Correlation and Path Coefficients of Seed and Juvenile Characters with Respect to Latex Yield in *Hevea brasiliensis* Muell. Arg.

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Keywords: *Hevea*- Latex yield- Seed and juvenile characters

Summary

Ten Hevea *clones were evaluated for direct and indirect effects of sixteen seed and juvenile characters on latex yield. Each clone was evaluated for five juvenile characters, eleven seed characters and latex yield. Genotypic variance and correlation were obtained through analysis of variance and covariance respectively. Phenotypic correlation was calculated as simple correlation of clonal means. The phenotypic correlation of each seed and juvenile character with latex yield was partitioned into direct and indirect effects through path analysis. The most reliable character for indirect selection for latex yield was ratio of seed length/width, which had relatively high direct effect and significant phenotypic and genotypic correlation with latex yield. This relationship had the stabilizing influence of ratios of seed/shell weight and seed weight/volume. The pattern of use of effect coefficients for simultaneous improvement of latex yield and associated characters is provided.*

Résumé

Etude des coefficients de corrélations et de variances de graines et de caractères juvéniles en vue d'évaluer le rendement en latex d' *Hevea brasiliensis* Muell. Arg.

*Cet essai étudie les effets directs et indirects de 16 paramètres relatifs aux graines et au stade juvénile, sur le rendement en latex chez 10 clones d'*Hevea*. Chaque clone a été évalué pour 5 caractères juvéniles et 11 caractères de la graine. L'évaluation de la variance et de la corrélation génotypique a été obtenue respectivement par l'analyse de la variance et de la covariance. La corrélation phénotypique des caractères juvéniles et de la graine en rapport avec le rendement en latex a été évaluée par comparaison des effets directs et indirects et cela par calcul de la variance. Le critère indirect, le plus fiable, permettant une évaluation du rendement en latex a été le rapport longueur/largeur de la graine. Ce rapport avait une corrélation significative entre le phénotype, le génotype et le rendement en latex. Il a été constaté en plus que ce rapport était corrélé au rapport poids graine/coque et au rapport poids/volume de la graine. Le mode d'utilisation de ce modèle d'effets de coefficients, pour une amélioration simultanée du rendement en latex et des caractères associés est fourni.*

Introduction

Hevea brasiliensis is tropical tree crop that is valued for its latex. The latex is referred to as natural rubber. Despite the competition with synthetic rubber, natural rubber is valued for the production of heat resistant plastic products such as tyre, tube and bearings (8, 16). *Hevea* has been exploited for latex since the nineteenth century, while the *Hevea* seed assumed economic importance in the 1970s. The *Hevea* seed is source of oil, which is a raw material for the production of alkyd resin (1). The resin is used for the manufacture of surface coatings such as paints, varnish, inks etc. Plant breeders presently face the challenge of developing and recommending clones with combined attributes of seed and latex production. Also important is immature vigour for early exploitation. The relationship among these three desired features of *Hevea brasiliensis* will influence the breeding procedure in the development of high latex yielding, vigorous and prolific seed producing clones. Hence the objective of this study, which is the application of correlation and path analyses to determine the relationship between latex yield and each of juvenile vigour and seed character in *Hevea brasiliensis.*

Material and methods

Ten *Hevea* clones were evaluated at the out-station experiment of the Rubber Research Institute of Nigeria (RRIN), located at Igbotako, Ondo State, Nigeria for latex yield, eleven seed characters and five juvenile characters. The ten clones were five RRIN developed clones (NIG 800 to NIG 804), and five exotic clones (RRIM 600, RRIM 614 and PB 217 from Malaysia, RRIC 45 and IAN 710 developed in Sri Lanka and Brazil respectively). The experimental design for each character was the randomized com-

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plete block with three replicates per clone and ten trees per clone per replicate. Plant spacing was 3.4 m x 6.7 m. The clones were planted in 1983 and evaluated for four juvenile characters in 1985. Data on each stand were taken as follows:

a) Stem height: measured with the aid of a telescoping measuring pole and recorded in metre.

b) Stem diameter: measured by vernier callipers and recorded in centimetre.

c) Bark thickness: a strip of the bark was excised and the thickness measured with the aid of vernier callipers and recorded in centimetre.

d) Leaf whorls: a count of the number of leaf whorls was taken.

