RP 636

COCONUT BREEDING: NEW VISTAS

K. U. K. NAMPOOTHIRI
Scientist-in-charge,
Central Plantation Crops Research Institute,
Palode, Trivandrum, Kerala.

Coconut with an annual production of 5600 m. nuts and covering an area of over 1.1 m. hectares contributes to one percent GNP of our country. With the shortage of vegetable oils and an all time high price for the coconut, the interest in coconut industry is ever increasing. India occupies third position in the world as far as coconut production is concerned, with Indonesia and Philippines holding the first and second positions. The per hectare production in the country is low as compared to that in Indonesia (Table 1).

Table 1. World Production of coconut (1982)

Country	Area (000 ha)	Production (000 tons)
Indonesia	1959	12075
Philippines	3160	9668
India	1150	4500
Sri Lanka	451	1716
Malaysia	327	1196
Thailand	267	836
Mexico	150	800
Papua New Guinea	222	755
Tanzania	270	330
Brazil	—	270
Solomon Islands	—	250
World	8490	36530

Source FAO

The hectarage and production in the various coconut growing states in India also vary considerably (Table 2). Kerala tops the list. However, there is added interest now in many states, especially Tamil Nadu and Karnataka. Apart from the economic considerations, coconut occupies a unique position in Kerala. As much as 70% of the total coconut area is concentrated in Kerala, a small state accounting for only 1.18% of the total land area of the country.

Table 2. Area and Production of coconut in India (1982-'83)

State	Area (000 ha)	Production (million nuts)	Productivity (nuts/ha)
Kerala	658.5	2444.3	3712
Tamil Nadu	143.0	1650.0	11538
Karnataka	178.9	930.1	5199
Andhra Pradesh	44.6	178.8	4009
Goa, Daman, Diu	18.7	100.0	5348
Orissa	22.5	98.8	4391
A & N islands	21.3	87.0	4085
Maharashtra	10.2	61.1	5990
Assam	6.5	45.9	7062
West Bengal	3.3	29.4	8909
Lakshadweep	2.8	21.7	7750
Pondicherry	1.6	15.5	9688
Total	1113.3	5644.3	5088

Source: Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India.

Although India is one of the largest coconut producing countries of the world, the per capita availability is as low as 11 nuts/year. It is 215 in Philippines and 60 in Indonesia. One of the main drawbacks in exploiting the full potential of coconut is the lack of genetically superior planting material in sufficient numbers. Though coconut research has been underway for almost eight decades, the results do not commensurate with the efforts made because of the special problems faced in perennial crop breeding. The main constraints are long life span and juvenile period leading to delay in obtaining results. Larger area required for experimentation, inconvenience due to height of palms, lack of vegetative propagation and high resources required for breeding trials are also barriers in undertaking cytogenetical and breeding investigations on coconut. Inspite of these, considerable progress has been made in the understanding of the crop as well as in evolving genetically potential material. We shall consider the major areas in which improvement has so far been made and the ones which can be thought of for future.

SELECTION

Coconut is known to be in India for over 3,000 years, and considerable genetic diversity is available with us. Selection is therefore a very relevant method to improve the available material. Selection can be practised at the mother palm level and seedling level. The following characters are generally taken into account for selecting good mother palms.

1. Age of flowering
2. Leaf production
3. Number of bunches
4. Number of female flowers
5. Distribution of female flowers
6. Nut set
7. Copra content
8. Oil yield
9. Pest and disease resistance
10. Non buckling
11. Alternate bearing
12. Barrenness
13. Special attributes

Mass Selection

In this method of mass selection, seednuts from high yielding, desirable tall palms are used to raise planting material. Though we cannot expect true to type progenies due to the heterozygous nature of the crop, the results so far obtained have fully justified this practice. This is so because heritability for yield of copra and weight per husked nut are fairly high (Lakshmanahar, 1959; Liyanage and Sakai, 1960). Yield in coconut is a complex character dependent upon a large number of components. For achieving reasonable improvement by selection, care should be taken to differentiate environmental and genetical components of variation. Although correlations are helpful in determining the components of a complex character like yield, they do not provide the exact picture of the relative importance of direct and indirect influences of each of the complex characters towards this trait. Sukumaran *et al* (1981) carried out path coefficient analysis to study the direct and indirect effects and thereby pin point the effects of these associations. They found that number of functional leaves, total leaf production, time taken for flowering, intermodal distance at a fixed mark, and number of female flowers have the largest influence directly on yield. These characters also showed a higher heritability than other components suggesting that these are important in selection programme.

