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GAS EXCHANGE P[illegible]TERS FOR EARLY SELECTION OF *HEVE[illegible]ILIENSIS* MUELL. ARG

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ABSTRACT

Selecting high yielding progeny from Hevea *breeding programmes is a money and time consuming approach and limits the progress of breeding. Girth, bark thickness, number of latex vessel rings, latex vessel density and first few years yield of 7--8 year old* Hevea *buddings are reported to be correlated to the yield potential. These parameters are used by some breeders for a primary selection using small scale clone trials. Latex is biosynthesised from sucrose in latex vessels and the potential of sucrose supply to latex vessels depends on* CO_2 *assimilatory capacity of the canopy and the partitioning of assimilates. Attempts were made to estimate the mean* CO_2 *assimilatory capacity of a healthy and a mature leaf whorl in year old* Hevea *clonal buddings. Preliminary studies show the mean* CO_2 *assimilatory capacity of a whorl and its ratio with water use efficiency value to be correlated with yield potential. These observations suggest that effective selection of clones for further testing in large scale clone trials could be done on this basis, when buddings are around a year old.*

INTRODUCTION

The progress of breeding *Hevea* for high yields is limited as a reliable early selection method is not available. A primary selection of promising clones, for further testing is possible based on first 2 years yield from conventional tapping (Alika, 1980; Huat, 1981). The girth, bark thickness, total number of latex vessel rings and density of latex vessels are also correlated to yield potential at this stage of growth i.e. when buddings are 7—8 years old (Paiva 1982; Gonclaves 1982; Ribeiro 1984). These parameters or the micro tapping yields cannot be used for screening when buddings are around a year old (Paardekooper, 1956). Alternative characters which could help in a primary selection at this stage of growth are therefore being sought.

In *Hevea* the economically important latex is biosynthesised from sucrose in the latex vessels (Tupy, 1985) and the potential of sucrose supply is determined by the rate of CO_2 assimilatory capacity of the canopy and the partitioning of assimilates. Correlations between leaf CO_2 assimilation and yield have been established in crops where the vegetative part is the economic product (Ceulmans, Impens, Hebrant and Moormans 1980; Rao and Rama Das 1981). Strong correlations between canopy photosynthesis and yield have been established for many food and timber crops, but leaf photosynthesis has rarely been correlated. For *Hevea* a correlation between leaf CO_2 assimilation rate and economic product was not found (Nugawela, Aluthhewage 1984; Samsuddin, Tan, Yoon 1985). Evans (1975) pointed out that there is little evidence of any positive relationship between yield and leaf photosynthetic rate in crops having a lower harvest index.

Though CO_2 assimilation rate per unit leaf area reflects the genetic potential of the leaves to accumulate carbon, the total carbon assimilated by a plant depends on other canopy characteristics as well. The importance of total leaf area were shown by Watson as early as in 1952 (Elmore, 1980) and also by Yoon, Leong and Wanchik (1976) for *Hevea*.

Selection for lower respiration rates could lead to considerable improvement in productivity. It is estimated that 75% of gross production might be respired by trees in tropical rain forests, 85% by tea and 80% by oil palm (Corley, 1980).

Attempts were made to estimate the mean CO_2 assimilatory capacity of a healthy and a mature leaf whorl in year old *Hevea* clonal buddings. Five *Hevea* clones having different yield potentials were used for the study. Though lower leaf diffusive resistance could facilitate influx of CO_2 to the leaf, it will also increase transpiratory water loss. Water use efficiency value *i.e.* the number of moles of water lossed per mole of CO_2 fixed is comparatively low in highly productive cultivars (Kozlowski, 1975). These parameters were studied in relation to *Hevea* selection.

MATERIALS AND METHODS

Plant material—Five *Hevea* clones of known yield potentials *viz.*, RRIC 100, RRIC 103 RRIC 45, PB 86 and IAN 710 were grown from budded stumps in field according to a fully randomize design. Each clone was replicated 20 times. Material for studies described below were gathered when plants were around 1—1½ years old.

