GENETIC IMPROVEMENT OF THE COCONUT PALM : SOME PROBLEMS AND POSSIBILITIES

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The need for research on the improvement of the coconut palm is now being increasingly recognised in many of the coconut growing countries. The genesis of research on the genetic improvement of coconuts is relatively recent and the progress so far achieved is by no means satisfactory. The main obstacle to quick progress and the attainment of tangible results is the unique breeding problems presented by the palm. In the first place, coconut is one of the very few crop plants in which the life time of the observer is less than that of the observed. The long generation period, the great height which the palm attains making access to the flowers of the mature palm very difficult, the apparent impossibility of clonal propagation, the long pre-bearing period, the length of time required to attain steady bearing after flowering, the extensive field requirements for growing sufficient numbers of progenies for experimental purposes etc., have imposed heavy restrictions on the progress of research on this crop.

Despite these limitations, attempts have been made in India and elsewhere to initiate and pursue breeding objectives that have been generally found useful in other short-lived plants with similar breeding problems. The purpose of the present paper is to briefly survey the progress so far achieved in coconut breeding and to discuss some of the problems and possibilities in the genetic improvent of the palm.

INTRODUCTION OF GERM PLASM

India is perhaps the foremost among nations which have a good record of work on coconut introduction. Introduction and study of foreign breeds of domestic coconuts was started about 50 years ago by the Madras Department of Agriculture, when breeds from New Guinea, Cochin-China, Siam, Java, Fiji, Ceylon, Straits Settlements, Laccadives, Andamans etc. were obtained and planted in the Agricultural Research Station, Nileshwar. About the same time a few foreign breeds were also introduced in the Experimental Farms at Trichur and Vyttila by the erstwhile Cochin Agricultural Department. Open pollinated and selfed progenies of the foreign breeds introduced at Nileshwar were planted in 1941 at the Central Coconut Research Station, Kasaragod, where a good number of world varieties were later introduced and are being studied.

Observations on the performance of 15 foreign breeds planted at Nileshwar (Ninan, Pankajakshan, Satyabalan, and Gopinath, 1961) have shown that introductions from Laccadive, Java, Ceylon and Philippines are better than the local tall variety in annual copra production. Among first generation progenies of these introductions planted at Kasaragod Laccadive ordinary and Philippines out-yielded the local tall variety. Compared to the latter, the straight introductions and the second generation (open-pollinated) progenies of the Laccadive variety have given excess average out-turn of 4 kg. and 5.2 kg. of copra respectively per palm per year. It thus offers much scope for large scale introduction and straight propagation, especially in view of other desirable characters of this breed like high female flower production, good setting, short peduncle length which prevents buckling of adult bunches and high oil content. Efforts on large scale introduction of this breed do not appear to have been made so far despite the relative ease with which large numbers of seed nuts could be procured from the Laccadives. This aspect of work requires immediate attention.

While promising varieties like Laccadive Ordinary which are found to behave consistently over generations may be used for straight propagation, the best way to utilise foreign breeds is to exploit the genetic diversity in them in intervarietal crosses with the local talls, with their long acquired traits of adaptability, as females. Ziller (1961) has shown that a kind of heterosis exists in crosses between varieties and strains of the oil palm from different geographic regions. With modern methods of preservation of coconut pollen (Whitehead, 1962) and conveniences for speedy transport, it would not be difficult to import pollen from various countries for these types of crosses. As a long range programme, outstanding breeds raised from introduced seed nuts could also be used as females in intervarietal crosses especially with local dwarfs as males, for selection of vigorous hybrids.

Improvement of the Tall Variety through Selection and Breeding

Among indigenous varieties of coconuts, the West Coast Tall is the most economic and more extensively grown. It is obligatorily cross-pollinated in nature and reproduces exclusively through seeds. Consequently, the palms are highly heterozygous. Considerable work on the improvement of the tall coconut has been done in India and elsewhere. This includes studies on selection of mother palms, seed nuts and seedlings.