Harland (1957) indicated that efficiency of mother palm selection can be increased through identification of prepotent palms. Prepotent palms are those palms which are capable of transmitting their high yield potential to the progeny irrespective of the pollen parent. Prepotency is presumably due to enblock transmission of favourable dominant genes to progeny. Such palms can be identified only through progeny analysis. Due to the time, land and other resources required, these studies have been limited and only a few palms have so far been identified. A quick method of identifying palms with high yield potential is suggested by Liyanage (1972) according to which the palms are selfed and the depression on endosperm and embryo weight per nut compared to open pollinated nuts from the same palm is taken as the criterion for identifying prepotents. Isolated seed gardens wherein only prepotent palms are planted can be used for large scale production of good quality seed nuts.

Iyer *et al* (1981) identified 18 *elite* palms which yield 200 to 500 nuts as against the national average yield of 35 nuts per palm / year. A few important characters of these palms are listed in Table 3

Table 3. Vegetative and reproductive characters of Elite palms.

Character	Mean	Range
Palm height (m)	—	10 to 16
No. of leaves on crown	39.4	34 to 50
Crown shape	—	Spherical to hemi spherical
Annual spathe production	16.35	12 to 34
Annual female flower production	439.5	273 to 843
Setting percentage	55.5	33 to 77
Annual yield of nuts	240	200 to 470

It will be of advantage if more such palms are identified and their progeny performance studied to use them in further coconut breeding programmes.

Seedling selection:

Due to the heterozygosity of the crop segregation for various characters are obtained in the nursery. Selecting seedlings with high yield potential can therefore be seen to be of definite advantage. The task lies in defining norms for selecting good seedlings. A character is considered important if there is a significant correlation between the character in question and yield or yield components. Genotypic correlations are much more valuable than the phenotypic correlations. Many seedling characters show correlation with adult palm yield (Table 4.)

Table 4 Correlations between seedling characters and adult palm yield

Seedling Characters	Coefficient of correlation with adult palm yield		Authors
1. Sprouting period of seednuts		−0.424	Liyanage 1955
	Between parents 'r'	Within parents 'r'	
2. a) Sprouting period of seednuts	0.0026	−0.1545*	Liyanage and Abeywardena 1957
b) Seedling height	0.0039	0.0821	
c) Seedling weight	−0.3838*	−0.0165	
d) Seedling leaf number	−0.0534	0.0704	
e) Seedling root number	0.0120	0.0347	
	Genotypic correlation	Phenotypic correlation	
3. a) Sprouting period of seednuts	0.170	0.0447	Nampoothiri et al 1975
b) Seedling leaf number	0.528**	0.2632	
c) Girth at collar	0.410*	0.3565**	
d) Seedling height	0.208	0.0173	

*Significant at P = 0.05 **Significant at P = 0.01

Seedlings are selected just before planting generally when they are one year old. The criteria now recommended are early germination (8 weeks or less), number of leaves (six or more) and girth at collar (above 10 cm). Seedlings which are lanky, etiolated or infected by disease or insects are obviously rejected. As early as in 1955, Liyanage showed the significant gain obtained by seedling selection (Fig. 1)