The fifth juvenile character (vigour index) was obtained as $\log_{10}$ of the product of stem height and diameter.

Latex exploitation in the plantation commenced in 1993 at half spiral, alternate daily ($^{1}/_{2}S$, $^{d}/_{2}$) tapping frequency as recommended by Opeke (12). Yield stimulants were not used. Tapping was carried out with the conventional tapping knife between 6.00 hours and 8.00 hours of each tapping day. Latex yield data collection was carried out for five years (1993 to 1997). Clonal mean latex yield was recorded as gramme per tree per tapping (g/t/t) was described by Aniamaka and Olapade (2), and RRIN (14).

In 1993 and 1994, the ten clones were evaluated for eleven seed characters. Data were taken on six seed characters with a sample of thirty seeds per replicate. Measurements were taken as follows:

a) Seed length and width: taken separately with vernier callipers and recorded in centimetre.

b) Seed weight: measured as bulk weight of the thirty seeds per replicate and recorded in gramme.

c) Seed volume: measured on each seed as the volume of water (ml) displaced in measuring cylinder.

d) Kernel and shell weight (g): measured by shelling the thirty seeds in each replicate. The kernels were separated from the shells and each group was weighed separately.

Five additional seed characters were obtained as ratios of seed length/width, seed/kernel weight, seed/shell weight, kernel/shell weight and seed weight/volume.

The clonal means of each of latex yield, the eleven seed characters and the five juvenile characters were calculated and utilized for inter-character phenotypic correlation coefficients. The Lotus 1.2.3. Release 5 computer programme was applied to determine the inter-character phenotypic correlations. The coefficients of phenotypic correlation provided the data matrix for determination of direct and indirect effects of each of the sixteen seed and juvenile character on latex yield. The same Lotus 1.2.3. Release 5 computer programme was applied to determine the path coefficients.

Estimates of genotypic variance (V_{gx} or V_{gy}) and covariance (V_{gxy}) were obtained through expected mean squares of analyses of variance and covariance respectively (6, 15). Genotypic correlation (Γ_{gxy}) was obtained as:

$$\Gamma_{gxy} = \frac{V_{gxy}}{\sqrt{(V_{gx}).(V_{gy})}}$$

There was F-test of clonal variation for each of latex yield, seed and juvenile character.

Results

Clonal variation was significant for nine seed characters, three juvenile characters and latex yield (Table 1).

Table 1

Clonal means (+) of significant *Hevea* seed (A – K) and juvenile (L – N) characters for path analysis of latex yield (Q)

