

# Coconut Improvement by Selection and Breeding— A Review in the Light of Recent Findings

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## Abstract

The major breeding objectives have been identified as higher yield of oil per unit area of coconut plantation and resistance/tolerance to serious diseases such as root (wilt), 'thattipakka', and stem bleeding.

The breeding systems vary widely in Tall and Dwarf cultivars. The advantages of selecting the best 10% of palms in a given population as mother trees for seed nut collection and breeding purposes have been indicated. Studies on the relationship between yield of nuts, copra content per nut, total yield of copra/palm, and yield of oil/palm showed that in West Coast Tall, the mean copra content/nut, though negatively correlated with yield, does not affect annual outturn of copra/palm, the threshold value being 162.6 nuts, and that the yield of oil/palm and yield of nuts were significantly and positively correlated. The necessity for applying selection pressure on weight of copra/nut and oil percentage in addition to number of nuts has been indicated keeping in view the variability and heritability data available for these characters.

Selfing of West Coast Tall palms confirmed the earlier observation that it is heterozygous for height while Chowghat Dwarf Orange variety is heterozygous for colour, vigour, and stature. Palms which breed true for these characters are also present in the population. In addition to the wide variations observed in the percentage of heterozygotes for vigour realised by selfing or under open pollination of Dwarf Orange or under specific cross combinations with Tall, the progenies were also observed to segregate for colour.

Further experiments are to be taken up for a better understanding of the genetic make up of the Tall and Dwarf varieties. The different approaches that may be pursued for improving their genetic base and the possibilities of realising a higher percentage of hybrids in the Dwarf × Tall crosses are discussed in the light of available data.

## Introduction

Charles (1961) made the last comprehensive review on selection and breeding of the coconut palm. However, certain aspects of crop improvement have been subsequently discussed by a number of workers (Ninan

and Satyabalan, 1964 ; Satyabalan, Ratnam, and Kunjan, 1970 ; Satyabalan, Ratnam, and Menon, 1968 ; Bavappa, Sukumaran, and Mathew, 1973 ; Bavappa and Nampoothiri, 1974 ; Liyanage, 1964 ; Nambiar and Nambiar, 1970 ; Satyabalan and Nambiar, 1968 ; Whitehead, 1968). Considerable data have been gathered in the last five years at the Central Plantation Crops Research Institute on various aspects of coconut breeding and a number of programmes have been developed based on theoretical principles. The present paper reports the results of breeding experiments conducted during this period and attempts to suggest certain approaches for future work.

### **Breeding Objectives**

Though it is generally assumed that the primary aim of coconut breeding is to increase yield of copra, in regions affected by serious diseases such as the root (wilt) disease in India, kadang kadang in the Philippines, lethal yellowing in Jamaica, etc., breeding for disease resistance has become as important as yield improvement itself. Since oil is the end product, it will be necessary to keep the yield of oil per unit area (tonnes/ha) as the criterion rather than number of nuts or copra tree/ha as is being done now. The relative importance of various characters in achieving these objectives is discussed in the concerned sections.

### **Floral Biology and Breeding Systems**

Propagation of coconut continues to be exclusively by seed though in the light of the success obtained in the vegetative propagation of oil palm (Smith and Thomas, 1973 ; Rabechault and Cas, 1974), production of coconut plantlets does not seem to be far from reality. Even if this is achieved, coconut improvement programmes through breeding will have to be continued for obvious reasons. A correct understanding of the breeding mechanism of the coconut varieties is, therefore, essential.

Patel (1938) reviewed the floral biology as it related to the West Coast Tall (WCT) variety. He reported only interspadix overlapping which was to the extent of 22%. It is now observed that there is intraspadix overlapping of male and female phases in WCT in about 10% of the bunches. Jack and Sands (1922) in their study of the three Malayan Dwarfs (Ivory yellow, Red and Green) observed that the flowers were as a rule self-pollinated. Whitehead (1965) observed 80% overlapping in a large group of Malayan Dwarfs. Rao and Koyamu (1955), while describing the Dwarf Green and Dwarf Orange types, observed that the former had "maximum purity" owing to high selfing possibility, while the latter had 80% "purity" as a consequence of both self and cross fertilization. However, no detailed study of the breeding system, taking into account the inter and intra-spadix overlapping, seems to have been made in the different coconut cultivars. Such studies on three Tall cultivars (West

The mean copra content/nut was found to decrease with increase in yield of nuts, but the annual out-turn of copra/palm was not seen to decline. By fitting a second degree equation to the data, the threshold value was found to be as high as 162.6 nuts/palm, showing thereby that selection of mother palms on the basis of yield of nuts can help to increase the out-turn of copra. Similar relationship was found to exist for yield of nuts and annual out-turn of oil also, with the threshold value for yield as 163.8 nuts/palm/year. Even though the mean copra content/nut is negatively correlated with number of nuts, in view of a high threshold value and higher heritability of the former, it may be advantageous to apply selection pressure for both the number of nuts and mean weight of copra. Due consideration in selection for oil percentage, which is independent of yield of nuts, in spite of its relatively narrow variability (68.9—74.6%) may also prove useful. It may be advantageous to study the heritability of this character.