Selection of high yielding palms as seed parents has been recommended by coconut breeders throughout the world as a method of genetic improvement of the palm and this practice has been in vogue in many countries including India. Under Indian conditions, trees yielding above 80 nuts are regarded as high yielders and the percentage of such palms in populations is only less than 10 (Ninan, Pankajakshan and

Menon, 1964). There is, however, difference of opinion among coconut breeders as to the efficiency of mother palm selection as a method of genetic improvement of the coconut palm. Liyanage (1953) in Ceylon obtained data suggesting that phenotypic selection of mother palms for high yield is ineffective as a means of genetic improvement. This has been further confirmed by his (1958) finding that there was no correlation between mother palm and daughter palm yields under open-pollination. He recommended controlled pollination between high yielding palms as a means of improving the genetic quality of the palm and suggested the establishment of seed gardens with seedlings obtained from crosses between high yielding palms. Harland (1957), however, pointed out that this programme is unsound as all high yielders do not transmit their high yield to their progenies and that real genetic improvement is possible only through the identification of prepotent palms, i. e., palms most of whose progeny have a high yield. He recommended the identification and use of prepotents in paired crosses and as males in pollinating phenotypically superior females for obtaining large quantity of improved planting material. Liyanage and Sakai (1960) worked out the heritability and genetic correlations amongst four characters namely flowering period, yield of nuts, yield of copra and weight per husked nut. They found that genetic progress in the progenies is likely to be more if the seed parent is selected on high yield of copra and of nuts rather than on weight per husked nut and flowering period.

Sakai (1960) has pointed out that values of heritability and the extent of genetic correlations differ with changes in environmental conditions such as locality, year etc. and especially changes in genetic constitution of populations. That these are important factors to be reckoned with in cocount heritability studies have been borne out from the observations of Lakshmanachar (1959) and Pankajakshan (1960). It is, therefore, desirable that similar studies are made in the West Coast Tall palms also, particularly in view of the need for determinining the reliability of available heritability values in coconuts, which on other grounds may be expected to be low (Haldane, 1958; Charles, 1961). It is pertinent to point out in this connection that studies in the Arecanut palm (*Areca catechu* L.) with similar breeding problems as coconut have clearly shown that heritability of yield is rather low (Bavappa and Ramachander, 1967).

Harland's (1957) recommendation of identification and use of prepotent palms appear to be the most practicable method for genetic improvement of the palm. According to him a high yielding palm may owe its high yield to a variety of reasons : (1) an unusually favourable environment, (a) selection for good vegetative characters, these being correlated with good adult performance, (3) hybrid vigour due to a favourable combination of genes in the heterozygous phase, and (4) genetical superiority in the form of dominant yield genes. Only palms of the fourth type could be relied on to transmit their superiority to their progeny. For the general population which includes all the four types, yield heritability will be low (Charles, 1961).

That Harland's assumptions on prepontency are correct is borne out from direct and indirect evidences now available. Direct evidence is provided by yield data on nine families of open-pollinated progenies given by Liyanage (1961). According to Liyanage, the differences in yield between the families are highly significant. Family IV has given significantly higher yields than most other families, the increase in yield per progeny over the general mean of the population being 35.8 per cent. Also 81.8% of the progenies in this family have given high yields of more than 36 lbs. of copra per palm per year. Liyanage has pointed out that according to the definition of Harland, parent No. IV is a prepotent palm.

Indirect evidence in support of the concept of prepotency in coconuts has been obtained from studies on seedlings. Observations on open-pollinated and hybrid (obtained from controlled crosses with dwarf pollen) progenies of a large number of palms of the West Coast Tall variety (Ninan and Pankajakshan, 1961) have shown clearly that certain palms tend to produce significantly better seedlings than others. Ninan, Pankajakshan and Abdu (1964) have further shown that trees which produce progenies with superior growth rate and vigour also produce uniformly good seedlings. These findings on seedling characters are in agreement with the above observations of Liyanage on adult tree performance. It would appear that the most effective approach to genetic improvement of coconuts will be by progeny testing. According to Charles (1961) this is the only method, that on present knowledge can be relied on to detect genetically superior palms. Once a few palms of outstanding breeding merit are identified they could be continuously used as pollen sources and also as seed parents for providing planting materials on a limited scale. Pollen and seeds of prepotent palms identified in various research stations could also be exchanged.