Clone	Seed length (A*)	Seed width (B*)	Seed weight (C*)	Seed volume (D)	Kernel weight (E*)	Shell weight (F*)	Ratio of A/B (G**)	Ratio of C/E (H*)	Ratio of C/D (K**)	Stem height (L*)	Stem diameter (M*)	Vigour index (N*)	Latex yield (Q**)
NIG 802	2.57 (1)	2.23 (2)	1.93 (6)	3.98 (1)	0.34 (8)	1.29 (3)	1.16 (3)	10.77 (1)	0.49 (9)	1.62 (9)	1.91 (8)	0.45 (9)	27.49 (6)
NIG 800	2.52 (2)	2.26 (1)	2.09 (1)	3.88 (2)	0.41 (6)	1.46 (1)	1.12 (6)	8.44 (3)	0.54 (7)	2.27 (4)	2.23 (7)	0.70 (7)	29.41 (4)
NIG 801	2.47 (3)	2.11 (9)	1.95 (5)	3.27 (7)	0.48 (5)	1.25 (5)	1.18 (1)	9.61 (2)	0.59 (1)	1.83 (8)	1.79 (9)	0.51 (8)	21.26 (9)
RRIC 45	2.45 (4)	2.14 (6)	1.89 (7)	3.46 (5)	0.57 (3)	1.15 (6)	1.15 (4)	5.51 (6)	0.55 (4)	2.57 (2)	2.49 (3)	0.80 (3)	29.56 (5)
NIG 803	2.45 (5)	2.21 (3)	2.09 (2)	3.86 (3)	0.56 (4)	1.34 (2)	1.11 (7)	3.94 (10)	0.55 (5)	2.36 (6)	2.40 (4)	0.74 (5)	40.59 (2)
RRIM 614	2.44 (6)	2.14 (7)	1.38 (9)	2.97 (9)	0.22 (10)	0.91 (9)	1.15 (5)	6.82 (4)	0.50 (8)	2.55 (3)	2.71 (2)	0.83 (2)	25.27 (7)
IAN 710	2.42 (7)	2.06 (10)	1.26 (10)	2.84 (10)	0.37 (7)	0.82 (10)	1.18 (2)	4.42 (9)	0.44 (10)	2.37 (5)	2.45 (6)	0.76 (4)	20.87 (10)
PB 217	2.36 (8)	2.16 (5)	1.99 (4)	3.40 (6)	0.59 (2)	1.11 (8)	1.10 (9)	5.10 (8)	0.58 (2)	2.79 (1)	3.10 (1)	0.94 (1)	30.88 (3)
RRIM 600	2.35 (9)	2.14 (8)	2.01 (3)	3.54 (4)	0.75 (1)	1.15 (7)	1.11 (8)	5.39 (7)	0.55 (6)	1.56 (10)	1.78 (10)	0.44 (10)	24.29 (8)
NIG 804	2.3 (10)	2.21 (4)	1.81 (8)	3.20 (8)	0.31 (9)	1.26 (4)	1.04 (10)	6.58 (5)	0.56 (3)	2.26 (7)	2.40 (5)	0.71 (6)	48.42 (1)
Overall mean	2.43	2.17	1.84	3.44	0.46	4.23	1.13	6.66	0.53	2.22	2.32	0.69	29.80
lsd.	0.03	0.03	0.13	0.13	0.23	0.10	0.01	1.90	0.03	0.34	0.34	0.14	3.79

*, * *: Significant at P= 0.01 and P= 0.05 respectively (F-test)
lsd: Least significant difference
(+): Figures in parenthesis represent rank

The best latex yielding clones were NIG 803 and NIG 804 at latex yield of 40.59 g/t/t and 48.42 g/t/t respectively (Table 1). These realized latex yields were significantly higher than latex yield of any of the exotic clones (Table 1). The clone RRIM 600 had clonal mean seed and kernel weight of 2.01 g/seed and 0.75 g/seed respectively. These values were significantly higher than overall means in each case. Clonal mean seed weight for PB 217 (1.99 g/seed), NIG 800 (2.09 g/seed) and NIG 803 (2.09 g/seed) were significantly higher than the overall mean (Table 1). For the juvenile characters, clonal means of stem height, stem diameter and vigour index for PB 217 at 2.79 m, 3.10 cm and $\log_{10}$ 0.94 were significantly higher than their respective overall means. The clonal mean stem height of RRIC 45 (2.57 m) was significantly higher than the overall mean while stem diameter and vigour index for RRIM 614 at 2.71 cm and $\log_{10}$ 0.83 (respectively) were significantly higher than their respective overall means. For combination of characters, NIG 803 and PB 217 ranked between first and fourth for four important characters viz seed and kernel weights, juvenile stem diameter and latex yield (Table 1). The genotypic correlation of bark thickness, and each of ratios of seed/shell weight and kernel/shell weight with most of the other characters were very low and hence negligible (Table 2).