#### Effect of Inbreeding

Bavappa, Sukumaran, and Mathew (1972) have shown that both Dwarf Green and West Coast Tall (WCT) are heterozygous for height, and depending upon the extent of heterozygosity of the parents involved in a cross, segregation pattern of  $F_1$  population would vary and suggested elaborate breeding experiments to assess the genetic variability in both Talls and Dwarfs for efficient exploitation of hybrid vigour. On the basis of the observation in the open pollinated progenies of WCT, parents heterozygous for stature were identified. They were selfed along with Chowghat Dwarf Orange (CDO).

Out of five WCT parents which had not segregated for dwarfness under open pollinated conditions, three segregated on selfing. The percentage of Dwarf segregants was, however, low (Table 3). Two parents bred true. At the same time, the percentage of Dwarfs obtained was as high as 48 in parents which had segregated under open pollination.

The growth measurements of Tall and Dwarf segregants (Table 4) show that the Dwarfs have smaller number of leaves, less girth, and only about half the height of Talls generally, and Dwarfs have a faster rate of leaf production. At the age of one year, the latter have about two leaves more than the Talls. However, the Dwarf segregants of WCT had less leaves. They also showed inconsistency in the early splitting of leaves unlike the normal Dwarfs. A detailed study of these Dwarf segregants alone can throw further light on their bearing habit, nut characteristics, etc.

The CDO on selfing gave much wider variability (Table 5). Out of the 13 palms, four gave only Dwarfs, while the remaining nine palms gave Dwarf plants and heterozygotes of different colour and stature in varying proportions. Based on colour and vigour, the population could be classified into three groups, viz., (1) Dwarfs with orange (parental) colour,

TABLE 3. Segregation pattern in S<sub>1</sub> progenies of West Coast Tall

Parent	Total seedlings	Dwarf	Inter-mediate	Tall	Percentage of Dwarf segregants	Percentage of Dwarfs under open pollination*
<i>(a) Nonsegregating under open pollination</i>						
2/40	7	1	0	6	14.2	Nil
40/414	20	0	0	20	0	0
41/546	7	1	0	6	14.2	0
275/869	16	1	0	15	6.2	0
39.3B/174	1	0	0	1	0	0
<i>(b) Segregating under open pollination</i>						
41/407	10	4	0	6	40.0	8.3
39.3B/531	27	13	0	14	48.0	10.2
31.3B/538	11	3	2	6	27.2	5.4
40/520	12	3	0	9	25.0	2.3
275/924	13	5	2	6	38.4	3.0

\* Data from Bavappa *et al.* (1973).

TABLE 4. Growth measurements in S<sub>1</sub> segregants of West Coast Tall

Variety	No. studied	No. of leaves		Girth (cm)		Height (cm)	
		Mean	C.V. %	Mean	C.V. %	Mean	C.V. %
Tall	112	5.3	18.7	11.0	16.4	128.2	20.9
Dwarf	32	4.7	23.9	8.4	26.1	76.6	26.5

(2) tall vigorous plants with parental colour, and (3) tall vigorous plants with brownish green colour (Table 6). The growth measurements of Dwarfs were different from those of others (Table 6). The CDO is thus heterozygous for colour and growth characteristics.

Only one report is available about the different types of segregants that are realised on selfing CDO (Ninan and Satyabalan, 1964). They observed two types, 'natural off types' and 'pure Dwarfs'. The present study showed three types of segregants, viz., dwarf orange, brownish green and orange heterozygous segregants were obtained from CDO in varying proportions (Table 6).