Breeding Value of Dwarf Coconuts

Dwarf coconuts are known to occur in most of the coconut growing countries, of which the Indian and Malayan dwarfs have been studied in some detail. The origin of the dwarf coconuts is still disputed, some holding them to be of mutant origin from talls (Handover, 1919 ; Anon., 1921 ; Dwyer, 1938 ; Jack and Sands, 1922 and Pancho, 1960) while others regard them as products of several generations of inbreeding in talls (Swaminathan and Nambiar, 1961). Due to the prevailing adaptation for self-pollination they are believed to be reasonably homozygous unlike the talls which are highly heterozygous. Despite the fact that they are uneconomic for cultivation on a plantation scale compared with the talls, they are precocious bearers, fruiting within 3-4 years of planting whereas the talls take 7-10 years for first flowering. This character of early bearing has been utilised in coconut breeding work in the production of early bearing hybrids.

Tall × dwarf hybrids : The idea of crossing tall and dwarf coconuts was first conceived by Dr. Patel who made a larger number of tall (female) × dwarf green (male) crosses and planted the hybrids in a two acre plot in the Agricultural Research Station, Nileshwar in 1936 along with open pollinated progenies from the same tall female parents and dwarfs for comparative study. Bhaskaran and Leela (1963) have made a detailed study of flowering, yield and growth habits of these hybrids which has confirmed the earlier predictions based on seedling characters and revealed very interesting facts concerning the tall × dwarf crosses. They have shown that the T × D hybrids not only bear earlier but attain steady bearing much earlier than the tall type and also considerably out-yield the tall parental type. The percentage of poor yielding palms in T × D plantations is also much lower than that in ordinary tall plantations. Analysis of growth habit and other characters has indicated that the hybrids show similar trends like the talls. This indicates that the longevity of the hybrids could be expected to be of the tall parental type.

Due to the very poor nature of the soil in which these hybrids were planted, the general performance of all the palms is very poor but comparison of the yield figures for the hybrids, talls and dwarfs given by Bhaskaran and Leela (1963) immediately reveal the clear renowned superiority of the hybrids (Table 1).

TABLE 1

Yield performance of T × D hybrids, tall and dwarf palms at Nileshwar (Bhaskaran and Leela, 1963)

Variety	Age	No. of trees	Mean yield of nuts
T × D	24	40	30.68
Tall	24	40	5.51
Dwarf	24	3	11.28

Comparison of the mean yields obtained during the bearing period of the best palm under each category as given in Table 2 also brings out the superiority of the hybrids over the parental types. They have also pointed out that while the steady bearing starts at the average age of 7.9 in T × D hybrids, the corresponding age for talls is 14.4. This would mean that by cultivating the hybrids the planter is benefitted by extra yields in nearly 7 steady bearing years.

Comparison of data (Table 3) on spathe and female flower production, yield of nuts, copra content per nut and annual out-turn of copra of a few T × D hybrids, talls and dwarfs, planted at the Central Coconut Research Station, Kasaragod also confirms this superiority of the hybrids (Ninan and Satyabalan, 1964).

TABLE 2

Yield performance of the best T × D hybrid, tall and dwarf palm at Nileshwar (Bhaskaran and Leela, 1963)

Variety	Age	Yield of nuts	
		Total	Average
T × D	24	1298	72.10
Tall	24	375	22.00
Dwarf	24	261	13.05

TABLE 3

Performance of T × D, tall and dwarf palms at Kasaragod (Ninan and Satyabalan, 1964)

Variety	No. of trees	Mean no. of spathes	Mean no. of female flowers	Mean yield of nuts	Mean copra content/ nut (gm.)	Yield of copra per palm per year (gm.)
T × D	3	12.3	375.3	107.0	194.1	24.4
Tall	3	11.5	251.2	86.7	177.6	15.9
Dwarf	3	8.0	232.7	42.7	40.0	1.6

It is clear from the above data and from observations on the excellent performance of hybrids supplied to cultivators that one of the immediate steps in increasing production of coconuts would be large scale production and distribution of these hybrids. Considering the potentialities for this task in our research stations, the present supply position of hybrid seedlings does not seem satisfactory. Further efforts have to be made in this direction.