In some instances, the direct effect was though in the same direction with correlation, there was a drastic reduction in magnitude from direct effect to correlation with latex yield. This was the case of seed weight with direct effect of 1.56 and correlation at $\Gamma_g = \Gamma_p = 0.33$ (Tables 2 and 3). This reduction was mainly due to negative indirect effects of seed volume and ratios of kernel/shell weight, seed weight/volume at -1.09, -0.72 and -1.34 respectively (Table 3). The positive indirect effect of shell weight at 0.91 is also important (Table 3). Fortunately, the direct effect of shell weight on latex yield was 1.03 with correlation of $\Gamma_g = 0.49$ and $\Gamma_p = 0.45$ (Tables 2 and 3). There were negative indirect effects of seed volume, ratios of kernel/shell weight, seed weight/volume and stem height at -1.12, -0.74, -1.04 and -0.52 respectively and positive indirect effects via seed weight, ratio of seed/shell weight and vigour index at respective indirect effects of 1.39, 1.21 and 0.62 in the relationship between shell weight and latex yield. The direct effect of stem height and correlation with latex yield were 1.65 and 0.26 respectively (Table 3).

The reduction from 1.65 to 0.26 was due to the influence of vigour index at indirect effect of -1.75 (Table 3). Vigour index had insignificant phenotypic and genotypic correlation with latex yield (Table 2).

Table 2
Phenotypic (upper diagonal) and genotypic (lower diagonal) correlation coefficients of *Hevea* latex yield (Q), seed (A – K) and juvenile (L – P) characters

	Seed lenght (A)	Seed width (B)	Seed weight (C)	Seed volume (D)	Kernel weight (E)	Shell weight (F)	Ratio of A/B (G)	Ratio of C/E (H)	Ratio of C/F (I)	Ratio of E/F (J)	Ratio of C/D (K)	Stem height (L)	Stem diameter (M)	Vigour index (N)	Bark Thickn. (O)	Leaf whorls (P)	Latex yield (Q)
A	=	0.29	0.14	0.52	-0.27	0.33	0.65*	0.63*	-0.11	-0.13	-0.27	-0.25	-0.35	-0.29	0.05	0.15	-0.38
B	0.33	=	0.63*	0.79**	-0.13	0.82**	-0.53	0.34	-0.65*	-0.65*	0.26	-0.11	-0.07	-0.11	0.29	0.70*	0.60
C	0.22	0.67*	=	0.83**	0.58	0.88**	-0.37	0.20	-0.65*	-0.63*	0.75*	-0.27	-0.29	-0.30	0.24	0.63*	0.33
D	0.01	0.83**	0.87**	=	0.31	0.84**	-0.15	0.32	-0.51	-0.51	0.29	-0.36	-0.35	-0.37	0.20	0.59	0.23
E	-0.31	-0.15	0.61	0.18	=	0.18	-0.11	-0.41	-0.03	-0.01	0.51	-0.17	-0.17	-0.18	-0.05	0.04	-0.10
F	0.36	0.91**	1.00**	0.90**	0.28	=	-0.36	0.42	-0.68*	-0.65*	0.58	-0.31	-0.38	-0.35	0.19	0.83**	0.45
G	0.67*	-0.53	-0.38	-0.15	-0.14	-0.38	=	0.29	0.41	0.40	-0.45	-0.18	-0.28	-0.21	-0.23	-0.43	-0.85**
H	0.79**	0.45	0.28	0.40	-0.37	0.46	0.38	=	-0.42	-0.44	0.04	-0.54	-0.54	-0.57	-0.22	0.12	-0.23
I	N	N	-0.87**	N	N	N	N	N	=	1.00**	-0.70*	0.14	0.14	0.17	-0.34	-0.47	-0.43
J	N	N	N	N	-0.11	N	N	N	0.42	=	-0.67*	0.13	0.11	0.15	-0.35	-0.43	-0.40
K	-0.58	0.30	0.75*	0.37	0.52	0.76*	-0.50	0.11	N	N	=	0.01	-0.05	-0.03	0.32	0.44	0.34
L	-0.33	-0.17	-0.33	-0.44	-0.04	-0.38	-0.23	-0.66*	N	N	0.01	=	0.94**	1.00**	0.65*	-0.16	0.26
M	-0.48	-0.13	-0.34	-0.43	-0.24	-0.51	-0.36	-0.65*	N	N	-0.04	0.96**	=	0.97**	0.65*	-0.28	0.27
N	-0.39	-0.16	-0.37	-0.46	-0.26	-0.44	0.01	-0.64*	N	N	-0.05	1.00**	0.97**	=	0.63*	-0.19	0.26
O	N	N	N	N	N	N	N	N	-0.13	-0.33	N	N	N	N	=	0.20	0.49
P	0.20	0.82**	0.92**	0.86**	0.04	0.79**	-0.61	0.32	N	N	0.66*	-0.80**	-0.97**	-0.85**	N	=	0.58
Q	-0.41	0.65*	0.33	0.21	-0.16	0.49	-0.97**	-0.34	N3	-0.16	0.41	0.36	0.36	0.39	N	0.85**	=