On the basis of "selfing possibility" and with limited data then available Rao and Koyamu (1956) indicated that CDO was 80% pure. Harland (1957) suggested that CDO might be used to identify prepotent palms and

TABLE 5. Segregation in  $S_1$  progenies of Chowghat Dwarf Orange

Parent	No. of nuts sown	No. of seedlings obtained	Percentage of plants raised		
			Dwarf Orange	Heterozygous segregants	
				Brownish green	Orange
39.3B/647	25	24	83.3	0	16.7
EB/55	25	11	100.0	0	0
EB/57	7	6	100.0	0	0
39.3B/634	21	13	84.6	0	15.4
34.3B/648	14	11	100.0	0	0
EB/77	17	13	69.2	0	30.8
EB/22	24	20	95.0	5.0	0
EB/56	23	21	14.3	0	85.7
XI/71	8	7	42.9	0	57.1
39.3B/649	12	11	100.0	0	0
EB/79	24	23	21.7	69.6	8.7
XISE/3	19	19	10.5	84.2	5.3
EB/21	23	14	28.6	42.8	28.6
Total	242	193	59.6	20.2	20.2

TABLE 6. Mean growth measurements in  $S_1$  segregants of CDO

		Dwarf Orange	Heterozygous segregants	
			Brownish green	Orange
No. studied		319	129	106
Girth (cm)	Mean	9.9	12.5	13.4
	C.V. (%)	19.0	18.3	10.8
Height (cm)	Mean	81.1	131.6	129.2
	C.V. (%)	24.3	21.3	9.5
No. of leaves	Mean	7.1	7.4	8.7
	C.V. (%)	17.1	19.2	10.3

also as an "autodiploid" in breeding experiments (Swaminathan and Nambiar, 1961). Ninan and Satyabalan (1964), while discussing the segregation in CDO, had however raised doubts about the utility of this cultivar for the above purposes. The present study has clearly shown that though the CDO cultivar as a whole is highly heterozygous, some trees are homozygous (Table 5). These could be made use for prepotency studies and production of autodiploids. This also brings us to another important

point that in WCT and CDO, every tree has in it a store of genetic variability and before breeding and genetic experiments are taken up, information on genetic constitution of the parent should be obtained.

In this context it may be interesting to consider the distribution of CDO. Their population is extremely limited as compared to WCT and the two cultivars are grown intermixed. Any outcrossing of the CDO has, therefore, necessarily to be with WCT only, and this would add to the heterozygosity of the population. In WCT on the other hand, outcrossing is by and large between Talls only.

The implications of such a wide variability for stature, vigour and colour in WCT and CDO are indeed very much from the point of view of hybrids production and exploitation of hybrid vigour in coconut. The first question that one is inclined to ask is whether in the place of the present low recovery, a higher proportion of hybrids in CDO  $\times$  WCT crosses can be realized. Though not homozygous, homogeneous lines seem to exist in WCT and CDO for growth characters and colour, which on crossing may be expected to give cent per cent population of hybrids, if complementary or epistatic gene action are not involved in the realization of parental or intermediate types. Homogeneous lines, both in WCT and CDO, can also be isolated in sufficient numbers by selfing new individuals or the  $S_1$  segregants, as the case may be.

Another question relevant in this context is whether all the hybrids (100%) realized in a cross combination after appropriate selection of parents are going to be high yielders. For this, a better understanding of the genetic basis of hybrid vigour for yield is required in coconuts.

#### CDO $\times$ WCT Crosses

While the above aspects have to be investigated through further breeding and genetical experiments, refinement of the existing crossing programmes for production of hybrids deserves immediate consideration. Ninan and Satyabalan (1964) reported that 65% of the Dwarf Orange  $\times$  Tall nuts sown were lost due to nongermination (30%) and death of sprouts (35%). Perusal of Table 7, however, shows a different picture.

The germination percentage in D  $\times$  T in 13 families ranged from 55 to 100% (mean : 71%). The death of sprouts was negligible. Bulk sowing of CDO  $\times$  WCT nuts gave 88% germination with 1.5% mortality of sprouts. In this context, it is pertinent to point out that nuts of CDO require special care, and if stored after harvest, dry up fast causing low germination. The attention required in the nursery is also equally important. Irrigation and shade if not provided in time and adequately can bring about both reduction in germination and death of sprouts. The observations made earlier of unduly low germination and death of sprouts may be due to these causes.

Data in Table 7 also show that the percentage of brownish green segre-

TABLE 7. Germination and segregation pattern in CDO × WCT crosses

Parents	No. of nuts sown	Percentage germination	Percentage* of		
			Vigorous segregants		Dwarf Orange
			Brownish green	Orange	
98 × 40/414	1	78.6	36.4	9.1	54.5
196 × 27S/954	5	100.0	100.0	—	—
B.19 × 40/419	12	58.3	71.4	28.6	—
110 × 39/225	6	83.3	40.0	20.0	40.0
96 × 40/414	14	78.6	54.5	27.3	18.2
103 × 41/405	8	75.0	50.0	33.3	16.7
132 × 27S/954	8	87.5	71.4	—	28.6
98 × 41/405	9	77.8	85.7	14.3	—
96 × 4B/124	8	62.5	60.0	40.0	—
94 × 39/144	15	66.7	50.0	30.0	20.0
167 × 1/41	9	55.6	80.0	—	20.0
186 × 40/419	11	54.5	66.7	16.6	16.6
110 × 39/204	7	57.1	100.0	—	—
<b>Total</b>	<b>126</b>	<b>70.6</b>	<b>62.9</b>	<b>18.0</b>	<b>19.1</b>

