

Variation and correlations of some pod and bean values in cacao (*Theobroma cacao* L.) with reference to the parental effects on fruit setting and bean number^{*1/}_____

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RESUMO

Os frutos analisados foram obtidos em dois experimentos de polinização controlada. O origem do pólen afetou significativamente o pegamento, assim como o número de sementes por fruto. O clone SCA 12 se mostrou menos sensível, que os demais clones, ao pênco fisiológico que ocorre 7 semanas após as polinizações.

Foram estudadas neste trabalho 7 características inerentes aos frutos e sementes e analisados os coeficientes de correlação. O rendimento em sementes secas por fruto estava melhor relacionado com o número do que com o peso médio das sementes, por fruto. Nos frutos com um número de sementes relativamente alta, porém, o peso médio assume maior importância, estando mais ligado a outros fatores tais como, o peso fresco do fruto e o peso seco do pericarpo.

Introduction

INFORMATION from the literature indicates, that the percentage of fruit setting might be an important factor in determining yield of certain cacao populations. Vello (8) shows a significant effect of the pollen source on the success of hand pollinations, and the observed differences were also related to the percentage of ripe fruits harvested. Opeke and Jacob (3) recorded a high correlation between fruit set and the number of fruits harvested, and

this latter character was also significantly affected by either the male or female parent.

Correlation studies on pod and bean values will supply a better understanding of fruit growth and might be of interest for selection work. Esquivel and Soria (1) demonstrated that during the first years of production the cacao yield of individual trees in hybrid progenies is directly related to the number of pods, which permits to simplify selection for yield within hybrid progenies. Ruinard (4) studied variation and correlations within and between trees of 50 different genotypes. The results provided also better criteria for mother tree selection. Van der Knaap (2) studied 50 fruits of each of 5 different clones and established interesting relations between fruit characters. Toxopeus and Wessel (6) and Ruinard (5) showed a great seasonal influence on pod characters and correlations. In the present work 7 different pod and bean values were studied and correlations between the traits were determined within 5 different clones.

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Material and methods

The data presented in this paper are the result of two pollination experiments carried out in 1970 in the clonal garden of the Cacao Research Center CEPEC in Itabuna, Bahia, Brazil. Eight clones were used as parents in each experiment. They were intercrossed 4 by 4 in two reciprocal schemes. The crosses were always made within a few weeks time to avoid the possible effect of the season on the characters. Pollinations were made by hand and to avoid insect visits glass tubes were placed on the flowers before and after pollination. Fruits were harvested at the same phase of ripening, *i.e.* when the yellow colour appears clearly on the greater part of the fruit. Misshapen fruits were excluded from the experiments.

Pollinations of experiment 1 were performed in September 1970, only from 5 clones a sufficient July 1970. Because of a heavy cherrille wilt, occurring number of fruits could be obtained (see Table 1) in order to analyse the records on 7 different pod and bean characters. Dry weights of pod wall, beans and testa (seedcoat without pulp) were taken after oven drying for 48 hours at 105°C. Variation and correlation studies were carried out using the data of all fruits per female clone.

The pollinations of the second experiment were made within two weeks of constant dry weather in December 1970. This permitted for a reliable determination of fruit set, because pollinations use to be less successful on rainy days, like experienced in the

Table 1.—Number of pods (P) and beans (B) per clone used for calculations of variation and intercorrelation of fruit and bean characters.