* ˌ **: Significant at P= 0.05 and P= 0.01 respectively (t – test)
N: Negligible

The ratio of seed length/width was negatively correlated with latex yield at $\Gamma_g = -0.97$, $\Gamma_p = -0.85$ and direct effect of -0.98 (Tables 2 and 3). The correspondence between the significant correlation and direct effect had stabilizing indirect effects of - 0.74 and 0.80 via ratios of seed/shell weight and seed weight/volume respectively (Table 3). There was a significant positive genotypic correlation of 0.65 between seed width and latex yield (Table 2). This was accompanied by phenotypic correlation of 0.60 (Table 2).

The direct effect of bark thickness on latex yield was 0.62 with correlation of 0.49. Despite the support of ratio of seed/shell weight and stem height at respective indirect effects of 0.60 and 1.09, the relatively high indirect effects of ratio seed weight/volume at -0.57 and vigour index at -1.11 (Table 3), caused a decline from direct effect to correlation. The fifth instance of a reduction in magnitude from direct effect to correlation was in the relationship between ratio of seed/kernel weight at direct effect of -0.54 and correlation of

Table 3
Direct (diagonal) and indirect (off – diagonal) effects of components of each phenotypic correlation coefficient between *Hevea* latex yield (Q) and the sixteen seed (A – K) and juvenile (L – P) characters