\*Calculated from the number of seedlings.

gants with imposed hybridity (hybrids) realized varies from 36 to 100% (mean : 63%). Though information on the genetic status of the Dwarf and Tall parents of these crosses for colour and vigour are lacking, the possibility of realising cent per cent hybrid population by appropriate selection of Dwarf and Tall parents as mentioned earlier seems to be possible.

#### Colour Studies in CDO and WCT

The pattern of colour segregation of CDO after self and open pollination, and controlled crossing was studied. The petiole of the second functioning leaf from bottom was observed on the abaxial side 1 cm below the leaf bearing portion. The colour shades were found to vary widely (Table 8). In the orange, there were three shades while in the brownish green, which is the colour of the WCT, there were seven groups into which majority of the progenies fell. The orange colour of the CDO and green colour of WCT, therefore appear to be quantitative rather than qualitative. It is also interesting to note that the Dwarfs and one group of heterozygous segregants have the same orange colour, while the "off types", hybrids, and S<sub>1</sub> progenies of WCT are brownish green as distinct from orange.

TABLE 8. Percentage segregation for colour in CDO self, open, CDO x WCT and WCT self palms\*

Population	Orange**					Brownish green**				
	5 YR 7/11	7.5 YR 7/11	10 YR 8/10	10 YR 6/8	10 YR 7/10	7.5 YR 6/9	7.5 YR 5/7	5 YR 6/7	2.5 YR 6/8	2.5 YR 5/5
CDO self Dwarf Heterozygous segregants	22.62*	64.3	11.6	30.18	13.2	12.26	11.32	12.26	—	8.4
	—	—	—	—	—	—	—	—	—	—
CDO open Dwarf Heterozygous segregants	17.8	65.75	12.32	—	—	—	—	—	—	—
	21.55	67.24	8.62	—	—	—	—	—	—	—
CDO x WCT Dwarf Heterozygous segregants	—	—	—	20.0	5.0	38.33	11.66	—	5.0	—
	20.0	40.0	40.0	—	—	—	—	—	—	—
WCT self	—	100.0	—	—	—	—	—	—	—	—
	—	—	—	40.35	19.2	—	—	10.5	26.3	—
	—	73.3	20.0	—	—	—	—	—	—	—
	—	—	—	8.1	5.4	16.2	—	19.6	—	8.8

\*Cases of less than 5% occurrence not included.

\*\*Colour designations according to Nicolson's Colour Chart.

### Nature and Origin of Heterozygous Segregants

The data now available give some insight into the nature and origin of the heterozygous segregants hitherto referred to as "off types" and "natural cross Dwarfs (NCD)". On selfing, open pollination, or crossing with WCT, CDO segregates for both colour and vigour in varying proportions (Table 9). On selfing, in addition to the Dwarf orange, greenish brown and orange coloured vigorous plants are also realised almost in equal proportion. It has also been shown that the brownish green Tall segregants (off types) give Dwarfs on selfing (Ninan and Satyabalan, 1964). In nature, CDO has been outcrossing with WCT and a large proportion of them are heterozygous for colour and vigour. Since orange and brownish green colours appear to be quantitative, plants selected for orange colour can give brownish green segregants. The brownish green segregants (off types) are, therefore, recombinants for colour and vigour. Under open pollination and on crossing, the proportion of these segregants increased from 23%, to 37% and 63%, respectively (Table 9) due to imposed hybridity.

TABLE 9. Segregation pattern of CDO under self, open, and controlled cross pollinations

Combination	No. of families studied	No. of nuts sown	No. of seedlings obtained	Percentage of		
				Dwarf Orange	Heterozygous segregants	
					Brownish green	Orange
Self	40	734	554	57.0	23.3	19.1
Open	37	279	226	60.2	36.7	3.1
CDO × WCT	13	126	89	19.1	62.9	18.1

Only the brownish green segregants have been studied so far from the economic point of view, and they have been reported to be high yielders having good copra characteristics (Satyabalan, 1956; Ninan and Satyabalan, 1964). However, it is likely that a small proportion of these segregants are Tall parental types with no heterotic effect for yield. The observation that all the plants selected as hybrids do not yield equally well lends support to this contention. It is also possible that the orange coloured vigorous segregants may prove to be high yielders. This is being checked.

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