

GENETIC/PHENOTYPIC STUDIES ON SPINES IN PEJIBAYE (*Bactris gasipaes* H.B.K., PALMAE)*

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ABSTRACT

The pejibaye, an Amazonian palm widely used for food, is starting to be genetically improved. Twenty-eight open pollinated plants were randomly sampled from a spineless stemmed sub-population from Yurimaguas, Peru, and their progeny were evaluated in a randomized block design with 4 repetitions. The character "petiole/rachis spines" showed high hereditabilities, both narrow sense (0.36) and wide sense (0.77), while the characters "leaflet edge spines" showed medium (0.26 and 0.60, respectively) and "leaflet nerve spines" showed low (0.14 and 0.41, respectively) hereditabilities. The magnitudes of the additive genetic variances were low, as were the genetic coefficients of variation and Vencovsky's "b" index (ratio of genetic C.V. to environmental C.V.). Statistically significant phenotypic correlations were observed between "petiole spines" and "leaflet edge spines" ($r = 0.82$) and between "leaflet nerve spines" and "edge spines" ($r = 0.58$) in the progenies, but not in the parent plants, suggesting the existence of endogenous factors that modify the expression of these characters during their development, which was confirmed for "petiole/rachis spines" in the field.

INTRODUCTION

The pejibaye (*Bactris gasipaes* H.B.K., Palmae), frequently called peach palm in English and pupunha in Brazil, was domesticated by the pre-Colombian Amerindians (Patiño, 1963) and is currently the object of intensive research efforts in several tropical American countries (Clement, 1986a). Mora Urpí (1984) and Clement and Mora Urpí (1987) evaluated its economic potential and demonstrated that pejibaye could become an important crop in the humid tropics, due to multiple uses for its fruit and its heart of palm (palmito). Potential yields, with good agronomic

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practices, are greater than 25 t/ha of fresh fruit or one t/ha of palmito. This potential can be elevated through genetic improvement (Mora Urpí, 1984).

The domestication process in pejibaye gave rise to numerous distinct morphotypes, recently classified by Mora Urpí and Clement (1988) as land races. Among the characters modified by selection, the density of the spines that arm the stem and leaves has practical importance in plant management and crop acceptance (Hunter, 1969; Camacho, 1972). According to Morera (1981) and Clement (1988) the spines are characteristic of the genus *Bactris* and are assumed to represent the primitive state. Their absence on the stem and/or leaves is therefore a derived state, selected by humans.

Clement and Mora Urpí (1988) found significant correlations between petiole/rachis spines and stem spines in Amazonian populations, although their magnitude varied considerably among populations. These authors suggested that selection against petiole/rachis spines could also eliminate stem spines. It is important, therefore, to determine the genetic parameters of these characters so as to predict the efficiency of this selection.

The present study obtained this information for a spineless stemmed pejibaye population, suggested as part of the genetic base of the improvement programs at the National Research Institute for Amazonia - INPA and at the University of Costa Rica (Clement and Mora Urpí, 1987). The genetic structure of three leaf-spine characters was studied, estimates of the magnitudes of their genetic parameters were obtained and the possibility of genetic advance through selection is discussed for this population.

MATERIAL AND METHODS

The germplasm used is from four open pollinated, spineless-stemmed plants of pejibaye obtained from Yurimaguas, Peru, maintained by the Agronomic Sciences Dept. at INPA, a sub-population (400 plants) of which was planted on the Fazenda Paxica, Km 12 ZF-1, in the SUFRAMA Agricultural District, Manaus, Amazonas, Brazil, in May, 1982. Twenty-eight open pollinated, randomly chosen plants were sampled in 1986, obeying methodology detailed by Kemp (1976) and Shimizu *et al.* (1982). One to three fruit bunches were collected from each plant, depending upon fruit number and maturation. After germination, the plantlets were established in a poli-bag nursery at INPA, using a substrate rich in organic matter and maintained in light shade (Sombrite 30%). Thirty-two plantlets of uniform size were randomly sampled from each progeny for this study. A randomized complete block design, with four repetitions, was used for the statistical analysis.

The 28 parent plants and their progeny were characterized with the descriptors established by Clement (1986b,c). Precise descriptor states for both parents and progeny were established by multi-population samplings previous to the evaluation,

as Clement (1986b,c) used subjective states. The definition of these descriptors and their respective states are presented in Tables I and II, respectively. Each plant, both parent and progeny, was individually characterized.

Table I - Descriptor definitions used to evaluate *Bactris gasipaes* spine characters on mature plants and plantlets.

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1. Number of spines on stem (in 16 cm² at breast height)
 2. Spines on petiole/rachis (ventral surface): Parents - in the 20 cm around the first leaflet (9th leaf); Progeny - in the 10 cm around the first leaflet (newest completely expanded leaf). (states: 0-9).
 3. Spines on central nerve (ventral surface): Parents - in the central part of the last leaflet of the 12th group (right side); Progeny - in the central part of the middle leaflet (right side). (states: 0-9).
 4. Spines on leaflet edges: Parents - as in item 3; Progeny - in the central part of the leaf (right side). (states: 0-9).
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Table II - Amplitude of the descriptor states (number of spines per class) used in evaluation of *Bactris gasipaes* spine characters.

