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VARIABILITY AND ASSOCIATION STUDIES IN GUAYULE *PARTHENIUM ARGENTATUM* A. GRAY

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Analysis of variance for twelve quantitative characters in 10 genotypes of guayule showed significant variability and potential for improvement through breeding. Plant height, basal branches per plant, main stem diameter, and leaf length and width had high genotypic coefficient of variability, high heritability and high genetic advance (% of mean). This shows that effective selection for improvement of these characters is possible in guayule. Rubber content had negative significant correlations with stem diameter. Rubber yield plant^{-1} showed positive significant correlation with plant circumference, basal branches plant^{-1}, fresh and dry shrub yield plant^{-1} and plant diameter. Basal branches plant^{-1} also recorded highest GCV (30.00), GA (61.72 %) and high heritability (99.4 %), thus can be used as a non-destructive predictor of high rubber yield. Possibilities to improve number of basal branches by selection are good. As stem diameter showed negative correlation with rubber content (%), the plant breeders will have to compromise at certain co-level of stem thickness and number of stems (basal branches) to get higher rubber yield per unit area from guayule cultivation.

Guayule, *Parthenium argentatum* A. Gray, is a member of family compositae. Out of the 16 species of this genus, *Parthenium argentatum* is the only species known to produce rubber. Rubber is contained mainly in the bark portion of the stems and roots with little or none found in the leaves and flowers (Curtis, JR., 1947). Besides *Hevea brasiliensis* (H.B. & K.) Muell, Aug., Guayule is the only source of natural rubber (Baird, 1975). *Hevea* can be cultivated only in the tropical zone whereas, guayule is cultivated in arid zones. With the increasing population growth, guayule, offers an opportunity for productively utilizing marginal lands by providing jobs and income to desert dwellers. *Hevea*, on the other hand, requires fertile land and a humid climate, which limits the possibility pressure of expansion of its cultivation owing to the mounting pressure on agricultural land for food production (Bhatia and Masohan, 1983).

Guayule's native habitat is a semiarid plateau 1,200 to 2,100 m high with temperature range -18° to 44°C and annual rain fall between 230-400 mm. The plant grows best in well-drained soils and can not tolerate water logging. More than 640 mm annual rainfall cause excessive vegetative growth, instead of rubber formation (Anon., 1977).

Guayule was introduced in India to develop an alternative source for natural rubber (Bhatia and Masohan, 1983). Much work has been done regarding guayule's utilization (Mc Ginnies and Haase, 1975); chemical composition (Haagen-Smit and Siu, 1944), method of rubber extration (Anon., 1977), etc. but reports on variability, character-association and aids to selection are few. It takes 2-4 years to study rubber yield and component characters as the rubber accumulates with the age of plant in guayule. Keeping this in view, the present studies were undertaken to determine the variability parameters, heritability (in broad sense), expected genetic advance and correlation between various quantitative traits to aid the plant breeder in predicting both rubber percentage and rubber yield of guayule.

MATERIALS AND METHODS

The experiment was carried out at the Research Farm, Haryana Agriculutral University, Hisar in India, a subtropical region situated in between 28°59' to 29°49' N latitude and 75°11' to 76°18'E longitude. It has arid/semi-arid, tropical climate. The annual mean temperature is more than 25°C with a wide range (-2.9° to 47.9°C). Annual mean rainfall is 450 mm ranging from 180 to 790 mm (Rao *et al.*, 1987). Ten genotypes of guayule received through National Bureau of Plant Genetic Resources (NBPGR), New Delhi were nursery raised in October, 1987. Transplanting was done on 2 February 1988 at the four seedling stage in randomized complete block design with three recplications. Each plot consisted of five rows, 5 m long and spaced 75 cm apart. Plant to plant distance was maintained at 45 cm. Seedlings were dwarf enough because guayule remains dormant during winter months (Anon., 1977). Observations were recorded after about three years of transplanting i.e., in January, 1991 on 10 randomly selected competitive plants in each plot. These plants were harvested by digging the entire shrub. Rainfall during 1988, 1989, and 1990 was 672 mm, 189.6 mm and 539.1 mm, respectively. In 1989, a few irrigations were supplemented during summer months. 1-2 irrigations were given during 1988 and 1990 also. Waterlogging was avoided by timely drainage of excess water from the field which is detrimental to the growth in guayule. Data were collected on (1) plant height, (2) plant circumference, (3) basal branches per plant, (4) leaf length (5) leaf width, (6) fresh shrub yield per plant, (7) dry shrub yield per plant, (8) plant diameter (width), (9) main stem diameter, (10) per cent dry matter, (11) rubber content and (12) rubber yield per plant. Dry shrub yield per plant excluded the weight of dry leaves as they contain non-significant rubber (Anonymous, 1977; Dierig *et al.*, 1989). Height and width (diameter) measurements were recorded for each plant prior to harvest. Rubber content was also determined (Donald *et al.*, 1981). The dried samples (excluding leaves) were put through chipper to obtain a coarsely ground sample. Thereafter, this sample was finely ground using a SEW Laboratory Willey Mill containing a 1.75 mm mesh screen. Samples of 20 grams were analysed for rubber content. The main stem diameter of each plant was measured at 5 cm above the ground.