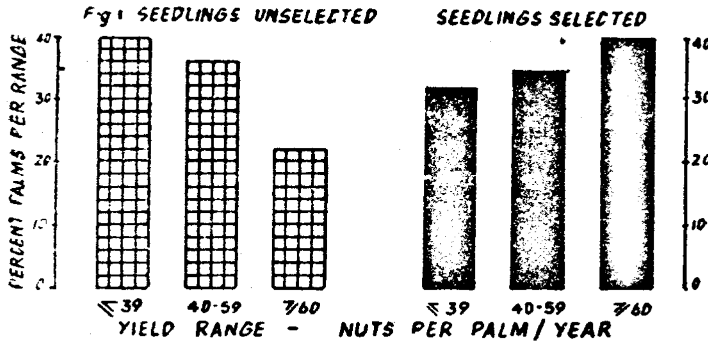


Fig. 1: **Effect of seedling selection on yield**

COLLECTION AND CONSERVATION

While it is true that considerable variability is available among the coconut populations in the country, 'we must remember that coconut belongs to a monotypic genus and hence we must collect and conserve as much of the variability as possible' (Swaminathan, 1982). With the efforts made since 1945, we have 62 exotic and 32 indigenous collections in the CPCRI germ plasm (CPCRI, 1980). Table 5 gives details of performance of some of the promising indigenous cultivars.

Table 5. Performance of indigenous coconut germplasm

Cultivar	Bearing age (years)	No. of nuts/ palm/year	Wt. of copra (g) per nut	Out turn of copra (kg)/ palm/year
Kappadam	6	90	299	26.9
Lakshadweep ordinary	5	127	172	21.8
Andaman Ordinary	5	127	169	21.5
West Coast Tall	7	70	176	12.3

Yield and bearing of certain exotic cultivers are presented in Table 6.

Table 6. Performance of exotic coconut germplasm

Cultivar	Bearing age (years)	No. of nuts/ palm/year	Wt. of copra/ nut (g)	Outturn of copra/palm/ year (kg)
San Ramon	6	64	346	22.1
Philippine Ordinary	5	110	198	21.8
Philippine Laguna	6	91	209	19.1
Java Giant	6	101	298	30.1
Nigerian Tall	8	76	290	22.0
Zanzibar	7	101	215	21.7

Besides the cultivars which out-yield the local cultivars, there are many dwarf forms in the collections which have given new dimensions to the hybridisation programme. Recently a systematic prospection was made in the pacific areas and the collections are raised and evaluated at the World Coconut Germplasm Centre in Andaman islands.

Due to reasons already explained, evaluation of germplasm in perennials is a long drawn process. Recently, Rao *et al* (1981) have indicated the possibility of nursery and juvenile evaluation to overcome this problem to a certain extent. Figure 2 is the scatter diagram based on mean and coefficient of variation indices of 21 cultivars.

The study was made on *inter se* mated progenies. For working out the nursery index the mean values were ranked in descending order except the number of days for germination which was ranked in the ascending order. The CVs were ranked in the descending order. This index in addition to giving preliminary evaluation procedure, also indicates the possibility of selecting palms for *inter se* mating. The significance of the information obtained is as follows:

Sector I: Cultivars with high mean and low variability. These can be taken as promising.

Sector II – Low mean and low CV, indicating recessive nature.

Sector III – High mean and high CV, indicating high heterozygosity and need to evaluate these cultivars further.

Sector IV – Low mean and high variability—Not useful.