The data presented above pertain to tall × dwarf crosses utilising the Chowghat dwarf green as male parent. There are a number of distinct races of dwarf coconuts in various countries and it is highly probable that they may produce crosses of differing breeding value. It would be very profitable if a programme of breeding work using selected tall variety palms as females and various geographic strains of dwarfs as males is started and performance of the hybrids evaluated. These are projects that can only be handled in coconut breeding stations, where some continuity of effort could be anticipated. A start could be made by utilising foreign and local dwarfs already available and also supplementing the dwarf germ plasm through introduction. Another advantage inherent in these crosses is that some of the dwarfs are reported to be resistant to coconut diseases which take heavy tolls of the annual production in many countries including India. The Malayan dwarf red has thus been found to be resistant to the lethal yellowing disease of Jamaica (Whitehead, 1962). The genetic basis of this resistance is not known. If it would be possible to transfer the genes for resistance in the dwarfs to the tall × dwarf hybrids, this would confer the double advantage of having hybrid vigour and disease reistance in a single individual. A systematic search for resistance to the Kerala wilt, especially among world varieties of dwarfs, might prove very useful.

Due to the high longevity of the palm, when once a hybrid seedling gets established, it goes on yielding for several years. Because of this peculiar feature, an area once brought under cultivation of hybrids needs attention only after 5 - 7 decades. With increased efforts on production and popularisation of hybrids, a large percentage of the area under coconut could be brought under hybrid cultivation. F_2 progenies of the hybrids planted at Nileshwar show that there is segregation to the parental dwarf type. While this is only normally to be expected in progenies of tall × dwarf crosses this need not discourage popularising hybrid cultivation as feared in some quarters (Charles 1961). Maintenance of nucleus seed gardens of talls for use as female parents in tall × dwarf crosses and regular supply of hybrid seedlings for future plantings might be necessary.

Semi-tall progenies from dwarfs: Some dwarf varieties are known to throw a proportion of "semi-tall" progenies. This has been observed in the Malayan dwarf green (Anon., 1938) and Chowghat dwarf orange and green (Satyabalan, 1956). Jack (1925) considers that such progenies are hybrids resulting from natural crossing of dwarfs with tall pollen. Dwyer (1938) and Tammes (1949, 1955) and Liyanage (1956) also mention about the occurrence of natural hybrids of dwarfs with talls. Studies on such off-type progenies of dwarfs carried out at Kasaragod have shown that the off-types, particularly those of the Chowghat dwarf orange, are early and prolific bearers compared to the dwarf parental types, the tall (female) × dwarf (male) hybrids and the West Coast Talls (Ninan and Satyabalan 1964). The yields of such off-type progenies of Malayan dwarfs are also reported to be much better than that of the tall varieties and most of the introductions tested in Malaya (Whitehead, personal communication).

Attempts made in different countries to produce such types by controlled crossing of dwarf females with tall males have, however, so far failed to give expected results in that a large proportion of the progenies turn out to be of the pure dwarf type (Patel, 1937; Liyanage, 1956; Ninan and Satyabalan, 1964; Whitehead, personal communication). From their studies on off-type progenies of the Chowghat green and orange dwarfs, Ninan and Satyabalan (1964) concluded that the hybridity of the off-types appear doubtful and that they probably might be heterozygotes segregating from the dwarfs. Whatever might be the mode of origin of the off-types, the failure of controlled crosses in all countries so far made, restricts greatly their propagation on a commercial scale. Further research on the genetics of the dwarfs and the mode of origin of the off-types is highly to be desired in view of their economic yield traits and the urgent need for popularising such high yielding types.

Dwarf × Dwarf crosses : It has been suggested that in view of the possible homozygous nature of dwarf coconuts, dwarf × dwarf crosses might be a fruitful field for exploitation of hybrid vigour in coconuts (Swaminathan and Nambiar, 1961). By comparison with the situation in other cross-pollinated plants like maize, it is only to be expected that crosses of inbreds might produce hybrid vigour. Available data (Ninan and Satyabalan, 1964) on a few such hybrids produced at Kasaragod, however, do not appear to justify this expectation. Examination of dwarf plantations reveals that the green fruited dwarfs especially are very variable. Palms with all combinations of dwarf and tall characters could be recognised. This makes it necessary to select suitable and typical dwarfs as parents for such crosses to get expected results. If it would be possible to locate really homozygous dwarfs, they may be of value in dwarf × dwraf crosses and perhaps may also provide better pollen sources for tall × dwarf crosses. It would thus appear that a thorough study of the dwarf palms would be highly essential before rational utilisation of the dwarfs could be made in dwarf × dwarf crosses.

