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GENETIC ANALYSIS OF YIELD ATTRIBUTES IN *COCOS NUCIFERA* L. VAR. WEST COAST TALL

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SUMMARY

The variance components analysis of characters influencing productivity in six yield groups of coconut in three sets of crosses has revealed that there is substantial additive genetic variation available for selection for yield and other associated characters like number of female flowers and percentage set as estimated by the relative sizes of σ_g^2, σ_s^2 and σ_e^2. The general combining ability of the higher yield groups is considerable for number of bunches, number of female flowers, yield of nuts but is limited for percentage set. The presence of interaction between yield groups and category of crosses and the extent of non-additive genetic variation as revealed by the magnitude of σ_s^2 indicate the necessity of maintaining substantial heterozygosity within each population. Since high yielders will be proportionally low in any unselected population, the limited diversity within these groups can be better utilized by interplanting them with similar phenotypes of diverse origin, to prevent inbreeding in their progenies and to maintain heterozygosity within the population.

The results have demonstrated the stability of the superiority of high yielding groups even in poor environment. In a more favourable environment with higher doses of fertilizer, the difference between the top two yield groups and the rest could possibly be larger. Therefore, choice of mother palms with high yield either for crossing purposes or for progeny testing appear to be reliable, provided that there is sufficient genetic diversity within the population.

INTRODUCTION

The selection of parents from a population for further propagation from certain outbreeding material like coconut is dependent on the parental performance and its progeny in controlled matings. Such an analysis will also permit the identification of genotypes with superior transmission of their traits to their progeny and the pattern of genetic variation which will enable a breeder to know the magnitude of genetic variation available for selection and the breeding procedure to be adopted (CHARLES, 1961; LIYANAGE, 1967). In a crop with a large generation interval like coconut, the relationship of early growth features with adult plant performance will help elimination of inferior genotypes at an early stage. The West Coast Tall variety grown extensively in Kerala and other coconut-growing areas of India is a locally adapted kind of material with considerable genetic variation for yield in the same location. Even under unirrigated conditions, palms yield up to 120 or more nuts per year, although the average yield in a plantation may not generally exceed 50 or 60 per tree/year. Therefore, a genetic analysis of seedling characters, yield of nuts and other characters associated with productivity has been undertaken in crosses between six yield groups under controlled matings. The results of such an investigation in this material with a stable yield level are reported in this paper.

MATERIAL AND METHODS

The material consists of 540 palms drawn from 108 parent palms with six levels of yield, namely:

1. over 120 nuts per year (G_1)
2. 101 to 120 nuts per year (G_2)
3. 81 to 100 nuts per year (G_3)
4. 61 to 80 nuts per year (G_4)
5. 41 to 60 nuts per year (G_5)
6. below 40 nuts per year (G_6)

chosen at random within each category. They will hereafter be referred to as G_1, G_2, G_3, G_4, G_5 and G_6 groups. Each of the group was crossed with:

a. Natural crossing, i.e. male parent not known

b. Pollen of the elite yielding group with a level of more than 100 nuts per palm per year

c. Pollen of the same group (inbred).

They will hereafter be refered to as a, b and c categories. The progenies of the 18 possible combinations were planted out in five replicates with an initial population of 540 seedlings in 1942. The data on yield and other related characters collected during the four years from 1965 to 1968 are analysed now, since this plantation has reached a stable yield level.

The crosses were made in 1940 at the Central Coconut Research Station, Kasaragod and the nuts were sown in the nursery in 1941 at the Central Coconut Research Station, Nileshwar. One-year-old seedlings were planted in the sandy loam soil of Central Coconut Research Station, Nileshwar in 1942. The quantity of manure of 0.34 kg of N, 0.2 kg of P_2O_5 and 0.68 kg of K_2O over a basal dressing of 25 kg of green leaf per adult palm is uniform for all palms. In summer the soil has a low moisture retentivity. The crop did not receive any supplementary irrigation during any stage of growth. The tract is also representative of the coastal region of coconut cultivation in West and South West India. The management was the same as practised by cultivators except for the afore-mentioned manurial schedule.

The characters that had been observed, were 1. Number of bunches emerged; 2. Number of female flowers produced; 3. Number of flowers set (number of nuts); 4. Percentage of flowers set; 5. Number of leaves in the crown; 6. Rate of production of leaves.