	SIAL 105	SIAL 169	SIC 802	SIC 806	Total number of pods analysed
IMC67 P	15	15	6	13	49
B	573	569	233	601	
SCA12 P	13	15	15	13	56
B	253	689	597	493	
ICS1 P	2	0	9	11	25
B	60	0	283	476	
UF677 P	6	11	0	7	27
B	117	428	0	216	
	IMC 67	SCA 12	ICS 1	UF 677	Total number of pods analysed
SIAL105 P	13	0	11	9	33
B	222	0	197	152	

Table 2.—Differences in % of surviving fruits due to a heavy cherrille wilt, that occurred 7 weeks after the time of pollination of experiment 2

	number of fruits 5 weeks after pollination	% of surviving fruits 8 weeks after pollination
SIAL 161	364	0.0
SIC 831	266	2.3
SCA 12	261	11.8
ICS 47	275	6.9
UF 613	180	0.0
SIAL 98	318	0.0
IMC 67	210	6.2
TSA 654	165	0.0

first experiment. At least 100 pollinations were realized per cross and each cross on various trees of the female clone. Fruit set was recorded 10 days, 5 weeks and 8 weeks after the date of pollination. A heavy cherrille wilt occurring in February 1970 caused nearly all fruits to die, even though before and after pollination all naturally set fruits were regularly removed from the experimental trees.

*Results**Incidence of cherrille wilt*

The heavy cherrille wilt occurring in February 1971, caused the death of nearly all fruits of experiment 2. However a remarkable tolerance was demonstrated by the SCA 12 clone. After 8 weeks still 41.8 per cent of the fruits were alive, while the other clones showed a nearly complete loss of their fruits (Table 2). Since no important differences in growing conditions or age were present between the clones, this tolerance appears to have a genetical base.

Parental effect on fruit set and number of beans per fruit

During the pollination work of experiment 1 great differences in success were noted depending on the pollinator parent. Specially the pollen of clone SIAL 105 caused very low fruitset percentages of $\pm 25\%$. The other male parents 'SIAL 69', 'SIC 802' and 'SIC 806' on the other hand showed about 60 per cent fruitut. However, due to the rainy wather no reliable countings could be made. When harvesting the fruit of experiment 1 the pollinator 'SIAL 105' also yielded many fruits with particularly low numbers of beans (Fig 1). Statistical analysis showed, that the effect of the 'SIAL 105' clone on bean number was significant at the 5 per cent level.

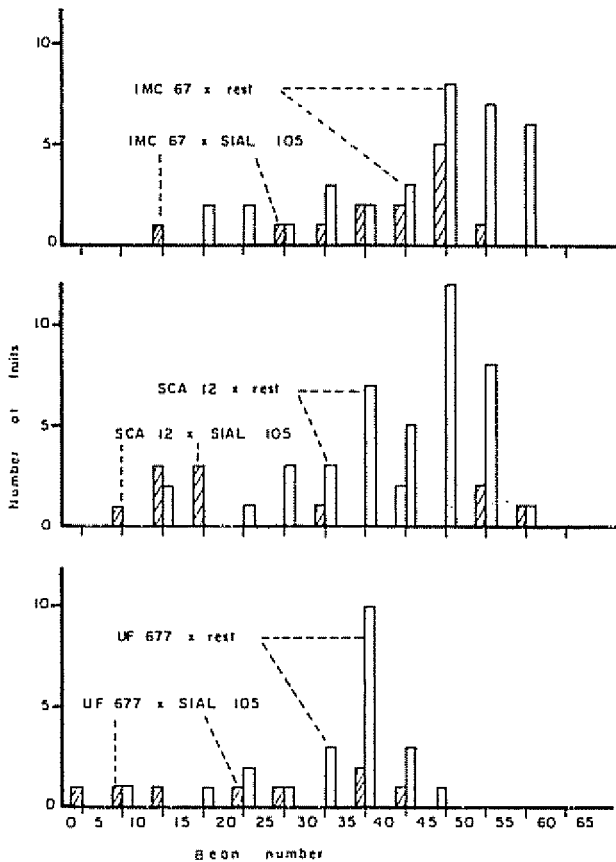


Fig. 1—Frequency distribution of the number of beans per fruit for different crosses. 'SIAL 105' as a male parent is compared to the total result of 3 other pollinators ('SIAL 169, 'SIC 802', and 'SIC 806', which are indicated as 'rest') Bean-number classes are 0 to 5, 6 to 10 beans etc

Experiment 2 permitted for accurate determinations of fruit set percentages 10 days after pollination. For both of the two reciprocal pollination schemes the effect of the female parents was not significant. However the pollinator parents showed highly significant effects on fruit set for one of the two crossing schemes (Table 3). The pollen of 'ICS 47' caused average fruit setting of 43 per cent while the other male parents varied from 63 to 80 per cent.