VEGETATIVE PROPAGATION, APOMIXIS AND HAPLOIDY

Harland (1957) and Davis (1962) have stressed the importance of vegetative propagation in the coconut palm. The possilbe use of twining, suckering and vivipary occurring in the coconut palm as well as possibilites of induction of adventitious buds have been stressed by Harland (1957). According to Davis (1962), the most hopeful method, though still difficult, is to reverse the flowers into vegetative shoots then get them back to the seeding habit after they have been successfully layered and propagated as individuals. Results of experiments carried out at Kasaragod have revealed that profuse root production could be induced in mature palms by the application of indole-3-butyric acid, naphthalene acetic acid etc. but so far shooting could not be induced. It should perhaps be possible by the adoption of special techniques such as are found useful in other monocots like orchids (Kamemoto, personal communication) to obtain many vegetative shoots from excised growing points of seedlings grown in constantly shaken culture. A trial on these lines would be well worth pursuing in the coconut palm.

Another aspect of research that seems to be equally important is the search for the existence of apomixis in coconuts and its possible induction. No serious attempts seem to have been given to studies on apomixis or related phenomena like polyembryony and parthenogenesis in coconuts. Venkataraman (1928) has reported the development of the embryo without fertilisation into bulbil like structures. The normal buttons reported by him as occurring in the same bunch did not show any trace of endosperm. Direct evidence of parthenogenetic development of embryo has been obtained by Ninan and Raveendranath (1965) when a haploid embryo was obtained from a nut and cytologically studied.

Several instances of otherwise normal nuts without trace of embryos have also been noted by us. These and other evidences from pollination trials using dead pollen appear to support the view of Sharma and Sarkar (1956) that the high percentage of pollen sterility occurring in coconuts stands against the assumption that sexual reproduction becomes effective in the production of fruits which are abundant in this species. They have suggested that pollination in coconuts may provide a stimulus for apomictic reproduction. The occurrence of haploid embryos and absence of embryos in otherwise well developed nuts might indicate that seed setting in coconuts is possible without fertilisation. It is possible that diploid parthenogenesis also occurs in coconuts. Critical studies on these aspects are highly to be desired.

Inbreeding

Inbred lines of 18 varieties of coconuts have been raised and studied in the Central Coconut Research Station, Kasaragod and Agricultural Research Station, Pilicode and their yield performance for a number of years are available now. Study of first generation inbreds (Ninan and Pandalai, 1961) has revealed that different varieties respond to inbreeding in different ways and to varying extents. Selfed progenies of a few breeds appeared to retain comparable vigour like their open pollinated sister trees. Most breeds, however, revealed considerable depression in the form of reduced vegetative vigour, yield and copra content of nuts. Data on varieties Kappadam, Fiji and Straits Settlements Green given in Table 4 clearly reveal this. The difference in copra content per nut between the inbreds and outbreds is most striking. In other inbreds certain plants showed complete production of barren nuts. Beneficial effects like early flowering were also observed in some others. Further inbreeding, for one or two generations, of varieties that have not shown considerable inbreeding depression in S_1 might be very interesting in that at least in some cases it could be possible to spot individuals that retain high productivity and vigour upon inbreeding as predicted by Harland (1957). Again, progenies of first cross between different inbred lines might show maximum vigour. Utilisation of S_1 and S_2 lines of talls now grown in the Research Stations at Kasaragod and Nileshwar in crosses with dwarfs as males might also produce better $T \times D$ hybrids as may reasonably be expected.

Studies on the Endosperm

Effect of pollen parent on the endosperm : Though the endosperm of coconuts, commercially known as copra, is the most important economic product obtained from the palm, this tissue has not been adequately studied in relation to the factors affecting its quantity and quality. Haldane (1958) suggested that hybrid vigour may show in nuts derived from cross-pollination since hybrid vigour in some species is largely due to increased seed weight. If so, a mixed plantation may produce a better crop than either of two breeds when grown alone. Trials conducted at the Central Coconut Research Station, Kasaragod revealed that pollination with Kappadam and Andaman Giant gave significantly higher copra content per nut in Laccadive micro-females compared to six other varieties used as males (Ninan Pankajakshan and Radhakrishnan, 1963). In another trial (unpublished) the highest copra content per nut was observed in pollination of the local tall variety with dwarf orange pollen compared to four other dwarf varieties used as pollen sources. If these results are confirmed by further trials, interplanting of tall and dwarfs could serve the double advantage of hybrid seed production as well as increased yields of copra from plantations.