Observations were recorded every month concerning the emergence of leaves, emergence of bunches and the number of female flowers in each bunch. The number of flowers set i.e. the number of nuts harvested is recorded when harvesting the nuts and the percentage of set is computed. The number of leaves in the crown is recorded in the month of December every year.

Statistical analysis for combining ability was done according to the line × tester model outlined by KEMPTHORNE (1957). Heritability was estimated as the proportion of the additive component in the total phenotypic variation. The entire analysis is based on a model with disproportionate class numbers. The data were analysed on an IBM 1620 computer.

RESULTS

Studies on the seedling and early growth on 12-month-old seedlings indicated substantial differences between the yield groups and the three categories of crosses. The seedlings from high yielding groups were better than the others in the number of green leaves, height and girth of the collar. By 1947, when the young palms were five years old, differences between yield groups were significant for the mean number of days for the emergence of successive leaves, number of leaves on the crown, length of leaf and number of leaflets, the group with 40 nuts and below being the poorest for all the characters. The differences between the three categories of crosses were not significant at this stage (SAYEED and NARAYANA 1953).

Further observations during the period 1954 to 1961 have confirmed the superiority of the yield groups with 100 or more nuts for the number of functional leaves in the crown and the number and proportion of trees which flowered.

The differences between yield groups were not significant for the other characters. While the number of functional leaves in group G_2 is slightly higher than that of the low yielding group (G_6), the length of leaf and total number of leaves produced by the palm remained essentially the same in all yield groups.

The differences between the three categories of crosses were significant for the number of functional leaves and the number of leaves produced during 1961 and the

Table 1. Comparison of leaf characters of progenies of mother palms of different yield groups and different categories of crosses–1961.

Particulars	Leaf characters		
	mean number of functioning leaves on the crown	mean number of leaves produced during the year	mean length of of leaf (cm)
Mother palm			
Above 120 nuts	19.9	9.5	450.9
101–120 nuts	20.1	9.8	432.3
81–100 nuts	19.0	9.5	425.5
61– 80 unts	18.3	8.9	430.4
41– 60 nuts	18.9	9.5	436.8
Below 41 nuts	17.7	8.7	475.6
Crosses			
Natural	19.4	9.3	442.7
Cross with elite pollen	19.4	9.7	439.6
Inbred	18.0	9.0	413.4

mean length of the leaf, the crosses with elite pollen (category b) being distinctly superior to the inbreds (category c) (Table 1).

So the earlier results up to 1961 have led to the following conclusions:

Firstly the high yielding palms (G_1 and G_2 groups) are superior to the other categories in early growth, rate of production of leaves, functional leaves in the crown and the proportion of plants which have started bearing by that time. So it is possible to get high yielders with early bearing.

Secondly, the differences between the three categories of crosses are perceptible even from the seedling stage. The crosses with elite pollen were distinctly superior to the inbreds as to the girth of seedlings, number of green leaves, leaves produced per year and height of the seedlings at the time of planting. Therefore, pollination with pollen from elite plants is useful in upgrading the material for early seedling characters and yield.

Thirdly, there is a distinct possibility of selection of superior genotypes in the seedling stage itself, since the performance in category 'b' of the crosses is superior to the inbreds category 'c' in yield and is also reflected in the seedling growth. Controlled hybridization with diverse parents with superior yield appears to offer good scope for improvement.

Finally, there is considerable genetic diversity in the West Coast Tall variety for the above attributes which can be exploited by selection in this variety itself and in crosses with other diverse varieties.

The analysis of the data for the period 1965–1968, showed substantial differences among crosses due to differences between the yield groups and also between three categories of crosses in respect of the characters influencing yield (Table 2–4).

Analysis of combining ability

The results of combining ability analysis (Table 4) have substantiated the results of early growth. The differences in crosses due to differences in yield groups are significant for number of bunches emerged, number of female flowers produced, yield of nuts and percentage of flowers set. G_1 and G_2 groups are distinctly superior to the rest, G_6 being the poorest. The general combining ability effects are high and in the desired direction for the two groups with 100 nuts or more as to number of bunches emerged, number of female flowers, female flowers set and number of leaves in the crown. The group with 120 or more nuts maintained its superiority over the other groups for the other two characters also. Among the three categories of crosses, the use of elite pollen (b) was superior to the other two in the means and combining ability effect for all the characters except rate of production of leaves.