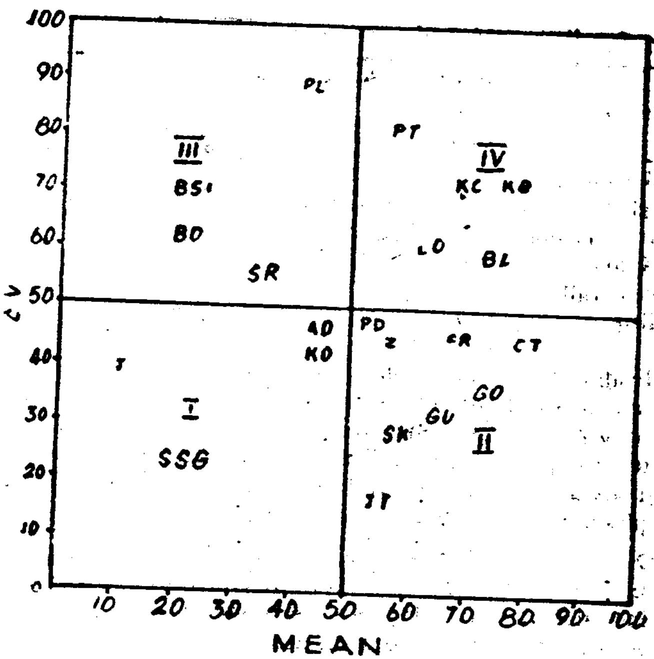


Fig. 2. Scatter diagram of 21 coconut cultivars based on mean and CV indices

1. AO : Andaman Ordinary
2. Bo : Borneo
3. Bl : Blanchissues
4. BSI : British Solomon Islands
5. CT : Ceylon tall
6. FR : Fiji Rotuma
7. Go : Gonthembili
8. Gu : Guam
9. J : Java
10. JT : Jamaica Tall
11. Ka : Kappadam
12. Ke : Kenya
13. KC : King coconut
14. LO : Laccadive Ordinary
15. PD : Philippines Dalig
16. PL : Philippines Lono
17. PT : Panama Tall
18. SK : Standard Kudat
19. SR : San Ramon
20. SSG : Strait Settlement Green
21. Z : Zanzibar

HYBRIDISATION:

Improvement in yield through hybridisation has been much more significant than those obtained by other methods adopted in coconut breeding and it offers further scope for refinement. The earliest work in the production of inter-varietal hybrids using tall as female and dwarf as male parents was done in India (Patel, 1937). Further studies showed that the hybrids exhibited hybrid vigour resulting in vigorous growth, early flowering, higher number of female flowers, more number of nuts and better nut characters. The superiority of T X D hybrids was later reported from Indonesia, Jamaica, Ivory Coast, Sri Lanka etc. As wide differences are observed within the same inter-varietal hybrids when different palms are used, it is essential to evolve specific combiners for deriving the maximum benefit.

Later it was found that Dwarf X Tall hybrids are earlier in flowering and better in yield than Tall X Dwarf hybrids. These hybrids can be spotted in the nursery by their vigorous growth, early splitting of leaves and petiole colour. Ninan and Satyabalan (1964) could obtain similar seedlings from open pollinated progenies of Chowghat Dwarf Orange. These are presumably produced in nature by the natural crossing of dwarfs with Talls. Such seedlings were therefore termed Natural Cross Dwarfs (NCD). Similar seedings were also recovered among seedlings produced by selfing Dwarf Orange palms or after emasculation and open pollination, though the percentage of such seedlings was less. This can be explained to be due to the heterozygous nature of the dwarfs which are partially self-pollinated. Besides these, hybrids involving West Coast Tall and Laccadive Ordinary with Gangabondam are also found to be promising. Performance of these hybrids are given in Table 7. A study of selected dwarf X dwarf hybrids planted at CPCRI showed that though they produce a higher number of nuts, their copra characters are poor.

MAWA (Malayan Dwarf X West African Tall) is another hybrid released from Ivory Coast and has become popular not only in that country but also in many other countries like Malaysia.

It is evident that the exploitation of hybrid vigour has been

BREEDING FOR DISEASE RESISTANCE

Breeding strategy will have to be designed depending on the nature of the end product required. Techniques will have to be different when varieties for special purposes like tender nut, oil production, multiple cropping system or disease resistance are required. We shall consider here only the efforts made in resistance breeding. This becomes very important when other measures of control are not very efficient in checking the disease. Lethal yellowing once threatened to wipe off coconut plantations in Malyasia. The resistance of Malayan Dwarf saved the situation. The most serious disease in India and Kerala in particular, is the root (wilt) disease. The disease is characterised by flaccidity, yellowing and marginal necrosis in the foliage of palms. There is significant reduction in the yield and quality of nuts, and it is debilitating. The disease is concentrated in areas stretching from Trivandrum District in the south to Trichur Dt. in the north. Efforts are made to check the spread of the disease further to the north by roguing and replacing with healthy seedlings. Isolated incidence of the disease has been recently reported not only from other districts but also from the neighbouring state of Tamil Nadu.