Variation and correlation of some pod and bean characters

One of the characters measured of all beans harvested of experiment 1 was their individual dry weight after having been peeled off. Frequency distributions were drawn for weight classes of 0.05 gram. The curves of all crosses resembled normal frequency distributions. No effect of the male parent on the average dry peeled bean weight was observed, female clones showing main effects. Interesting differences in variation for bean weight between mother clones were

Table 3—Percentage of fruits set ten days after pollination. Cross TSA 654 x SCA 12 appeared to be incompatible, all fruits dropped within 10 days. Figure "a" was estimated by the missing plot technique.

	SIAL 161	SIC 831	SCA 12	ICS 47	average
IMC 67	82	63	82	31	65
UF 631	71	56	59	37	56
SIAL 98	72	73	86	51	71
TSA 654	96	58	a=84	51	72
average	80	63	78	43	

Table 3-a.—Analysis of variance for parental effects on fruit set.

source	df	ms	F	
male parents	3	1207.2	12.14	P<0.005
female parents	3	221.8	2.23	0.10<P<0.25
rest	8	99.4		

noted. Specially 'ICS 1' showed low coefficients of variation (C.V.) of about 8 per cent. The other clones were more variable with C.V. values of 12 to 19 per cent.

Furthermore the next 7 different pod and bean characters were determined:

- 1—fresh weight per pod (Pfw)
- 2—dry weight of pod wall + central placenta (PWdw)
- 3—number of beans per pod (N)
- 4—fresh weight of all beans + pulp per pod (bdw)
- 5—dry weight of all peeled beans per pod (Bdw)
- 6—average dry weight of peeled beans per pod ($\bar{B}dw$)
- 7—percentage of testa per pod

$$\left(\frac{\text{dry weight testa}}{\text{dry weight testa + beans}} \right) \times 100\% = \%T$$

Table 4.—Correlation coefficients between some pod and bean characters. For explanation of the codes for the traits see text. Levels of significance are indicated by one or two dots (1 and 0.5% levels respectively)

character	N x P fw	N x PW dw	N x B dw	N x b dw	b dw x P fw	b dw x PW dw	b dw x B dw	b dw x % T
clone								
IMC 67	0.73	0.42	0.82	-0.43	0.16	0.50	0.13	0.21
SCA 12	0.44	0.40	0.95	-0.61	0.10	0.34	-0.33	0.21
ICS 1	-0.06	-0.14	0.83	-0.20	0.56	0.61	0.38	0.16
UF 677	0.71	0.54	0.96	-0.17	0.38	0.47	0.08	0.19
SIAL 105	0.64	0.54	0.83	0.15	0.65	0.56	0.66	-0.07

Variation of most characters was high. Character 1, 2, 3, 4 and 5 varied in their C. V. values from 15 to 41 per cent, but the average dry bean weight and the percentage of testa showed considerable smaller variation (C. V. from 9 to 18%). Interesting differences between clones were noted. 'ICS 1' appeared to regulate its characters more narrowly with C. V. values being about half of the C. V.'s of the other clones. 'U. F. 677', on the contrary, was the clone showing the highest C. V. values, being nearly always over 35 per cent.

