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Genetic Variability and Correlation Analysis in Quantitative Traits of Ten Genotypes of *Hevea brasililensis* Muell. Arg. at Seedling Stage.

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Abstract

Understanding the variability and the association existing among natural rubber genetic materials for important traits is vital for the effective utilization of such materials for breeding purposes. The aim of this study was to determine the genetic variability and associations among the nine traits used as indices for picking drought tolerant genotypes. The test genotypes were RRIM 600, NIG 800, NIG 801, NIG 802, NIG 803, NIG 804, PR 107, RRIM 628, GT I, and PB 5/51. Observations were made on plant height, number of leaves, plant girth, plant vigor, percentage plant survival, leaf yellowing, leaf senescence and leaf fall among the ten genotypes. Results obtained from the analysis of variance (ANOVA) showed that there were significant variations for all the characters studied. The plant height, number of leaves, plant girth, leaf area, leaf yellowing, leaf senescence and leaf fall, showed highly significant variations across the genotypes and drought stress periods. Genotypic variances were relatively high for number of leaves, leaf fall, plant survival and plant girth leading to high broad sense heritability estimates 0.96, 0.82, 0.76 and 0.71 respectively. Also high genotypic coefficients of variation (GCV) for all the traits from 29% to 395% and high genetic advance at 20.98% in leaf area to 25.55% in plant girth, leaf yellowing (34.13%), plant vigor (36.16%) and 69.98% in number of leaves were obtained. All the traits except percentage plant survival had positive and significant association with each other. The negative correlation between plant survival and other agronomic characters suggests that a considerable decrease in percentage plant survival will increase agronomic traits such as plant height, girth and vigor. Striking a balance between plant survival, also a desired trait and other agronomic characters is necessary.

Keywords

Natural rubber Seedlings, genetic variability, correlation analysis, agronomic characters

1. Introduction

Rubber tree (*Hevea brasiliensis* Muell. Arg.) belongs to the family of *Euphorbiaceae*. The plant is indigenous to the Amazon basin in South America, and widely cultivated in tropical Asia and Africa. It is a major source of natural rubber used in the manufacture of tyre, tube, bearings, gloves etc. (Omokhafe *et al.*, 2008). High yielding clones have been developed by Rubber Research Centers in various countries (Bassey, 2014). High yielding clones are generally obtained through long-term breeding programs by crossing between clones having special characters. The goal of rubber breeding is to obtain superior clones which have a high production of latex or wood, tolerant to drought stress and resistant to diseases (IRRI, 2005). The selected parent clones usually originate from the previous generation having a high production potential and better agronomical characters. Phenotype characters are helpful in determining the genetic variability among accessions and hence the potential for genetic improvement using the test population.The objectives of this study was to determine the genetic variability and associations among the nine traits to serve as a guide to selection for desirable traits such as plant height and girth.

2. Materials and Methods

Ten genotypes of rubber seedlings (*Hevea brasiliensis* Muell. Arg), used for this research work were collected from Rubber Research Institute of Nigeria, Iyanomo, Benin City, Edo State, Nigeria. The genotypes were RRIM 600, NIG 800, NIG 801, NIG 802, NIG 803, NIG 804, PR 107, RRIM 628, GT I, and PB 5/51. The origin of these clones is as follows: RRIM 600, RRIM 628 and PB5/51 from Malaysia; GT1 and PR 107 from Indonesia, and the five NIG 800 series clones developed in Nigeria (Omokhafe *et al.*, 2017). Field experiment was carried out at the research farm of the National Root Crops Research Institute (NRCRI), Umudike (latitude 05^0, 29'N; longitude 07^0, 33'E), in 2016 planting season. The field design was randomized complete block design (RCBD) replicated three times. Each plot size was ($6m^2$) 3m long by 2m wide seed beds with 1m apart and contained 30 plants spaced 30cm within and 1m between the rows to give a seedling population of 33,333 seedlings per hectare. The four drought periods are described as follows: 0 (after establishment), 26, 33 and 40 days of drought stress.