TABLE 4

Yield of nuts and copra content in outbred and inbred plants of a few varieties of coconuts

Variety	Nature of progeny	Yields of nut	Weight of copra per nut (gm)	Annual out-turn of copra (kg)
Kappadam	OP	77.1	280.9	2.7
	S_1	80.3	155.9	12.5
Fiji	OP	111.0	193.4	3.1
	S_1	28.9	108.4	20.5
Strait Settlements Green	OP	138.4	230.5	5.4
	S_1	33.3	146.4	31.9

Cytological studies : Abraham and Mathew (1963) first reported the results of cytological studies on the endosperm of the tall variety of coconuts. They found the occurrence of C-mitotic type of division in endosperm cells resulting in high levels of endopolyploidy. Abraham (1963) and Abraham, Ninan and Gopinath (1965) found an inverse relation between oil content and ploidy level in endosperm from different zones in the same nut of the tall variety as also between varieties. Another interesting observation has been the cytological abnormalities in the endosperm of makapuno coconuts which resemble the situation in tumour cells. Extension of cytological studies to the endosperm of barren nuts, nuts without embryos, those with haploid embryos, nuts of inbred strains and hybrids might provide very valuable information on various aspects of endosperm development in coconuts.

SUMMARY

Progress of research on the genetic improvement of the coconut palm has been briefly reviewed and recommendations made for a practical approach to coconut breeding. Introduction of foreign breeds of coconuts, particularly dwarfs, should be speeded up with a view to search for possible source of resistance to the Kerala wilt, and for exploitation of hybrid vigour in tall × dwarf crosses. Though the use of the selection index computed by Liyanage is a very practical approach in detecting palms of outstanding breeding merit, the reliability of the

index has to be ascertained from results of studies on the West Coast Tall palms. Identification and utilization of prepotent palms is recommended as the most valuable method of genetic improvement of tall coconuts. Large scale propagation of tall × dwarf hybrids is an immediately practicable method of stepping up coconut production in India. The dwarf palms require more intense study to determine the genetical nature of their high yieling off-type progenies. Experiments so far done indicate that it is easy to select off-types at an early stage from seedlings raised from open-pollinated nuts of dwarf orange. The use of inbred talls as females in 'Tall × Dwarf' crosses and the need for search on the occurrence of apomixis in coconut are stressed.

References

Abraham, A. (1963) Chromosome constitution and oil content in the coconut endosperm. *J. Indian bot. Soc.*, **42A** : 1-3.

——— and Mathew, P. M. (1963) Cytology of coconut endosperm. *Ann. Bot.*, **27** : 505-512.

———, Ninan, C. A. and Gopinath. P. (1965) Cytology of development of abnormal endosperm in Phillippine makapuno coconuts. *Caryologia*, **18** : 395-409.

Anonymous (1921) Further information about dwarf coconuts. *J. Jamaica Agric. Soc.*, **2** : 285.

——— (1938) Dwarf coconuts in Malaya. *Malay agric. J.*, **26** : 282-287.

Bavappa, K. V. A. and Ramachander. P. R. (1967) Improvement of arecanut palm (*Areca catechu* L.). *Indian J. Genet.*, **27** : 93-100.

Bhaskaran, U. P. and Leela, K. (1963) Hybrid coconuts—Tall × dwarf. A comparative study with parental types. *Agric. Res. J. Kerala*. **2** : 67-83.

Charles, A. E. (1961) Selection and breeding of the coconut palm. *Tropical Agric.*, **38** : 283-296.

Davis, T. A. (1962) Vegetative Propagation in the coconut. *Nature, Lond.*, **196** : 904-905.

Dwyer, R. E. P. (1938) Coconut improvement by seed selection and plant breeding. *N. Guinea agric. Gaz.*, **4** : 25-102.

Haldane, J. B. S. (1958) Suggestions for research on coconuts. *Indian Cocon. J.*, **12** : 1-9.

Handover, W. P. (1919) The dwarf coconut. *Malay agric. J.*, **7** : 295-297.

Harland, S. C. (1957) *Improvement of the coconut palm through breeding and selection. Cocon. Res. Inst. Ceylon, Bull. No 15.*

Jack, H. W. (1925) Dwarf coconut. *Trop. Agric.*, **64** : 75.