	Seed lenght (A)	Seed width (B)	Seed weight (C)	Seed volume (D)	Kernel weight (E)	Shell weight (F)	Ratio of A/B (G)	Ratio of C/E (H)	Ratio of C/F (I)	Ratio of E/F (J)	Ratio of C/D (K)	Stem height (L)	Stem diameter (M)	Vigour index (N)	Bark Thickn. (O)	Leaf whorls (P)	Latex yield (Q)
A	0.0875	0.1541	0.2204	-0.6942	0.0866	0.3415	-0.6455	-0.3381	0.1948	-0.1487	0.4818	-0.4156	0.1102	0.5101	0.0316	-0.0485	-0.38
B	0.0222	-0.5424	0.9919	-1.0447	0.0465	0.8512	0.5263	-0.1844	1.1512	-0.7437	-0.4640	-0.1829	0.0220	0.1935	0.1833	-0.2262	0.60
C	0.0107	-0.3348	1.5645	-1.0947	-0.2111	0.9134	0.3674	-0.1091	1.1612	-0.7208	-1.3384	-0.4488	0.0913	0.5277	0.1517	-0.2003	0.33
D	0.0398	-0.4198	1.2921	-1.3460	-0.1109	0.8719	0.1490	-0.1745	0.9133	-0.5835	-0.4997	-0.5984	0.1102	0.6509	0.1264	-0.1906	0.23
E	-0.0207	0.0691	0.9290	-0.4139	-0.3478	0.1868	0.1092	0.2236	0.0531	-0.0114	-0.9201	-0.2826	0.0535	0.3166	-0.0316	-0.0129	-0.10
F	0.0252	-0.4357	1.3856	-1.1214	-0.0644	1.0280	0.3575	-0.2290	1.2143	-0.7437	-1.0350	-0.5153	0.1196	0.6157	0.1201	-0.2714	0.45
G	0.0497	0.2816	-0.5826	0.2003	0.0394	-0.3737	-0.9831	-0.1581	-0.7362	0.4577	0.8030	-0.2992	0.0881	0.3694	-0.1454	0.1389	-0.85
H	0.0474	-0.1807	0.3149	-0.4272	0.1467	0.4360	-0.2880	-0.5353	0.7339	-0.5034	-0.0714	-0.8976	0.1700	1.0027	-0.1391	-0.0388	-0.23
I	-0.0084	0.3454	-1.0334	0.6809	0.0107	-0.7058	-0.4072	0.2290	-1.7611	1.1552	1.2382	0.2327	-0.0441	-0.2990	-0.2149	0.1519	-0.43
J	-0.0099	0.3454	-0.9919	0.6809	0.0036	-0.6747	-0.4072	0.2289	-1.7611	1.1552	1.1956	0.2161	-0.0346	-0.2639	-0.2212	0.1389	-0.40
K	-0.0207	-0.1382	1.1919	-0.3738	-0.1825	0.6020	0.4469	-0.0218	1.2398	-0.7666	-1.7955	0.0166	0.0157	0.528	0.2023	-0.1389	0.33
L	-0.0192	0.0585	-0.4251	0.4806	0.0608	-0.3218	0.1788	0.2945	-0.2480	0.1487	-0.0178	1.6523	-0.2959	-1.7491	0.4109	0.0517	0.26
M	-0.0268	0.0372	-0.4566	0.4673	0.0608	-0.3944	0.2781	0.2945	-0.2480	0.1257	0.0892	1.5726	-0.3258	-1.7063	0.4109	0.0905	0.27
N	-0.0222	0.0585	-0.4724	0.4940	0.0644	-0.3633	0.2086	0.3108	-0.3011	0.1716	0.0535	1.6723	-0.3054	-1.7691	0.3982	0.0614	0.26
O	0.0038	-0.1541	0.3779	-0.2670	0.0179	0.1972	0.2284	0.1200	0.6022	-0.4005	-0.5710	1.0905	-0.2046	-1.1082	0.6221	-0.0646	0.49
P	0.0115	-0.3720	0.9762	-0.7877	-0.0143	0.8729	0.4270	-0.0654	0.8424	-0.4920	-0.7673	-0.2660	0.0881	0.3342	0.1264	-0.3341	0.58
Residual effect																	0.02

-0.23 (Table 3). This was mainly due to the positive indirect effects of ratio of seed/shell weight at 0.73 and vigour index at 1.00 but negative indirect effect of -0.90 via stem height. Lastly, the direct effect of ratio of seed/shell weight on latex yield was -1.76 with correlation of -0.43 (Table 3). The direct effect of -1.76 was influenced by positive indirect effects of 0.68, 1.16 and 1.23 via seed volume and ratios of seed/shell weight, seed weight/volume respectively. On the other hand, seed weight and shell weight were in favour of the negative relationship between ratio of seed/shell weight and latex yield through indirect effects of -1.03 and -0.71 respectively.

There was a reversal of the direction of correlation compared to direct effect on latex yield in some characters. Prominent among these is the relationship between leaf whorls and latex yield. There was significant genotypic correlation between leaf whorls and latex yield at Γ_g = 0.85, relatively high phenotypic correlation at Γ_p = 0.58 and negative direct effect at -0.33 (Tables 2 and 3). The positive indirect effect of seed weight, shell weight and ratio of seed/shell weight at 0.97, 0.87 and 0.84 (respectively) influenced the direct effect of -0.33 to produce correlation coefficient of 0.58. Seed volume and ratio of seed weight/volume were in favour of the negative direct effect with respective indirect effects of -0.79 and -0.77 (Table 3). In addition, genotypic and phenotypic correlations, and direct effect of seed width on latex yield were 0.65, 0.60 and -0.54 respectively (Tables 2 and 3). The negative direct effect was influenced by seed weight, shell weight and ratio of seed/shell weight at indirect effects of 0.99, 0.85 and 1.15 respectively (Table 3). Negative indirect effects of seed volume at -1.04 and ratio of kernel/shell weight at -0.74 are also important in the relationship between seed width and latex yield. The direct effect of seed volume on latex yield was -1.35 with correlation of 0.23. The change in the direction was due to the influence of seed weight, shell weight, ratio of seed/shell weight and vigour index at indirect effects of 1.29, 0.87, 0.91 and 0.65 respectively (Table 3). The direct effect of ratio of kernel/shell weight at 1.16 was influenced by indirect effects of seed weight at -0.99, shell weight at -0.67, ratio of seed/shell weight at -1.76 to produce a correlation of -0.40 with latex yield (Table 3). The relatively high indirect effects seed volume at 0.68 and of ratio of seed weight/volume at 1.20 on the relationship between ratio of kernel/shell weight and latex yield are also important (Table 3).