Data were collected on nine agronomic traits as follows:

Plant height (cm) was measured as the distance from the ground level to the tallest leave using meter rule after establishment and at 26, 33 and 40 days of drought stress. Number of leaves per plant was taken by counting the leaves of each plant within the net plot and plant girth (cm) was measured using vernier caliper. Plant vigor was assessed visually using scale ranges from 1-5. Plant survival was recorded as percentage plant survival and drought symptoms (leaf yellowing and leaf senescence were scored by visual assessment of the nursery field at different periods of drought exposure using a scale ranges of 1-5 scoring according to Ravichandran *et al.*, (2010). Leaf area (cm^2) was measured and calculated i.e leaf area (cm^2) = L × W × K, where L is leaf length, W is maximum width of the leaf and K is a correction factor of 0.654. Leaf fall was calculated by subtracting number of leaves obtained at 26, 33 and 40 days of drought stress from the total number of leaves after establishment. Analysis of variance was conducted. Simple Pearson's Correlation Coefficient was performed to study the association among the traits. Genetic parameters such as variance components (genotypic, phenotypic and error variances) and heritability in the broad sense were calculated according to Allard (1987) as follows:

$$Vg = \{MSG - MSE/rd\},\ Vp = \{MSG/rd\},\ Ve = \{MSE/rd\} \ldots\ldots 1$$

Where MSG, MSE, Ve and r are the Mean Squares of genotypes, Mean Squares of error, environmental variance and numbers of replications respectively. Phenotypic (PCV) and genotypic (GCV) coefficients of variation were also evaluated.

$$\text{Viz: PVC} = \sqrt{vp\sqrt{x}} \times 100,\ \text{GCV} = \sqrt{vg\sqrt{x}} \times 100 \ldots\ldots 2$$

Where Vp, Vg and $\bar{x}$ are the phenotypic variances, genotypic variances and grand mean respectively for the character under consideration. Genetic advance (GA) expected and genetic advance as percent of the mean assuming selection of the superior 5% of the genotypes, were estimated in accordance with the methods illustrated by Fehr (1987) as follows:

$$GA = K\ (Sp).\ h_b^2\ \text{GA (as \% of the mean)}\ (\sqrt{\frac{GA}{\bar{x}}}\ )\ x\ \frac{100}{1} \ldots\ldots 3$$

Where K is a constant (which varies depending upon the selection intensity and, if the latter is 5 %, it stands at 2.06), Sp is the phenotypic standard deviation $\sqrt{vp}$. h_b^2 is the heritability ratio, and $\bar{x}$ refers to the mean of the characters.

3. Results and Discussion

The rubber tree is cultivated for the natural rubber, which is exploited at tapping maturity.

The maturity index is minimum girth of 45cm at 100 to 150cm height from the ground (Omokhafe *et al.*, 2015). Tree height and girth are important characters in development of latex-timber clones of *H. brasiliensis*. Characters such as height, girth and associated characters are therefore important in genetic improvement of H. brasiliensis. Seedling survival is important as seedling development is either for vegetative propagation or germplasm maintenance (Wong and Abubakar, 2005).