Plot means were used for statistical analysis. Analysis of variance was carried out (Steel and Torrie, 1980) and genotypic, phenotypic and error variances were calculated (Prasad *et al.*, 1981).

The variance components were used to compute the genotypic coefficient of variation (GCV), heritability (in broad sense) and genetic advance. The GCV was computed (Kumar *et al.*, 1985; Burton, 1952) whereas heritability and expected genetic gain were estimated according to Allard (1960) assuming a selection intensity of 5 per cent. Simple correlation coefficients were worked out among all the characters.

RESULTS AND DISCUSSION

Analysis of variance for twelve guayule characters studied is indicated in Table 1. The mean squares for genotypes were highly significant for all the characters under study.

Table 1. Analysis of variance for 12 traits in guayule

Character	Mean square values for accessions	F value
Plant height (cm)	514.43	34.88 **
Basal branches per plant	42.49	174.62 **
Plant circumference (cm)	977.12	421.28 **
Plant diameter (cm)	89.36	16.98 **
Main stem diameter (cm)	2.74	43.50 **
Leaf length (cm)	10.73	287.84 **
Leaf width (cm)	1.22	1475.71 **
Fresh shrub yield (g $plant^{-1}$)	8339.37	29.30 **
Dry shrub yield (g $plant^{-1}$)	1097.33	9.28 **
Per cent dry matter	5.05	3.32 *
Rubber content (%)	2.25	5111.36 **
Rubber yield (g $plant^{-1}$)	42.46	75.60 **

*, **, Significant at P = 0.05 and P = 0.01, respectively

Table 2. Range, mean, standard error and least significant difference (LSD) for 12 characters in 10 guayule genotypes

Characters	Range in values and genotypes				Mean	S.E.±	LSD
	Min. value	Genotype	Max. value	Genotype			P = 0.05
Plant height (cm)	54.33	General	99.30	HG–8	64.15	1.38	6.26
Basal branches per plant	8.73	HG–10	19.53	HG–8	12.51	0.40	2.02
Plant circumference (cm)	233.50	USDA	295.90	HG-8	256.04	1.90	7.83
Plant diameter (cm)	74.84	USDA	94.20	HG–8	82.05	1.87	3.63
Main stem diameter (cm)	3.26	Arizona-101	5.84	HG–8	4.71	0.21	0.45
Leaf length (cm)	5.83	HG–10	11.42	HG-8	7.72	0.002	0.30
Leaf width (cm)	1.57	Arizona-101	3.73	HG–8	2.35	0.001	0.17
Fresh shrub yield (g $plant^{-1}$)	690.00	USDA	873.00	HG–8	758.70	5.56	21.57
Dry shrub yield (g $plant^{-1}$)	362.00	USDA	432.33	HG–8	388.80	2.01	13.84
Per cent dry matter	49.33	HG–10	53.10	G–3	51.34	1.01	1.71
Rubber content (%)	4.72	General	7.37	Arizona-101	6.11	0.09	0.14
Rubber yield (g $plant^{-1}$)	18.17	General	28.47	HG–8	23.51	0.39	2.08

The ranges in minimum and maximum values, the genotypes expressing these values, the mean, the standard error and the least significant differences (LSD) at $P = 0.05$ for the twelve characters are presented in Table 2. The best rubber yield plant^{-1} was recorded from HG-8 and the lowest from General which also showed lowest expression for plant height and rubber content. Maximum rubber content was recorded for Arizona-101 coupled with thinnest main stem. It is worth mentioning that HG-8 recorded maximum expression for all the characters except per cent dry matter and rubber content. Generally, a fairly good range of gross variation was found for all characters except for per cent dry matter and rubber content.

Estimates of genotypic and error variance components for the twelve characters are given in Table 3 which indicates that the variability observed in the phenotype is influenced more by genetic factors than non-genetic. The GCV, h^2 and GA as per cent of the mean are also given in Table 3. Which indicated that the variability observed in the phenotype is influenced more by genetic factors than non-genetic. The GCV, h^2 and GA as per cent of the mean are also given in Table 3.