———, and Sands, W. N. (1922) The dwarf coconut in Malaya. *Malay agric. J.*, **10** : 4-13.

Lakshmanachar, M. S. (1959) A preliminary note on the heritability of yield in coconut. *Indian Cocon. J.*, **7** : 65-68.

Liyanage, D. V. (1953) Report of the Botanist. *Rept. Ceylon Cocon. Res. Sch.*, pp. 27-30.

——— (1956) *Intra-specific hybrids in coconuts. Cocon. Res. Ins., Ceylon. Bull. No.* 7.

——— (1958) Report of the Botanist. *Rept. Ceylon Cocon. Res. Bd.* pp 30-37.

——— (1961) The use of isolated seed garden for coconut seed production (Presented at the F. A. O. Conference on Coconut Production, Protection and Processing, Trivandrum).

——— and Sakai, K. I. (1960) Heritabilities of certain yield characters of the coconut palm. *J. Genet.*, 57 : 245-252.

Ninan, C. A. and Pankajakshan, A. S. (1961) Progeny studies in coconuts I. Relationship between parent yield and seedling charaters of progeny with special reference to open pollinated and hybrid progenies of West Coast Talls and its bearing on the concept of pre-potency in coconuts. *Indian Cocon. J.*, **14**: 100-109.

Ninan, C. A., Pankajakshan, A. S. and Radhakrishnan, V. (1963) Preliminary observations on the influence of pollen parent on copra content in coconuts (*Cocos nucifera* L.) *Indian Cocon. J.*, **16** : 174-179.

Ninan, C. A., Pankajakshan, A. S. and Abdu, K. M. (1964) Some observations on growth rate and vigour of coconut seedlings. *Indian Cocon. J.*, **18** : 12-17.

Ninan, C. A., Pankajakshan, A. S., Satyabalan, K. and Gopinath, P, (1961) A comparison of the performance of some cultivars of coconuts in the Central Coconut Research Station, Kasaragod and the Agricultural Research Station, Nileshwar (Pelicode). *Indian Cocon, J.*, **15** : 12-19.

Ninan, C. A. and Pandalai, K. M. (1961) Recent trends in Coconut breeding in India (Presented at the first meeting of the F. A. O. Technical Working Party on Coconut Production, Protection and Processing, Trivandrum).

Ninan, C. A. and Satyabalan, K. (1964) A study of natural self and cross (dwarf× tall) progenies of dwarf coconuts of the West Coast of India and its bearing on the genetics of dwarfs and the putative hybridity of their off-type progenies. *Caryologia*, **17** : 77-91.

Nian, C. A. Pankajakshan, A. S., and Menon, R. M. (1964) Study of yield distribution and copra production in West Coast Tall coconuts., *Indian Cocon. J.*, **17** : 62-68.

Ninan. C. A. and Raveendranath, T. G. (1965) A naturally occurring haploid embryo in the coconut palm (*Cocos nucferia* L.) *Caryologia*, **18** : 619-623.

Pancho, J. V. (1960) The Tambulilid. *Cocon. Bull.*, **13** : 403-404.

Pankajkshan, A. S. (1960) A note on the relative contribution of genetic and environmental factors on the yield of uniformly treated coconut trees. *Indian Cocon. J.*, **14** : 37-43.

Patel, J. S. (1937) Coconut Breeding. *Proc. Ass. econ. Biol.*, Coimbatore, **5** : 1-16.

Sakai, K. I. (1960) Method of breeding of coconut palms. A comment on "The improvement of the coconut palm by breeding and selection of Dr. S. C. Harland". *Trop. Agriculturist, Ceylon*, **116** : 185-189.

Satyabalan, K. (1956) A note on the performance of the natural cross (dwarf female × tall male) in coconut. *Indian Cocon. J.*, **9** : 166-173.

Sharma, A. K. and Sarkar, S. K. (1956) Cytology of different species of palms and its bearing on the solution of problems of phylogeny and speciation. *Genetica*, **28** : 361-488.

Shrikande, V. J. (1957) Some considerations in designing experiments on coconut trees. *J. Indian Soc. agric. Statist.*, **9** : 82-99.

Swaminathan, M. S. and Nambiar, M. C. (1961) Cytology and origin of the dwarf coconut palm. *Nature, Lond.*, **192** : 85-86.