Analysis of variance (ANOVA) showed that there were significant variations for all the characters studied except leaf fall (Table 1). The plant height, number of leaves, plant girth, leaf area, leaf yellowing, leaf senescence and leaf fall, showed highly significant variations across the genotypes and drought stress periods. However, the high significant genotypic effect observed for all the traits indicated a high level of variability in the genetic composition of the rubber genotypes tested which may provide ample scope for further improvement (Adifaiz *et al.*, 2018). There were significant differences for genotype x drought stress periods interaction on number of leaves, leaf yellowing, leaf fall and leaf senescence. This means that some of the genotypes were more tolerant to drought stress conditions and can be further explained by stability analysis as recommended by Omokhafe and Alika (2003). Using Fisher's least significant difference (F-LSD) at 5% level of probability, superior performance was obtained for GT 1 (eight characters), followed by RRIM 600 for six characters. Among the Nigerian clones, NIG 800 and NIG 804 recorded superior performance for three characters each. This high vegetative growth among the four clones may make them candidates for rootstock nursery development, especially where rootstock development is rain-fed. The superior performance of NIG 804 as a Nigerian clone for plant height (213.44cm) and vigour (3.25 on a scale of 1-5) was noted more so as NIG 804 is among the highest latex producing NIG 800 series clones (Omokhafe and Imoren, 2014). Evaluation of genetic variability as basis of plant breeding is important for crop management, crop improvement by selection, utilization of crop germplasm, detection of genome organization and transfer of desirable traits to other plants. Breeders use desired morphological traits to evaluate genetic variability because they are cost effective, rapid and easier to score (Sohrabi *et al.*, 2012). This aspect may be revised depending on the variance figures using the appropriate denominator. The phenotypic, genotypic and environmental variances and the heritability estimates (broad sense) of the 9 traits measured across the 10 genotypes of rubber seedlings in the field experiment is presented in Tables 1. The genotypic variances were higher than the environmental variances. Consequent upon this, the broad sense heritability (h^2_b %) estimates were generally high. Number of leaves showed the highest genotypic variance (S^2g) (2040.24) and a high heritability (h^2_b) estimate of (0.97) Table 1.The plant height also had a high genotypic variance of 300.86 and a heritability estimate of 0.54. Leaf fall, percentage plant survival and leaf area had high genotypic variances of 665.12, 135.19 and 58.20, and high heritability estimates of 1.13, 0.76 and 0.41 respectively (Table 1). Plant girth, plant vigor, leaf yellowing and leaf senescence had lower genotypic variances of 0.33, 0.31, 0.22 and 0.32 respectively. This accounted for their heritability (h^2_b) estimates of 0.72, 0.64, 0.65 and 0.35 respectively.The greater genotypic suggest greater influence of the heritable (genetic) component over the non- heritable component on the total variances observed. Gain under this scenario will be fast, and will not take considerable time. Partitioning of the total phenotypic variance (S^2p) of each trait into heritable (genetic) and non-heritable (environment) components is useful in determining the proportions of heritable variations that could be explore during selection for superior individuals (Adifaiz *et al.*, 2018). Genetic improvement of plants for quantitative trait requires reliable estimate of heritability in other to plan an efficient breeding program (Tolessa 2017). Table 1 also shows the estimates of phenotypic and genotypic coefficients of variation (PCV and GCV respectively), expected genetic advance (GA) and genetic advance as a percent of the mean for each of the 9 traits of rubber genotypes studied. In all the traits measured, phenotypic coefficient of variation (PCV) was more than the genotypic coefficient of variation (GCV). Also genetic advance (in % mean) was greater than genetic advance (expected) in all the traits except for plant height and number of leaves. The other traits exhibited varying degrees of genetic variations. Among all the traits, leaf fall had the highest potential gain (%) from the selection (452.8%) followed by number of leaves (69.98%). Other traits had lower genetic gains (GA %) at less than 20% in plant height, leaf senescence and leaf yellowing. Genetic gains from selection for the improvement of the traits with high GA (%) will be very fast and may not take many cycles of selection for appreciable improvement. Heritability (broad sense) estimates alone indicate the effectiveness, with which selection of genotypes can be based on phenotypic appearance, but heritability in conjunction with genetic coefficient of variation provides a more dependable measure of amount of genetic advance to be expected from selection (Tolessa 2017). High PCVs and GCVs indicate that worthwhile improvement could be achieved for such characters through simple selection, and high genetic advance values indicates that population means for those characters may be changed substantially by selecting the superior 5% of the material evaluated (Baye, *et al.*, 2005).

Plant height had positive and significant correlation with all the traits except percentage plant survival at r = -0.41 (Table 4). Number of leaves, plant girth, and plant vigor showed significant association with one another, and with the other traits except percentage plant survival. Percentage plant survival was negatively correlated with plant girth, plant vigor, leaf yellowing and leaf senescence at r = -0.34, -0.67, -0.74 and -0.57 (Table 4). Leaf fall showed positive significant correlation r = 0.45 with percentage plantsurvival. Most of the traits exhibited significant and positive association with each other, except for percentage plant survival having negative correlation with all characters but leaf fall. The highly significant positive correlation between plant height, number of leaves and other traits indicated increase in each of them. Significant intercharacter correlation has been reported by Omokhafe and Alika (2003a and 2003b). Tan (2008) also studied the significant relationships between plant height in natural rubber nursery and mature yield. The negative correlation of plant height and number of leaves against percentage plant survival in the current study, indicates that a considerable decrease in percentage plant survival will increase the plant height and number of leaves and vice versa.

4. Conclusion

There was high genotypic and phenotypic coefficient of variation (PCV), high heritability estimate (h^2_b) and high genetic advance (GA%) in most of the traits. This suggests that improvement of natural rubber considering these quantitative traits could be useful for further selection and improvement. Plant height and girth had significant and positive relationship with all other traits except percentage plant survival. Indirect improvement in plant height and girth is therefore possible with improvement in all characters except plant survival.

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Table 1. The sources of variation, degree of freedom and mean squares of the analysis of variance of the nine agronomic traits measured across the ten genotypes of rubber seedlings in 2016 cropping season.