The change in the direction of the relatively high direct effects to correlation was also recorded in the relationship between latex yield and each of ratio of seed weight/volume and vigour index. The direct effect of ratio of seed weight/volume on latex yield was -1.80 with correlation of 0.33 (Table 3). The major characters that influenced this relationship were seed weight, shell weight and ratio of seed/shell weight at indirect effects of 1.19, 0.60 and 1.24 respectively (Table 3). The ratio of kernel/shell weight provided some support at indirect effect of -0.77 to the negative direct effect. The direct effect of vigour index on latex yield was -1.77 with correlation of 0.26. Notwithstanding the support of seed weight at indirect effect of -0.47, the negative direct effect was reduced by positive direct effects of seed volume and stem height at 0.49 and 1.67 respectively (Table 3).

Three characters viz seed length, kernel weight and stem diameter had relatively low and insignificant phenotypic and genotypic correlation and direct effects on latex yield. These were less than ± 0.45 in each case (Tables 2 and 3). The residual effect of the path analysis of latex yield using the sixteen characters was 2% (Table 3).

Discussion

The significant clonal variation for nine seed characters and latex yield will permit selection among the clones for latex yield and any of the nine seed characters. This is important for the three economic characters which are latex yield, seed weight and kernel weight. Seeds are purchased from farmers on weight basis while the kernel is a rich source of the rubber seed oil (7, 9). The superior performance of two clones developed in Nigeria (NIG 803 and NIG 804) for the three economic characters is noteworthy. Applying a correction term of 69.3 to the gram per tree per tapping (10), latex yield of 2800 - 3300 kg/ha/yr is obtainable for NIG 803 and NIG 804. This is higher than latex yields of the exotic *Hevea* clones in this study. The significant clonal variation for the seed and juvenile characters will lead to clonal selection for these characters. In addition, PB 217 and NIG 803 which stand out for high values of latex yield, seed and juvenile characters are recommended for use as a parents-in-crosses to develop progenies with combined attributes of high latex yield, seed and juvenile characters.

The practical utility of phenotypic correlation, as a result of measurements often taken on the phenotype, was emphasized by Ariyo *et al*. (3). Since inter-character genetic correlations determine the success of selection due to correlated response, genetic correlations serve to estimate the reliability of phenotypic correlations (5). The significant genotypic correlation between latex yield and each of seed width, ratio of seed length/width and leaf whorls is very important. This is more so as the direction of the phenotypic and genotypic correlation with latex yield was the same for each of the three characters. Path analysis of phenotypic correlation further enhances the application of correlations for genetic improvement of *Hevea brasiliensis* (11, 13).

The relationship between the number of leaf whorls (two years after planting) and latex yield can be applied to reduce the number of genotypes to be tested in field trials through selection for high number of leaf whorls. Selection in the upward direction for leaf whorls is expected to produce clones with high mean latex yield. This will be enhanced by simultaneous selection for high values of seed weight, shell weight and ratio of seed/shell weight. The significant genotypic correlation, which was higher than the phenotypic correlation suggests the relative importance of effect of genes. As none of the other juvenile characters had appreciable indirect effect on this relationship, indirect selection for latex yield based on leaf whorls may not require simultaneous selection for any of the other juvenile characters.