Correlation coefficients were calculated between all characters measured. They appeared to be positive and significant for all possible combinations of characters 1 to 5. This is to be expected since one trait is part of the other. However it is interesting to note, that the number of beans is closely related to many fruit characters. Table 4 shows e.g. a high correlation of

bean number (N) to the dry cacao production per pod (Bdw). It appeared, that the average bean weight (bdu) is less important in determining dry cacao production per pod, being a rather constant and independent character. This is demonstrated by the low correlations of this trait with pod weight (Pfw) and number of beans per pod (N). However, two clones notably have significant negative correlations for bdu x N. Differences between clones existed also for other correlations.

The number of beans appeared to be positively related to the weight of the pod wall (N x PWdw). However also the average bean weight showed positive and often significant correlations with the dry weight of the pod wall (bdw x PWdw). This seems to indicate that the average bean weight is partly dependent on the same physiological conditions that regulate the growth of the pod wall.

Table 5.—Correlation coefficients calculated for two groups of fruits: (a) the pods with less, and (b) the pods with more beans than the average number per clone. For explanation of the code for the characters see text. The level of significance is indicated by one or two dots (1 and 0.5% level respectively).

Characters	N x B dw		b dw x B dw		b dw x P fw		b dw x PW dw	
group of fruits	less	more	less	more	less	more	less	more
clone								
IMC 67	0.81	0.30	0.36	0.81	0.44	0.63	0.64	0.74
SCA 12	0.98	0.47	-0.14	0.71	0.23	0.72	0.40	0.71
ICS 1	0.87	0.28	0.29	0.90	0.39	0.71	0.37	0.79
UF 677	0.99	0.60	0.16	0.77	0.26	0.82	0.29	0.80
SIAL 105	0.66	0.58	0.48	0.87	0.50	0.73	0.58	0.49

Of further interest is the lack of correlation between average bean weight and percentage of testa ($bdw \times \%T$). A negative correlation was expected, since the bean surface should increase less than the bean volume with increasing bean weight.

Influence of the bean number per pod on some correlations

Some correlations between the traits have been recalculated for fruits with relatively few and fruits with relatively many beans. The fruits were divided into two groups: (a) the ones with less beans and (b) the ones with more beans than the average number of the particular clone. By this way of recalculation some interesting changes in correlations appeared (Table 5). While Table 4 shows, that the dry cacao production per pod is mainly dependent on the number of beans, from Table 5 it is clear that the average bean weight also plays an important role. The correlation of $Bdw \times bdw$ is very positive and significant for the group of fruits with more beans than the average number.

Furthermore the average bean weight (bdw) is considerably closer related to Pfw and $PWdw$ for the group of fruits with many beans, than for the group with low bean numbers.

Discussion and conclusions

Toxopeus and Jacob (7) suggested that insufficient natural pollination may account for low fruit set percentages and fruits with low number of beans as shown by a skew frequency distribution of the bean number per fruit. The fruits obtained by controlled hand pollinations in our experiments showed a similar shape of distribution. Low number of beans in this case might be related to differences in pollination success as affected by the weather conditions. From field observations we concluded, that specially on rainy days the success was very low. Secondly the male parent appeared to have a significant effect on the fruit setting, which is in accordance with the results of Vello (8). Also the number of beans per pod differed significantly between male parents, indicating that genetical differences in pollen fertility might exist. In the study of Vello (9) the pollen source did not affect the bean number; however he compared only two clones in his experiment. Since the yield of cacao trees could be well affected by pollen fertility, research in this direction might be valuable.

In the correlation study special attention was paid to the factors related to the production of dry cacao per fruit. Van der Knaap (2) and Ruinard (4) found, that within clones both the average bean weight and the number of beans will determine the dry cacao production per pod. In our experiment the number of beans generally showed to be of major importance. However we have seen, that in fruits containing rela-

tively many beans the average bean weight becomes the main factor.

Average bean weight, according to many authors, is a rather independent character (2,4 and 6). These authors found e.g. non-significant correlations between average bean weight and number of beans per pod. Present work indicates, however, that differences between clones must be expected. Two of the 5 clones showed significant negative correlations. Also highly positive correlations were found between average bean weight and pod weight for fruits with relatively many beans. The conclusion may be that the physiological conditions controlling fruit growth may limit growth of individual beans, specially when many beans are present.