Classes*	Parents		Plantlets		
	Stem	Pet/Rach	Nerves**	Pet-Rach	Nerves**
0	0	0	0	0	0
1	1-10	1-100	1-10	1-30	1-5
2	11-20	101-200	11-20	31-60	6-10
3	21-30	201-300	21-30	61-90	11-15
4	31-40	301-400	31-40	91-120	16-20
5	41-50	401-500	41-50	121-150	21-25
6	51-60	501-600	51-60	151-180	26-30
7	61-70	601-700	61-70	181-210	31-35
8	71-80	701-800	71-80	211-240	36-40
9	81-	801-	81-	241-	41-

* Class values were transformed by $(x + 1/2)^{1/2}$ for analysis.

** Values also used for evaluating leaflet edge spines.

Pet/Rach = Petiole/Rachis.

The same descriptors, with different state definitions, were used to correlate the character expressions between parents and progeny; it is thought that this procedure permits a reasonable approximation of the biology of the characters. The Pearson correlation coefficients were estimated following Gomes (1978). The genetic parameters and the value of the "b" index ($b = C.V.g/C.V.e$) were estimated following Vencovsky (1987) and are presented in Table III.

Table III - Mathematical expectations for the sums of squares [E(SS)], derived from the analysis of variance (Vencovsky, 1987). Experimental degrees of freedom indicated.

Source of variation	D.F.	S.S.	E(SS)
Blocks	(r-1)=3	-	-
Progenies	(s-1)=27	SS ₁	$\sigma_d^2 + n\sigma_e^2 + nr\sigma_p^2$
P x B Interaction	(r-1)(s-1) = 81	SS ₂	$\sigma_d^2 + nr\sigma_e^2$
Within Progenies	rs (n-1) = 784	SS ₃	σ_d^2
Total	rsn - 1 = 895		

$$h_{\text{(narrow)}} = \frac{4\sigma_p^2}{\sigma_d^2 + \sigma_e^2 + \sigma_p^2} \quad h_{\text{(wide)}} = \frac{\sigma_p^2}{\sigma_d^2/nr + \sigma_e^2/r + \sigma_p^2}$$

r = no. blocks; s = no. progenies; n = no. individuals/plot; σ_d^2 = variance between individuals of the same progeny within plots; σ_e^2 = interaction variance due to progeny response to environment; σ_p^2 = genetic variance among progenies; (narrow) sense heredibility; (wide) sense heredibility.

RESULTS AND DISCUSSION

All of the 28 parent plants presented spineless stems. In Table IV the absolute phenotypic frequencies of the leaf spine characters are presented for both the parent plants and their progeny. The three characters have different frequency distributions, especially when comparing parents and progeny. The Yurimaguas, Peru, population has been intensively selected for spineless stems (Mora Urpí and Clement, 1988) but not for other spine characters. These data suggest a high degree of correlation among stem, petiole/rachis and leaflet edge spines, but less so for leaflet nerve spines. The differences between parents and progeny suggest segregation due to open pollination or differential character expression with age.

Table IV - Phenotypic frequencies of *Bactris gasipaes* leaf spine characters of the 28 parents and progenies, from the Yurimaguas, Peru, sub-population.

Classes	0	1	2	3	4	5	6	7	8	9	Total
Parents											
Petiole/rachis	22	5	0	1	0	0	0	0	0	0	28
Leaflet nerve	13	12	2	1	0	0	0	0	0	0	28
Leaflet edge	24	0	0	1	0	0	2	0	1	0	28
Progenies											
Petiole/rachis	646	3	12	10	9	6	8	2	0	0	896
Leaflet nerve	276	22	340	95	138	23	1	1	0	0	896
Leaflet edge	841	0	4	3	20	4	19	2	3	0	896

Table V presents the Pearson correlation coefficients between pairs of these characters. A general lack of significant correlations between parent characters is evident, except for the characters "leaflet nerve" and "leaflet edge spines", which appears to make biological sense as they are both on the leaflet. The correlation between stem and petiole/rachis spines was especially low, which contrasts with the relatively high correlation reported by Clement and Mora Urpí (1988). In contrast, the progeny showed a high correlation between petiole/rachis and leaflet edge spines, and a moderate one between leaflet nerve and leaflet edge spines.

Table V - Correlations between *Bactris gasipaes* leaf spine characters evaluated in the 28 parents and progeny (estimated by the treatment means), from the Yurimaguas, Peru, sub-population.