Comparison of CO_2 exchange rates—Differential measurements of CO_2 assimilation rates were done using a laboratory system based on an Infra Red Gas Analyser (ADC Mark II, Type 225) and is described elsewhere (Nugawela and Aluthhewage 1984). Leaves of the second whorl, in plants where the top whorl had hardened were used for the study. Photorespiration rate was estimated by measuring post illumination CO_2 outburst and CO_2 efflux to CO_2 free air, immediately after measuring CO_2 assimilation rates. Dark respiration rates were measured using leaf chambers painted in black. Leaves sampled for dark respiration rate measurements were given a 2 hour dark pretreatment at 25° C prior to measurements.

Comparison of mean leaf size and mean leaf area per single whorl

A random sample of 10 plants were taken from each clone. From a plant, two leaf whorls were selected at random. In each leaf whorl the number of leaves were counted. Three leaves were selected from a whorl, one from the bottom, middle and top for leaf area measurements using a compensating polar plannimeter (Chromopack, Mederland). The average area of the three leaves sampled was taken as the mean leaf size of the particular whorl and this multiplied by the number of leaves in the whorl was taken as total leaf area of the lleaf whorl. The average of all 10 replicates were taken to find mean leaf size and mean leaf area per whorl.

Water use efficiency—Measurements of transpiration rates and leaf diffusive resistance have been described earlier (Nugawela, Wickremasinghe and Aluthhewage 1984). Water use efficiency (WUE) value was determined as shown below:

$$\text{WUE value} = \frac{\text{Transpiration rates } (/^{u}\text{mol H}_2\text{O m}^{-2}\text{s}^{-1})}{\text{CO}_2 \text{ Assimilation rates } (/^{u}\text{mol CO}_2 \text{ m}^{-2}\text{s}^{-1})}$$

Stomatal density—This was done using the silicone rubber impression method. Five plants per clone and 2 mature leaves per plant were sampled for this study. Two counts were taken from each leaf.

RESULTS

The CO_2 assimilation rates (A) and photorespiration rates (R_p) of the clones studied were significantly different. Clonal differences in dark respiration (R_d) is not significant (Table 1).

Table 1. *CO_2 assimilation rates—A ($/^{u}$ mol m^{-2} s^{-1}), dark respiration rates —Rd (/u mol m^{2}- s^{1}) photorespiration rates—Rp ($/^{u}$ mol m - ^{2} s -^{1}) and yield potentials (g t^{-1} t^{-1})of the* Hevea *clones studied.*

Clone	A	Rd	Rp	Yield
RRIC 100	5.1781	1.6293	1.1286	33.94
RRIC 103	7.3014	1.5590	0.9115	39.93
PB 86	7.2463	1.8274	0.9497	29.94
RRIC 45	6.4675	1.6391	1.2331	21.20
IAN 710	6.2191	1.5046	0.9941	34.74
Significance	***	n.s.	***	
LSD	0.4604		0.1289	

*** $P < 0.001$

The differences in mean leaf size (*la*), mean leaf area in a single leaf whorl (*La*) and stomatal densities are significant (*Table* 2).

Table 2. *Mean leaf size—la* (cm^2), *mean leaf area in a single leaf whorl—La* (cm^2) *and stomatal densities* (cm^{-2}) *of the selected* Hevea *clones.*

Clone	la	La	Stomatal density
RRIC 100	320.88	7059	41,450
RRIC 103	234.54	4691	41,853
PB 86	234.54	4460	49,520
RRIC 45	204.64	3479	38,743
IAN 710	259.72	5974	48,136
Significance	***	***	***
LSD	25.98	685	1593

***$P < 0.001$.

Water use efficiency values of the clones with their transpiration rates (*E*) and leaf diffusive resistance (Nugawela *et al.*, 1984) are given in Table 3.