Selection for high mean seed width is also expected to lead to high mean latex yield due to the significant and positive genotypic correlation between the two characters. As in the relationship between leaf whorls and latex yield, the relative importance of gene effects compared to the bulk phenotypic effect was manifested. Simultaneous selection for high values of seed weight, shell weight and ratio of seed/shell weight will enhance the positive relationship between seed width and latex yield.

Among the seed characters, the ratio of seed length/width provided the most reliable relationship with latex yield with the significant genotypic and phenotypic correlation and relatively high direct effect on latex yield. This relationship, which was entirely negative, means that selection for lower values of ratio of seed length/width will lead to increase in mean latex yield. In order to utilize this relationship, simultaneous selection for the stabilizing factors, i.e. ratios of seed/shell weight and seed weight/volume, is recommended. In this regard, latex yield will be the dependent trait while the primary independent character will be ratio seed length/width with ratios of seed/shell weight and seed weight/volume as secondary independent characters. The direct effect of the primary independent character and indirect effects of the secondary independent characters will serve as weighting factors. An equation for the use of the direct and indirect effects is provided as follows:

$$-0.85\ Q = -\ 0.98\ (G^*) - 0.74\ (I) + 0.80\ K$$

$$\therefore -Q = -\ 1.15\ (G^*) - 0.87\ (I) + 0.94\ K$$

The negative sign on Q (latex yield) is retained to show the negative correlation. G* (ratio of seed length/width) is the primary character. This implies that on a standard normal scale, a selection of 1.15 units in the lower trend for ratio of seed length/width should be accompanied by 0.87 units on the downward trend for ratio of seed/shell weight (I) and 0.94 units on the higher trend for ratio of seed weight/volume (K). This will result in an increase in mean latex yield. Since effect coefficients are not reversible, the model of the use of direct and indirect effects of any primary character of interest will be developed separately.

The relatively high indirect effects despite low correlation with latex yield, which were obtained for some seed and juvenile characters, can be utilized in breeding programmes. This will involve the simultaneous selection for the secondary characters in such relationship. This is more relevant when the direct effect and correlation of the primary character with latex yield are in the same direction. In this case, such secondary characters that have the same sign as the correlation and direct effect are more useful. For instance, the positive correlation between seed weight and latex yield can be utilized by selecting for high values of seed weight and shell weight while applying independent culling method, at a fixed value, on the characters having negative indirect effects (seed volume, ratios of kernel/shell weight and seed weight/volume). Fortunately, the characters with negative indirect effects appear to be independent of latex yield due to their insignificant correlation with latex yield. This procedure can also be applied to use the relatively high and positive direct effects of stem height and shell weight on latex yield in spite of their low correlation with latex yield.

The utilisation of the negative direct effect of ratio of seed/shell weight on latex yield will involve simultaneous selection for low levels of ratio of seed/shell weight, seed weight and shell weight while maintaining a constant level of characters with positive indirect effects. This will tend to maximize latex yield. In practical terms, the relationship between ratio of seed/shell weight and latex yield may not be applied since the reverse of high values of seed/shell weight and seed weight are desired. The same principle for the use of the relationship between seed/shell weight can be applied in the relationship between ratio of seed/kernel weight and latex yield.

The change in the direction/sign from direct effect to correlation presents a difficult relationship. This is more so when the correlation is not significant. Such correlations when applied without path analysis will produce results that are different from expected. In this regard, the relationship between latex yield and each of seed volume, ratios of kernel/shell weight and seed weight/volume, and vigour index appear to be inconsistent in this study.

Selection for any of the characters having insignificant direct effect and correlation with latex yield can be carried out without any appreciable effect on latex yield. This will be applicable to seed length, kernel weight and stem diameter. The residual effect of 2% suggests a high level of reliability of the results in path analysis. The low residual effect can be attributed to the large number of causal (independent) factors and the significant clonal variation for the dependent character (latex yield) and most of the causal factors. Bakshi and Hemaprabla (4) suggested the likelihood of low un-accountable effect under these two conditions.

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