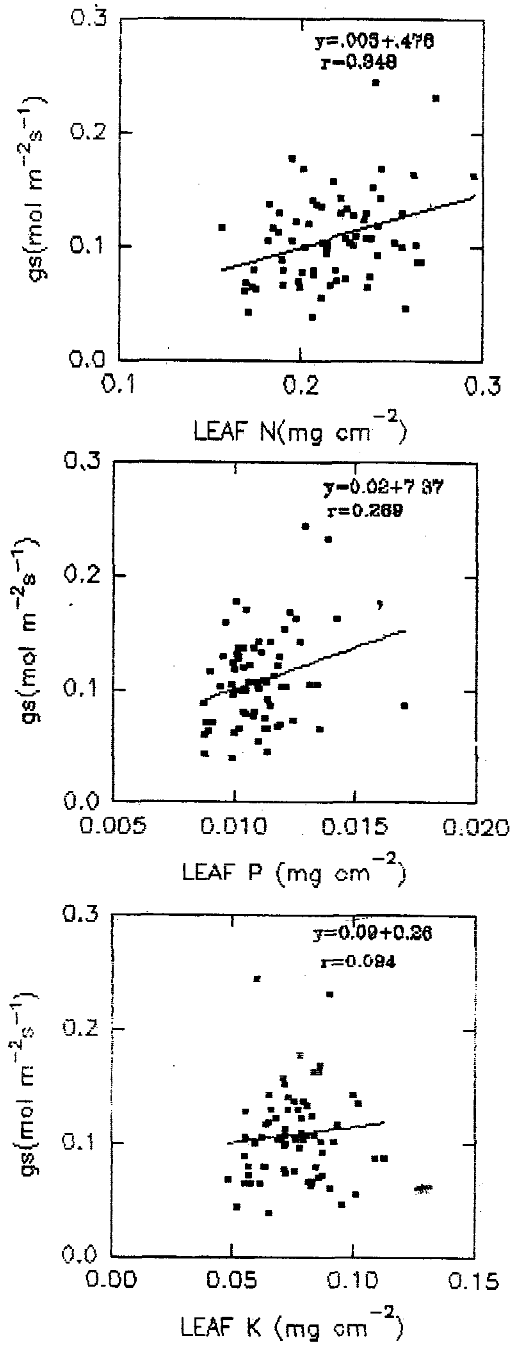

Fig. 3. Relationship between leaf N, P and K with gs

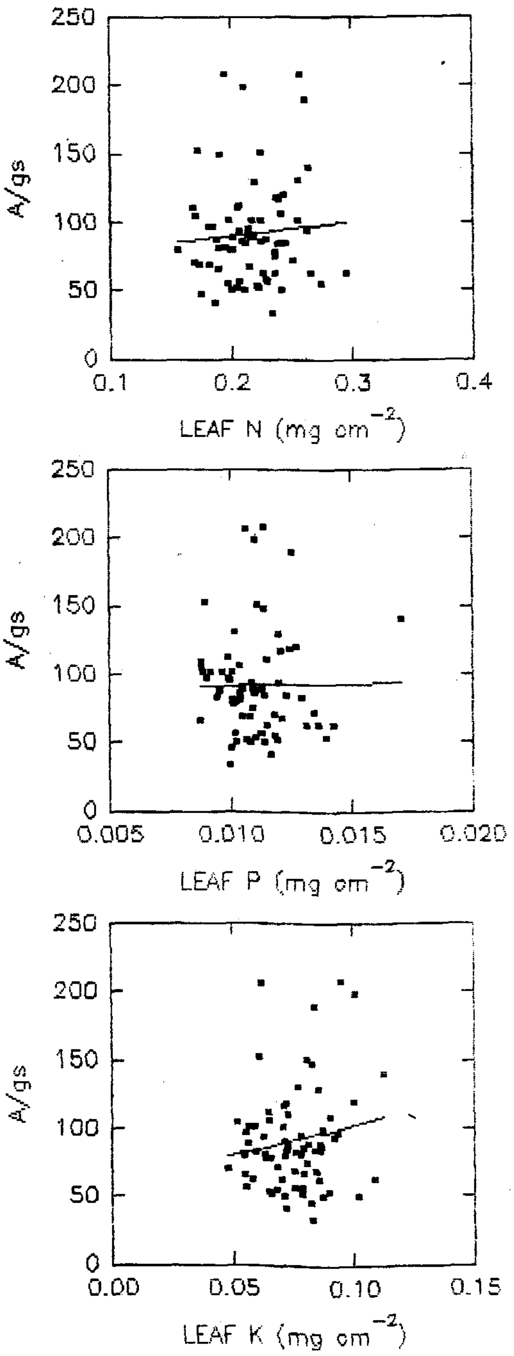

Fig. 4. Relationship between leaf N, P and K with A/gs

categories showing A/gs ratios below 60 mol, between 60-90 mol and between 90-135 mol CO_2/mol H_2O (Figure 4 & 5). The considerable variation in this ratio was positively correlated with leaf N,P and K suggesting that the higher the leaf nutrient contents, the better the instantaneous water use efficiency. This is because the increase in CER per unit increase in leaf mineral content was more than the increase in gs or transpiration.

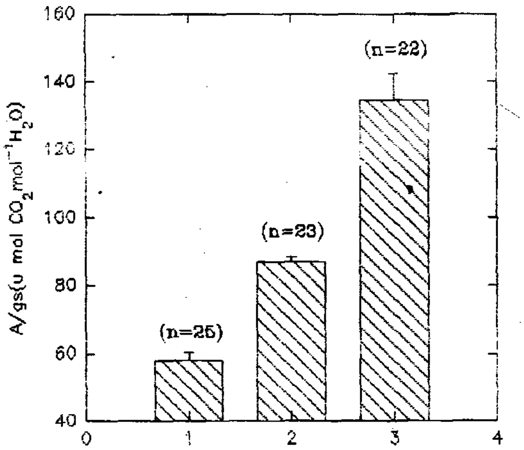

Fig. 5. Frequency distribution of A/gs among the polyclonal seedling population of *Hevea brasiliensis*

The genotypic variation in leaf mineral nutrients, gs and CER and the correlations existing among these factors indicate that the nutrient use efficiency and water use efficiency of the genotypes were markedly different in the polyclonal seedling population. Nitrogen is reported to be the most common nutritional factor limiting CER and biomass production (DeJong, 1982). Phosphorus may exert a direct effect on photosynthesis by modifying the energy metabolism. Potassium indirectly affects photosynthesis through its effect on gs.

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