Table 3. *Transpiration rates—E* (μ *mol* m^{-2} s^{-1}), *diffusive resistances—DR* (s cm^{-1}) *and water use efficiency value—WUE of the selected* Hevea *clones.*

Clone	E $(\times 10^3)$	DR	WUE
RRIC 100	3.4911	3.323	674.20
RRIC 103	4.3430	2.592	601.66
PB 86	5.7635	1.908	795.37
RRIC 45	4.9506	2.674	765.45
IAN 710	5.4827	2.051	881.59
Significance	*	**	
LSD	1.3867	0.7230	

*$P < 0.05$ **$P < 0.01$

DISCUSSION

Mean yields of clones RRIC 100, RRIC103, RRIC45, PB86 and IAN710 from genotype environment trials (Jayasekera, 1985) were considered as their yield potentials. The correlation of the yield potential with gas exchange parameters and anatomical features were worked out to find out the possibility of using them in early selection for yield. The correlations were positive but no single parameter showed a significant correlation with yield potential (Table 4).

Table 4. *The correlation (r) of mean leaf size (la), mean leaf area in a single whorl (La), CO_2 assimilation rate (A), photorespiration rate (Rp) and water use efficiency (WUE) with yield potential.*

Parameter	Correlation coefficient	Significance
la	0.4613	n.s.
La	0.5585	n.s.
A	0.0754	n.s.
Rp	0.7671	n.s.
WUE	0.4748	n.s.

CO_2 assimilation rates showed a remarkably low correlation with yield potential, anyhow with an n of 5 only the strongest correltations are likely to be detected. Similar findings have been reported for *Hevea* earlier by Nugawela et. *al.*, (1984) and Samsuddin et. *al.*, (1985). In breeding for improved yields by selecting for high photosynthetic rates, selection for other important factors such as total assimilatory area and phloem transport capacity should be considered (Elmore, 1975). This suggests that if canopy photosynthesis is estimated it could show a closer correlation with yield potential.

The leaf area in a leaf whorl differed significantly in the 5 *Hevea* clones studied. This could give an indication of the differences in total assimilatory area of the canopies in mature plants of the same clones. Likewise the assimilatory capacity of a leaf whorl (A. La) may reflect the differences in assimilatory capacity of canopies in mature plants. In year old buddings with a hardened top whorl, the leaves of the second whorl showed highest CO_2 assimilation rates (Nugawela et. *al.*, 1984). Hence the mean CO_2 assimilation capacity of a whorl (A.La) estimated this way will give the maximum CO_2 assimilation capacity of a whorl. Photorespiratory loss of carbon tends to be low in high yielders. This was taken into consideration (A-Rp. La) to estimate net assimilatory capacity of a leaf whorl. The mean assimilatory capacity per leaf whorl calculated with and without considering photorespiratory loss of carbon significantly correlates with the yield potential in the 5 clones studied. The value for water use efficiency tends to be low in high yielding clones (Tables 3 and 4). The ratio A—Rp. La/WUE calculated for the 5 clones showed a very close correlation with the yield potential (Table 5).

Table 5. *The mean assimilatory capacity per whorl (μ mol CO_2 s^{-1}) without and with considering photorespiration, the ratio of the latter with water use efficiency value and their correlation (r) with yield potential (g t^{-1} t^{-1}).*

Clone	Yield	A.La	A-Rp .La	A-Rp La/WUE
RRIC 100	33.94	3.5652	2.997	.0042
RRIC 103	39.93	3.4250	2.997	.0049
PB 86	29.94	3.231	2.808	.0035
RRIC 45	21.20	2.250	1.821	.0023
IAN 710	34.74	3.715	3.1214	.0035
r		8.613	.9051	.9444
Significance of r		*	*	**

*$P < 0.05$ **$P < 0.01$

The parameter, A-Rp .La/WUE could be calculated when *Hevea* clonal buddings reach a four whorl stage (around one year growth). By comparing this parameter of the new progeny with that of control clones (known yield potential) grown together in field, promising clones could be identified for further testing using large scale clone trials. Studies are being continued for verification of the findings from this preliminary study.