Tammes, P. L. M. 1949) Native cultivation of coconuts especially in East Indonesia. *Meded. Dep. econ. Zak.* (*Ned. Ind.*) *No.* **11** : 72.

———— (1955) Review of coconut selection in Indonesia. *Euphytica*, **4** : 17-24.

Venkataraman. K. (1928) Parthenogenesis in Coconut. *Yearbook Dept. Agric. Madras* Pp. 29-32.

Whithead, R. A. (1962) *Second Report of the Research Department.* The Coconut Industry Board, Jamaica.

Ziller, (1961) Suggestion for an international project for exchange of coconut germ plasm (Presented at the F. A. O. Technical working party on coconut production, and processing, Trivandrum).

DISCUSSION

K. V. A. Bavappa : T×D seed production programme may be done with caution due to the existence of combining ability as evident from the indifferent performance of T×D in certain cases.

C. A. Ninan : From available reports and observations it is clear that the performance of T×D hybrids is superior to that of the local tall variety. Investigations carried out at Kasaragod show that not all mother palms give equally good hybrid progenies and to get the best results mother palms which give the best seedlings have to be used in crosses. The performance of hybrids planted in different localities may vary and this may be due to several factors including soil type etc. Whether this is due to combining ability or not is to be ascertained; but as far as our knowledge goes progeny performance in coconuts to a large extent, is determined by the mother parent.

K. V. A. Bavappa : Have we got adequate population studied to say that D×T is poor ? Why should it not be considered that the off-types obtained in D open pollinated nuts are those of D×T origin.

C. A. Ninan : D×T crosses so far made in different countries have not given encouraging results and most of the progenies are dwarfish with a few 'off type' seedlings similar to those obtained from natural dwarf seeds. In other words, the results of controlled pollination of dwarfs with tall pollen do not differ from what happens under natural pollination of dwarfs. The act of pollination of dwarfs with tall pollen does not mean that all resulting progenies are D×T hybrids, specially when there are characteristics by which the dwarfs in the progeny can be unequivocally distinguished in the seedling stage. If there were no segregation of dwarfs and off-types in the F1 of D×T cross, and also under self-pollination of dwarfs, it would have been easy to imagine that the progenies are all hybrids, as happens in the reciprocal crosses. The hybridity of the off-types is therefore uncertain though this cannot be completely ruled out. This problem requires further investigation.

K. V. A. Bavappa : The use of heritability and selection index should be done on a much wider scale in coconut.

C. A. Ninan : Adequate studies on heritability and selection index have not yet been made on the west coast tall coconuts. It is extremely necessary that such studies are conducted.

M. S. Swaminathan : Have you found any evidence to suggest that apomixis (agamospermy) may occur in coconut ?

C. A. Ninan : No direct evidence has so far been found to suggest that meiosis and fertilisation are circumvented but in the formation of bulbils, it appears that this is a completely asexual process. There have also been evidences of haploid and possibly diploid parthenogenesis and of formation of nuts with normal endosperm but without a trace of embryo.

M. S. Swaminathan : You referred to the need for screening material for resistance to the root wilt disease. Do we know enough about this disease for undertaking screening programme ?

C. A. Ninan : By growing world varieties and races of coconuts in diseased areas it would be possible to locate types that are resistant or immune to the disease. It has been possible in Jamaica to locate by field trials a source for resistance to the mysterious lethal yellowing disease in the Malayan dwarf type and systematic investigations in this line are in progress in that country. The same procedure could be adopted in India also to find out whether there are sources of resistance to Kerala wilt in indigenous or exotic breeds of coconut available in this country.

A. ABRAHAM : I wish to add only a few points :

(1) T×D has already proved to be good and we should have a good programme for production of large numbers of hybrid seeds under proper supervision. There is tremendous demand from cultivators for these hybrids and without waiting for further information, which may take time to collect, we should produce hybrid seeds by the hundreds of thousands.

(2) The value of the "off-types" of Orange Dwarf has been well established. These can be easily detected in seedling stage from two characters (a) the lighter colour of the petiole and (b) the early development of the mature-leaf character. i. e., leaves with leaflets separate from each other. Therefore, it is very easy to distinguish the "off-types" in the seedling beds.

In a palm like coconut in which so little work has been done on the genetical aspects, we should exploit available information and improve on our techniques as we go along.