Characters, viz., basal branches per plant, leaf width and leaf length showed high GCV values. Moderate GCV values were found for plant height, main stem diameter, rubber content and yield per plant and low values for rest of the traits.

Heritability values were more than 89 per cent for all the characters except 69.82 for per cent dry matter (Table 3). The genetic advance expected from selecting the top 5 per cent of the genotypes, varied from 3.63 for per cent dry matter to 61.62 for basal branches per plant (Table 3). Leaf width, leaf length, fresh shrub yield per plant, plant height and main stem diameter have shown high values in the order mentioned. Rubber yield per plant and rubber content have indicated a potential for moderately high genetic advance. Plant diameter, dry shrub yield per plant and per cent dry matter showed high heritability with very low genetic advance thus indicating selection to be less effective.

Correlations coefficients between various characters are presented in Table 4. Stem diameter had highly significant negative correlation with rubber content. The implied relationship is that as stem thickness increases, per cent rubber decreases. Since rubber is contained primarily in the bark rather than the wood portion, thicker stems, having a lower bark : wood ratio than thinner stems, would also have a lower rubber percentage. Dry shrub yield per plant had non-significant correlations with rubber content as also observed (Ray *et al.*, 1933; Benitez and Kuruvadi, 1985 and Thompson *et al.*, 1988); on the contrary, negative significant correlation between dry shrub weight and rubber content was observed (Dierig *et al.*, 1989).

Table 3. Estimates of genotypic variance (Vg), error variance (Ve), genotypic coefficient of variability (GCV), heritability (H), genetic advance (GA) and GA as percentage of mean

Characters	Vg	Ve	GCV (%)	H (%)	GA	GA as per cent of the mean
Plant height (cm)	166.56	4.91	20.12	97.13	26.20	40.84
Basal branches per plant	14.08	0.080	30.00	99.44	7.71	61.62
Plant circumference (cm)	324.93	0.773	7.04	99.76	37.09	14.48
Plant diameter (cm)	28.03	1.75	6.45	94.11	10.58	12.89
Main stem diameter (cm)	0.892	0.021	20.06	97.70	1.92	40.83
Leaf length (cm)	3.56	0.012	24.45	99.44	3.87	50.20
Leaf width (cm)	0.405	0.0003	27.07	99.99	1.31	55.78
Fresh shrub yield (g $plant^{-1}$)	2684.92	94.87	6.82	96.59	331.64	43.71
Dry shrub yield (g $plant^{-1}$)	326.37	39.41	4.65	89.23	35.15	9.04
Per cent dry matter	1.17	0.507	2.11	69.82	1.87	3.63
Rubber content (%)	0.750	0.0001	14.16	99.99	1.78	29.18
Rubber yield (g $plant^{-1}$)	13.97	0.187	15.90	98.73	7.60	32.24

Table 4. Simple correlations among various traits in guayule

	PC	BB	LL	LW	FSY	DSY	RC	RY	PD	% DM	SD
PH	0.735*	0.646*	0.711*	0.695*	0.728*	0.743*	0.170	0.513	0.741*	-0.485	0.417
PC		0.413	0.425	0.522	0.999**	0.956**	0.391	0.749*	0.980**	-0.834**	0.081
BB			0.894**	0.551	-0.260	0.496	0.585	0.683*	0.659*	-0.140	-0.124
LL				0.530	0.426	0.504	0.612	0.593	0.532	-0.146	-0.143
LW					0.504	0.529	0.271	0.419	0.597	-0.297	0.249
FSY						0.960**	0.402	0.763*	0.981**	-0.834**	0.073
DSY							0.417	0.779**	0.955**	-0.643*	0.131
RC								0.429	0.518	-0.293	-0.777**
RY									0.825**	-0.583	-0.415
PD										-0.786**	-0.014
% DM											0.095

PH = Plant height (cm), PC = Plant circumference (cm), BB = Basal branches/plant, LL = Leaf length (cm),
LW = Leaf width (cm), FSY = Fresh shrub yield (g/plant), DSY = Dry shrub yield (g/plant), RC = Rubber content (%), RY = Rubber yield (g/plant), PD = Plant diameter (cm), % DM = Per cent dry matter, and
SD = Main stem diameter (cm)

*, ** Significant at P = 0.05 and 0.01, respectively.

Rubber yield had significant positive correlations with plant circumference, basal branches per plant, and fresh and dry shrub yield plant^{-1}. Present experiment involved various characters which may serve a non-destructive predictor for rubber yield such as plant circumference, plant diameter and basal branches per plant i.e. more vigorous plants would yield more rubber. This is in agreement with the view of Federer (1946) who indicated that there appears to be good possibility for increasing rubber yields by selecting larger plants.