Parents	l. nerve	l. edge	stem
pet/rach	-0.191	0.001	0.003
l. nerve	-	0.467**	0.004
l. edge		-	0.002
Progenies			
pet/rach	0.361	0.823**	
l. nerve	-	0.584**	

pet/rach = petiole/rachis spines; l. nerve = leaflet nerve spines; l. edge = leaflet edge spines.

**Significant at 1% probability by the t test.

The differences between the parental and the progeny frequencies and correlations is most intriguing. Further observations were therefore made in the peji-baye germplasm bank at INPA and it was found that the petiole/rachis spines of the lateral shoots of adult plants varied with age: the older (thus lower) leaves had a greater number of spines, while the younger (thus higher) had fewer spines. This suggests that endogenous factors modify character expression as the plant attains physiological maturity. It also suggests that leaf spines are important defense mechanisms for the juvenile plant and that the juvenile expression of these spine characters has not been selected against (Amerindian and peasant selection is generally practiced on mature (fruiting) individuals, not on plantlets).

Table VI presents the estimates of the genetic parameters of the leaf spine characters. The character "leaflet nerve spines" presented a significant block effect and a smaller progeny effect, while also presenting a small negative σ^2 (-0.0004), which can be accepted without invalidating the other estimates because of its very small value (Dudley and Moll, 1969). A more detailed examination of block orientation and apparent environmental exposure in the nursery did not reveal obvious environmental effects that might explain this result.

Table VI - Estimates of the genetic parameters of the *Bactris gasipaes* leaf spine characters in 6 month old progeny from the Yurimaguas, Peru, sub-population.

Character	σ_d^2	σ_e^2	σ_p^2	$h^2_{(n)}$	$h^2_{(w)}$	σ_A^2	C.V. _g	C.V. _e	b
pet/rach	0.089	-0.0004	0.0088	0.36	0.77	0.035	11.89	37.6	0.32
l. nerve	0.245	0.0241	0.0095	0.14	0.41	0.038	6.90	46.6	0.15
l. edge	0.134	0.0106	0.0101	0.26	0.60	0.040	12.99	60.8	0.21

pet/rach = petiole/rachis spines; l. nerve = leaflet nerve spines; l. edge = leaflet edge spines.

The character "petiole/rachis spines" presented the largest estimates of heredibility, both wide sense (0.77) and narrow sense (0.36). Since this is the most important character for agricultural management of peji-baye and can be highly correlated with stem spines, these heredibilities suggest a high probability of rapid advance in selection against spines.

The estimates of additive genetic variance are relatively and uniformly low, which suggests that genetic advance through open pollinated mass selection will be difficult. These low values may be explained by the high frequency of alleles for spinelessness, which generally lowers additive genetic variance (Falconer, 1981) and may be due both to strong selection against stem spines practiced by Yurimaguas inhabitants and the strongly biased collection methodology used in obtaining this germplasm. Self-pollination of this material should allow identification of any

heterozygous parents, facilitating their elimination from the population and fixing the spineless alleles.

The "b" indices estimated had values lower than 0.32. According to Vencovsky (1987), in experiments with maize (*Zea mays* L.), "b" values equal to or superior than 1.0 indicate genetic conditions favorable to rapid genetic advance. If this criterion is valid for pejibaye also, the low level of genetic variability observed will mean slow genetic advance in this subpopulation unless more sophisticated breeding designs are used.

CONCLUSION

The results presented permit the following conclusions: 1) the character "petiole/rachis spines" has relatively high heredability estimates, 0.35 narrow sense and 0.77 wide sense, that should respond rapidly to selection; 2) the magnitudes of the additive genetic variances, the coefficients of genetic variation and the "b" indices were low, suggesting the need for more refined selection programs to obtain significant genetic advances.

RESUMO

A pupunha (*Bactris gasipaes* H.B.K.), palmeira alimentícia da Amazônia, está começando a ser melhorada geneticamente. De uma sub-população de pupunha sem espinhos no estipe, procedente de Yurimaguas, Peru, foram amostradas ao acaso 28 progênies de polinização aberta, cujas mudas foram avaliadas num delineamento de blocos casualizados, com 4 repetições. O caráter "espinhos no pecíolo/rachis" apresentou altas heredabilidades, tanto no sentido restrito (0,36) como amplo (0,77), enquanto os caracteres "espinhos na bordadura do folíolo" foi média (0,26 e 0,60, respectivamente) e "espinhos na nervura do folíolo" foi baixa (0,14 e 0,41, respectivamente). As magnitudes das variâncias genéticas aditivas, bem como o coeficiente de variação genética e o índice "b", foram baixas. Foram encontradas coeficientes de correlação fenotípicas significativas entre os caracteres "espinhos do pecíolo" e "na bordadura" ($r = 0,82$) e "na nervura" e "na bordadura" ($r = 0,58$) nas progênies, mas não nas matrizes, sugerindo a existência de fatores endógenos que modificam a expressão destes caracteres durante o desenvolvimento da planta, que foi confirmado no campo.

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