Sources of variation	df	Plant Height	No. of Leaves	% Plant survival	Plant girth	Plant vigor	Leaf area	Leaf yellowing	Leaf senescence	Leaf fall
Reps	2	1513.423**	148.855	145.64815*	0.3324100	0.10000	354.191112*	0.13333	0.608333*	0.776^{NS}
Treatments (T)	9	4030.916***	27402.84***	1660.99794***	4.316659***	3.982407***	739.66485***	3.114815***	2.9824074***	1.754
Drought periods (DP)	3	128316.199***	182634.076***	3815.64815***	75.031058***	12.275000***	2408.44143***	25.96667***	50.5638889***	494209.453**
T x DP	27	420.5563	3019.972***	38.69342	0.3093490**	0.2688272	41.314943	0.4851852***	0.6070988**	7983.189***
Error	78	258.276	73.762	42.03941	0.1322946	0.17692308	85.27241	0.1162393	0.608333*	75.150

Level of significance t: *: P < 0.05, **: P < 0.01 and ***: P < 0.0001

Table 2. Mean values of the nine agronomic traits measured across the ten genotypes of rubber seedlings in 2016 cropping season.

Genotypes	Plant height (cm)	Number of leaves	% Plant survival	Plant girth (cm)	Plant vigor	Leaf area (cm^2)	Leaf yellowing	Leaf senescence	Leaf fall
GTI	200.39	247.71	74.444	4.129	1.667	15480.56	1.667	1.330	24.73
NIG 800	200.11	172.01	67.222	3.506	3.000	7379.50	3.890	3.110	43.27
NIG 801	170.05	192.07	55.000	3.268	2.333	6946.16	2.780	2.220	43.91
NIG 802	188.82	180.03	57.500	3.288	2.500	9134.09	3.220	2.670	34.19
NIG 803	190.53	190.9	53.611	3.477	2.333	9986.80	2.667	2.550	33.37
NIG 804	213.44	226.76	64.444	4.134	3.250	11024.7	2.330	2.330	38.09
PB 5/51	142.99	64.758	48.611	2.484	2.500	2396.28	3.890	3.220	48.59
PR107	191.05	218.18	64.722	3.188	1.583	11157.1	2.330	1.990	42.15
RRIM 600	182.22	223.61	76.111	4.106	3.25	11523.5	1.890	1.446	36.97
RRIM 628	155.66	73.183	38.058	2.191	1.667	2582.15	3.440	3.220	42.53
Overall mean	183.52	178.92	52.36	3.377	2.566	8761.1	2.810	2.408	38.85
F-LSD$_{(0.05)}$	26.12	13.96	10.53	0.591	0.683	15.01	0.554	0.675	14.09

Table 3. Phenotypic, genotypic, environmental variances and heritability estimates, coefficients of variation and genetic advance.

Traits	Vp	Vg	Ve	h^2_b	PCV%	GCV%	GA Expected	GA (%)	$\bar{x}$
Plant height	559.14	300.86	258.276	0.5381	189.66	139.12	26.22	16.86	155.45
Number of leaves	2114.0	2040.2	73.762	0.9651	402.29	395.23	91.41	69.98	130.62
Plant girth	0.4662	0.3339	0.1323	0.7162	34.383	29.098	1.007	25.55	3.9435
Percentage Plant Survival	177.23	135.19	42.039	0.7628	171.91	150.14	20.91	34.87	59.972
Plant Vigor	0.4662	0.3095	0.1769	0.6363	44.331	35.362	0.894	36.16	2.4750
Leaf area	143.47	58.196	85.2724	0.4056	173.39	110.44	10.01	20.98	47.717
Leaf yellowing	0.3353	0.2191	0.1162	0.6534	38.320	30.977	0.7793	34.13	2.2833
Leaf senescence	0.4110	0.3210	0.2120	0.3500	50.799	39.456	0.4617	18.82	2.4530
Leaf fall	589.97	665.12	75.150	0.1274	2176.16	2310.6	56.41	452.8	1.2458

Table 4. Correlation Coefficients Matrix of Nine Traits Measured on 10 genotypes of rubber seedlings in the year 2016.

	Plant height	**Number of leaves**	**Percentage plant survival**	**Plant girth**	**Plant vigor**	**Leaf area**	**Leaf yellowing**	**Leaf senescence**	**Leaf fall**
Plant height	= =	0.8768***	-0.4113***	0.8997***	0.3843***	0.6236***	0.7175***	0.6573***	0.8194***
Number of leaves		= =	-0.1152	0.9108***	0.0464*	0.6412***	0.4737***	0.4046***	0.6803***
Percentage plant survival			= =	-0.3406***	-0.6651***	-0.0673	-0.7351***	-0.5694***	0.4511***
Plant girth				= =	0.1852*	0.5880***	0.6733***	0.6806***	0.6890***
Plant vigor					= =	0.0531	0.2440**	0.3661***	0.4660***
Leaf area						= =	-0.2014**	0.7489***	0.5265***
Leaf yellowing							= =	0.8829***	0.6601***
Leaf senescence								= =	0.6786***

*: P < 0.05, **: P < 0.01, ***: P < 0.0001