Basal branches per plant, a non-destructive predictor for higher rubber yield showed positive significant correlation with leaf length (Table 4) which suggests that selection of plants with larger leaves to get higher rubber yielding ones is appropriate.

Basal branches per plant also recorded highest GCV (30.0), genetic advance as per cent of mean (61.62) and appreciably high heritability (99.44). These values indicate very good chances to increase number of basal branches through simple selection. Stem diameter showed negative and significant correlation with rubber content (-0.777) which is not a desirable association. Therefore, task of a breeder becomes more complex as he will have to compromise at certain co-level of stem thickness and number of stems per plant to get better rubber yield. Looking at the GCV and heritability values for rubber content, it seems that selection would prove effective, so the breeder can go for the selection of bushy plants with thinner stems having farily good rubber content.

Fig. 1. Guayule *Var.* HG-8

Among the genotypes studied, HG-8 (Figure 1) may serve the best donor for all the characters except per cent dry matter, stem thickness and rubber content. Whereas Arizona-101 recorded maximum rubber content. This genotype also expressed lowest value for stem thickness which is important to have plants with high rubber content. Direct selection for number of basal branches per plant and plant diameter can be made to get plants having higher rubber production but the selection based on the former trait would be more effective.

REFERENCES

Allard, R.W. 1960. Principles of Plant Breeding, New York, Wiley, 485 pp

Anonymous. 1977. Guayule : An alternative source of natural rubber, National Academy of Sciences, Washington, D.C. pp 80.

Baird, L.E., 1975. Guayule : The viable second source of natural rubber. *Rubber World* **171** (6) : 44-49.

Benitez, A.L. and S. Kuruvadi. 1985. Variation in yield components and correlations in guayule. *El Guayulero* 7 (1 & 2) : 19-23.

Bhatia, V.K. and A. Masohan. 1983. Guayule (*Parthenium argentatum* A. Gray) : An alternative to *Hevea* (*Hevea brasiliensis*) (H.B. & K.) Muell. Aug., *J. Scient. Industr. Res.* **42** : 273-280.

Burton, G.W. 1952. Quantitative inheritance in grasses, *Proceedings of the Sixth International Grassland Congress*, Pennsylvania State College, USA, 17-23 August 1952, pp. 277-283.

Curtis, O.F., 1947. Distribution of rubber and resins in guayule, *Plant Physiol.* **22** : 333-359.

Dierig, D.A., A.E. Thompson and D.T. Ray. 1989. Relationship of morphological variables to rubber production in guayule. *Euphytica* **44** : 259-264.

Donald, J. Garrot Jr., D.L. Johnson and D.D. Rubis. 1981. Extraction of rubber from guayule using liquid nitrogen, *Annal. Chem.* **53** : 543-544.

Federer, W.R. 1946. Variability of certain seed, seedling and young-plant characters of guayule. U.S. Dept. Agr. Tech. Bull. 919.

Haagan-Smit, A.G. and R. Siu. 1944. Chemical investigation in guayule. 1. Essential oil of guayule (*Parthenium argentatum* Gray), *J. American Chem. Soc.* **66** : 2068-2074.

Kumar, A., S.C. Misra, Y.P. Singh and B.P.S. Chauhan. 1985. Variability and correlation studies in triticale. *J. Maharashtra Agri. Univ.* **10** : 273-275.

Mc Ginnies, W.G. and E.F. Haase. 1975. Guayule : A rubber producing shrub for arid and semi-arid regions, Arid lands Resource Information Paper No. 7, Univ. of Arizona, Tucson, Arizona-85719, USA pp 267.

Prasad, S.R., R. Prakash, C.M. Sharma and M.F. Haque. 1981. Genotypic and phenotypic variability in quantitative characters in oat. *Indian J. Agric. Sci.* **51** : 480-482.

Rao, U.V., D. Singh and O.P. Bishnoi. 1987. Characterisation of agricultural climate of Hisar area, Agrimet. Publication-6, H.A.U., Hisar, India, 22 pp.

Ray, D.T., D.J. Garrot and M.R. Rose. 1983. Aspects and Prodecures of Statistics, A. biometrical approach, Second edition, New York, McGraw-Hill, 633 pp.

Thompson, A.E., D.T. Ray, M. Livingston and D.A. Dierig. 1988. Variability of rubber and plant growth characteristics among single-plant selections from a diverse guayule breeding population. *J. Amer. Soc. Hort. Sci.* **113** : 608-611.