A comparison of the means has shown that the differences among the yield groups are significant for all the characters, the first two groups being significantly superior to the rest as to number of bunches emerged, number of female flowers produced, female flowers set and percentage set. The interaction between the yield groups and categories of crosses was only significant for the rate of leaf production. Therefore, it is possible to select for the parental performance and general combining ability effects.

The components of variances for combining ability (Table 3) indicate that there is substantial additive genetic variation available for selection for the first four charac-

Table 2. Analysis of variance table. Line × tester analysis of combining ability in some crosses of West Coast Tall variety of coconut.

Source of variation	d.f.	Mean sum of squares					
		number of bunches emerged	number of female flowers produced	number of female flowers set (yield of nuts)	flowers set (%)	number of leaves in the crown	rate of production of leaves (in days)
Replications	4	5.5385	1812.9600*	317.8425*	47.2625	13.3255	19.2575
Lines	5	4.3636	2784.9580**	479.6092**	112.3700*	5.4494	9.4400
Testers	2	7.2108	579.9000	596.5630**	338.3650**	13.0265	19.8900
Lines × Testers	10	2.2566	679.3060	94.5493	21.6670	9.8405	23.6920*
Residual	68	2.3586	678.1250	109.1146	33.9727	6.0569	10.9255

*$P<0.05$; ** $P<0.01$

Table 3. Components of genetic variation for some crosses in West Coast Tall variety of coconut.

	number of bunches emerged	number of female flowers produced	number of female flowers set (yield of nuts)	flowers set (%)	number of leaves in the crown	rate of production of leaves (in days)
$\hat{\sigma}g^2$	0.1569	44.5831	19.7127	9.0534	−0.0268	−0.4012
$\hat{\sigma}s^2$	0.4312	130.0899	17.9812	4.0443	1.9166	4.6454
$\hat{\sigma}e^2$	0.1004	28.8564	4.6432	1.4456	0.2577	0.4649
$\hat{\sigma}h^2$	0.2279	0.2190	0.4656	0.6225	–	–

Table 4. Means and general combining ability effects of reproductive characters.

	Number of bunches emerged		Number of female flowers produced		Number of female flowers set (Yield of nuts)		Percentage of flowers set		Number of leaves in the crown		Rate of production of leaves (in days)	
	mean	$\hat{g}$	mean	$\hat{g}$	mean	$\hat{g}$	mean	$\hat{g}$	mean	$\hat{g}$	mean	$\hat{g}$
Line 1	6.08	0.55	96.10	18.33	35.08	7.99	38.64	4.74	21.68	0.55	35.17	0.12
2	6.15	0.61	92.68	14.90	32.76	5.68	33.84	–0.05	21.73	0.60	34.18	–0.85
3	5.07	–0.46	65.18	–12.58	23.00	–4.07	32.39	–1.50	20.84	–0.28	35.02	–0.01
4	5.41	–0.12	74.62	– 3.15	25.61	–1.46	34.42	0.52	21.26	0.14	34.25	–0.79
5	5.67	0.13	73.96	– 3.80	25.43	–1.64	33.70	–0.19	21.13	0.00	35.28	0.23
6	4.81	–0.72	64.09	–13.68	20.59	–6.48	30.38	–3.51	20.10	–1.02	36.35	1.30
Tester 1	5.43	–0.10	79.97	2.19	27.19	0.10	33.04	–0.85	21.21	0.08	35.90	0.85
2	6.07	0.53	80.64	2.86	31.48	4.40	37.60	3.70	21.74	0.61	34.28	–0.76
3	5.10	–0.43	72.71	– 5.06	22.57	–4.51	31.05	–2.84	20.43	–0.69	34.95	–0.09
General mean	5.53		77.77		27.08		33.89		21.12		35.04	
S.E. of difference of means of lines	0.56		9.51		3.81		2.13		0.90		1.21	
of testers	0.40		6.72		2.70		1.50		0.64		0.85	
of line × tester	0.97		16.47		6.61		3.69		1.56		2.09	

$\hat{g}$: estimates of general combining ability effects.

ters viz number of bunches emerged, number of female flowers produced and number and percentage of flowers set.