A knowledge of leaf characters linked with high CO_2 assimilatory capacity might be useful for breeders to identify parental clones in breeding for high CO_2 assimilatory capacity. Initial studies show that there is a tendency for clones with smaller leaf size to have a high CO_2 assimilation capacity per unit leaf area. Such observations are abundant in literature. Elmore (1975) suggests that this is due to the photosynthetic apparetus getting diluted when leaf area is large. Hence clones with smaller leaves, but a large number to increase total assimilatory area could form a canopy with a high CO_2 assimilatory capacity. Diffusive resistance to water vapour exchange was low in clones with a high stomatal density. In *Hevea* stomatal diffusive resistance influences transpiratory water loss than CO_2 influx during photosynthesis (Nugawela et. *al.*, 1984). A higher gain in transpiration rates than in CO_2 assimilation rates due to lower stomatal diffusive resistance could result in a comparatively higher water use efficiency value and hence a lower productivity.

REFERENCES

ALIKA, J. E. (1980). Possibilities of early selection in *Hevea brasiliensis*. *Silvea. Genet.* 29(3/4), 161-162

CEULMANS, R. IMPENS, L. HERBRANT, F. MOORMANS, B. (1980). Evaluation of field productivity for several poplar clones. *Photosynthetica* 14, 355—362.

CORLEY, R. H. V. (1980). Potential productivity of Tropical perenial crops. *Expt. Agric.* 19, 217—237.

ELMORE, C. D. (1980). The paradox of no correlation between leaf photosynthetic rates and crop yields, in predicting photosynthesis for Ecosystem models Svol. 2 J. D. HESKTH, J.W. JONES, *Ed.*, CRC Press, Inc., 156-164.

EVANS, L. T. (1975). The physiological basis of crop yield, In Crop Physiology, EVANS, L. T. *Ed.*, Cambridge University Press, U.K.

GONCLAVES, PANLO DE SOYZA (1982). Collection of *Hevea* materials from Rondonia Territory by Brazil. A preliminary study. *Pesqui. Agropecu. Brus.* 17 (4), 575-582.

HUAT, O. S. (1981). Correlations between yield, girth and bark thickness of RRIM clone trials. *J. Rubb. Res. Inst. Malays.* 29(1), 1—14.

JAYASEKERA, N. E. M., KARUNASEKERA, K. A. B. and RUPATUNGE, K. W. (1984). Genotype—enviornment interaction studies. *A. Rev, Rubb, Res, Inst. Sri Lanka.* 27—43.

KOZŁOWSKI, T.T. (1975). Water relation and tree improvement, in tree physiology and yield improvement. M. G. R. Cannel and F. T. Last *Ed.*, Academic Press, London. 307—329.

NUGAWELA A. and ALUTHHEWAGE, R. K. (1984). Net photosynthetic activity and its relationship with potential productivity of some *Hevea* clones. *Proc. Int. Rubb. Conf. Colombo.* 137-149

NUGAWELA, A.WICKREMASINGHE, W. N. and ALUTHHEWAGE, R. K. (1984). Variations involved in field measurments of transpiration rates and stomatal diffusive resistance. *Jl. Rubb. Res Inst. Sri Lanka* 62, 47—58.

PAARDEKOOPER, E. C. (1956). Further data on early selection in *Hevea*. *Archives of Rubber Cultivation* 33, 160—194.

PAIVA, J. R. (1982). Use of path coefficient in *Hevea brasisliensis* breeding, *Pesqui, Agropecu, Bras*, 17 (3), 433—440.

RAO, A. N. and RAMA DAS, V. S. (1981). Leaf photosynthetic characters and crop growth rate in six cultivars of ground nut. *Photosynthetica* 15, 97—103.

RIBEIRO, S. L. (1984). Correlation among 9 characters of rubber tree clones at Porto velho condition, Rondonia State. *Pesqui Agropecm. Bras*, 19 (10), 1235—1246.

SAMASUDDIN, Z. TAN, H. and YOON, P. K. (1985). Variations, heritabilities correlations of photosynthetic rates, yield and vigour in young *Hevea* seedling progenies Proc. *Int. Rubb. Conf- Kuala Lumpur.*

TUPY, J. (1985). Some aspects of sucrose transport and utilization in latex producing bark of *Hevea brasiliensis*. *Biol. Planta (Prague)* 27 (1), 51—64.

YOON, P. K. LEONG, W. and WANCHIK, G. B. (1976). An approach to modify branching habits —its effects and potentials Proc. *Int. Rubb. Conf. Kuala Lumpur.*