Of further interest is the observed tolerance of the 'SCA 12' clone to the physiological phenomenon of cherelle wilt. Maybe also due to this character 'SCA 12' appeared to be an important parent clone for the productions of high yielding hybrids.

Summary

Fruits obtained from two pollination experiments were analysed for various characters. Differences in fruit setting and bean number per pod were significant between male parents, indicating genetical differences in pollen fertility. When a heavy cherelle wilt occurred 7 weeks after pollination, the only clone showing considerable tolerance was 'SCA 12'.

Correlations between 7 pod and bean characters have been determined within 5 clones. Generally dry bean production per pod was closer related to bean number, than to the average bean weight. However, in fruits with a relatively high number of beans the average bean weight is of major importance. In this group of fruits the average bean weight becomes a less independent character, showing high correlations with pod weight and dry weight of the pod wall.

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Resumen

Se analizaron varios caracteres de frutos de cacao de dos experimentos de polinización en Itabuna, Brasil. Las diferencias en el cuajado de frutos y número de almendras por mazorca fueron significativas entre los progenitores masculinos, lo que indica diferencias genéticas en fertilidad del polen. Cuando ocurrió una

marchitez cherrille intensa, siete semanas después de la polinización, el único clon que mostró considerable tolerancia fue 'SCA 12'.

Se han determinado en cinco clones correlaciones entre siete caracteres de mazorca y almendras. Por lo general, la producción de almendras secas por mazorcas estuvo más estrechamente relacionada al número de almendras, que al peso promedio de la almendra. Sin embargo, en frutos con un número relativamente alto de almendras, el peso promedio de la almendra es de la mayor importancia. En este grupo de frutos, el peso promedio de la almendra se vuelve un carácter menos independiente, y muestra altas correlaciones con peso de la mazorca y con el peso seco de la pared de la mazorca.

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Reseña de Libros

Otros libros recibidos

SALAZAR C., ENRIQUE, GUERRA, M. de S. e SILVEIRA, C. D. da. Manual de insecticidas e acaricidas; aspectos toxicológicos. Pelotas, Brasil, Editora Aimara, 1976. 351 p.

Este libro es bastante oportuno por contener la información que el agrónomo consultor o administrador de fincas necesita tener a la mano en el desempeño de su labor. Se pueden encontrar datos toxicológicos en manuales en inglés, pero no conocíamos un manual en uno de los idiomas ibéricos (en este caso, el portugués técnico es casi indistinguible del español).

El libro incluye 132 insecticidas y 25 acaricidas, más coadyuvantes, agrupados en grupos químicos como clorados, fosforados, carbamatos, vegetales, fumigantes, etc. Para cada producto, además de la sinonimia y datos químicos, presenta toxicidad en dosis letal DL

50, tanto oral como dermal, poder residual, modo de acción, tolerancia, y dosis para los usos principales. Los autores pertenecen al cuerpo docente de la Facultad de Agronomía Eliseu Marciel de la Universidad Federal de Pelotas.

Creemos que el librito merece una buena difusión, por su utilidad práctica y que tenga más de una edición. Así habrá oportunidad de incluir los insecticidas minerales como los arseniatos de plomo y de calcio, todavía muy usados, y al HCN como fumigante.

También se debe poner en la bibliografía el libro de W. T. Thomson, del cual se ha tomado una tabla de DL 50 y al que se menciona como fuente de los datos de toxicidad de varios compuestos. En uno de estos cuadros la rotenona figura como altamente tóxica, cuando hay textos que la consideran inocua para mamíferos.

Algunas fórmulas estructurales no corresponden al nombre químico. Para el Aramite (p. 294) por ejemplo en su estructura falta un múltiplo 3 para el primer CH₃, y aparece como fosfito en lugar de sulfito.