The negative estimate of general combining ability for the other two reveals that there is little scope for selection for these attributes at this age. The highest estimate of heritability was obtained for the percentage of flower set followed by number of female flowers set. Therefore, selection for these two characters should result in rapid improvement. The heritability for the other two characters viz number of bunches and number of female flowers is above 20% and therefore offers scope for selection.

DISCUSSION

The results of this study are at variance with the conclusions drawn by CHARLES (1961) on the effectiveness of selection of mother palms and nursery selection of seedlings. The results confirm the findings of LIYANAGE (1967) about the utility of selection of high yielding mother palms.

The consistent superiority of G_1 and G_2 groups over the rest for these characters emphasizes selection of palms with 100 or more nuts/year. There are significant differences between the three categories of crosses. Those with elite pollen (b) yielded significantly higher values for all the characters except for number of female flowers produced, followed by the open-pollinated; the inbred were poorest. Therefore, use of elite pollen can mean a uniform improvement of all the lower yield groups.

There appears to be interaction between yield groups and mode of crossing. Use of elite pollen has improved substantially the low yielding groups for all the characters but not to the same extent in the high yield groups. This may be due to partial inbreeding in the high yielding group since the pollen of their own category was used.

G_1 and G_2 appear to be good general combiners. Therefore, selection of mother palms with high yield has a distinct genetic basis. The use of their pollen for upgrading low yielding groups is an advantage.

The variance components analysis in the present study has revealed that there is substantial additive genetic variation available for the selection for yield as estimated by the relative sizes of σ_g^2, σ_s^2 and σ_e^2. This is true for other associated characters like number of female flowers and percentage set. The general combining ability of yield groups G_1 and G_2 is high for the number of bunches, number of female flowers, yield of nuts and limited for percentage of set. Therefore, the superiority of these genotypes is of an additive nature. However, these two high yielding groups will be proportionally low in any population and consequently they will restrict the sample size available for these categories and limit the diversity within each of these groups. Even such a limited diversity within these two groups can be utilized by crossing them with similar high yielding palms of diverse origin. The pollen of this elite group can be used to upgrade all other lower yield groups with considerable success.

The presence of interaction between yield groups and mode of crossing and the extent of non-adidtive genetic variation as revealed by the magnitude of σ_s^2 indicates the necessity of maintaining substantial heterozygosity within each plantation. This requires diverse hybrid material to be planted in large areas. It is also possible to interplant material of diverse origin with similar phenotype instead of several palms of related origin. This will prevent inbreeding in their progenies and facilitate the supply of hybrid nuts to new plantations. This is essential for elite seed gardens.

The heritability estimates from different investigations reported already are given below:

	(1) from line × tester analysis (present study)	(2) parent-progeny regression of same yield group as (1)	(3) Parent-progeny regression in random. Population of high yielders only (Pilicode)	(4) LIYANAGE and SAKI (1960)
Number of female flowers	0.22	0.27	0.68	–
Yield of nuts	0.47	0.22	0.63	0.48
Percentage set	0.62	0.05	0.76	–
Number of bunches	0.23	–	0.08	–

The estimates of heritability in this study are similar to the results from parent-progeny regressions but slightly higher for yield of nuts. The heritability estimate for yield reported by LIYANAGE and SAKI (1960) is similar to the present result. The estimates are higher for number of female flowers, yield of nuts and percentage set in the Pilicode material as compared to the others. This is expected since the progeny of Pilicode are from highly selected groups for yield.

The results have clearly demonstrated the stability of superiority of high yielding groups even in a poor environment. In a more favourable environment with regular and higher fertilization, the differences between G_1 and G_2 from the rest of the groups could possibly be higher due to their higher general combining ability. While selection in superior environment will be desirable, selection of high yielding palms even in an unfavourable environment is still practicable, if such selection is restricted to the topmost group with adequate population size. Therefore, the choice of mother palms with high yield either for crosses or for progeny testing appears to be reliable provided, that there is sufficient genetic diversity within the population from which the selection is made. The extent of such a variation needs to be studied in other geographical types. The magnitude of difference between yield groups due to improvement in environment is being investigated in the same material as in the present study.

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