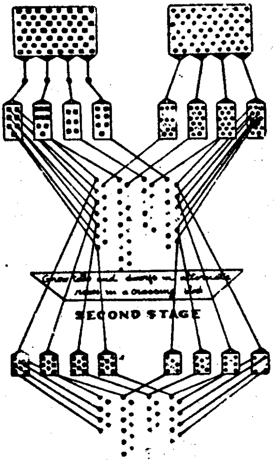
Recently evidences have been obtained to indicate that the disease is caused by Mycoplasma Like Organisms (CPCRI, 1984). The best solution to the problem is therefore to locate resistance or tolerance to the disease. Based on a survey in farmer's garden it was reported that T x D and D x T are tolerant to the disease. Further experiments on this have indicated that the results vary according to the combination and environment. However, evidences now show that D x T have a lower incidence of the disease and are more productive compared to the WCT (Table 8).

Table 8. Performance of D x T and WCT in root (wilt) affected area

Age (years)	Disease incidence%		Yield of nuts/palm/year	
	WCT	D X T	WCT	D X T
4	2.2	1.8	Nil	Nil
5	4.3	3.6	Nil	56.0
6	8.8	5.0	Nil	101.0
7	22.5	5.0	17	76.0
8	29.3	8.9	40	91.0
9	35.5	22.1	50	105.0

Figure 3. Breeding Programme for the Production of Seed Coconut

FIRST STAGE



1. Select mother palms-33.3 % above the population mean.
2. Raise seedlings family-wise
3. Record all growth characters before transplanting.
4. Transplant all seedlings family-wise
5. Record all vegetative and productive characters annually and determine their h^2 and correlations
6. Screen the palms for all characters having high heritability and high correlation with yield
7. Emasculate unselected talls
8. Collect improved seeds (T x T) from selected talls for distribution

1 Self the selected dwarfs

2 Raise seedlings family-wise
3 Reject segregants
4 Record all growth characters of selected dwarfs before planting

5 Transplant the seedlings family-wise
6 Record all vegetative and productive characters annually and determine their h^2 and correlations
7 Screen the palms for all characters having high heritability and high correlation with yield
8 Emasculate all dwarfs
9 Collect hybrid seeds (D x T) from selected dwarfs for distribution

SECOND STAGE

1. Allow open pollination among selected talls after emasculation of all dwarfs and unselected talls
2. Raise seedlings family-wise
3. Screen seedlings for characters of high heritability and correlation with yield
4. Plant selected seedlings family-wise
5. Repeat selection as in item 6 of first stage.
6. Emasculate unselected talls

1 Allow self and *inter-se* pollination by emasculating all Talls and unselected dwarfs for one-year
2 Raise seedlings family-wise
3 Reject segregants
4 Screen seedlings for characters of high heritability and correlation with yield
5 Plant selected seedlings family-wise
6 Repeat selection as in item 7 of first stage
7 Emasculate all dwarfs
8 Collect hybrid seeds (D x T) from

A varietal and hybrid screening programme to evaluate the yield potential and resistance/tolerance to root (wilt) disease has been in progress since 1972. Now there are 45 cultivars and 62 hybrid combinations under field testing in research stations and cultivator's gardens.

BREEDING STRATEGY

A breeding programme for production of superior coconut genetic material has been drawn up by Bavappa and Nampoothiri (1974). While outlining the programme (Fig. 3) the principles taken into consideration are the primary selection of the mother palms based on their performance in the population, selecting the seedlings of the resultant progeny, for all characters showing high heritability and correlation with yield, emasculating the non-selected palms to prevent their participation in natural crossing and using the S_1 generation of the dwarf parents selected so as to obtain the maximum possible uniformity in the planting material in one generation. The D x T and improved talls (T x T) will be available at the end of the first stage.

In the second stage of the programme the progenies of the selected talls will be allowed to open pollinate among themselves. In the dwarf parent further homozygosity is brought in by raising S_2 and genetic advance is achieved by repeating selection. The F_1 hybrids of D x T from the second stage are likely to be much more uniform and also better than those from the first stage in view of the additional homozygosity that has been brought into the parents as well as the improvement in their genetic base. The above programme can be applied to different tall and dwarf parents as and when information is available on their better performance.

TISSUE CULTURE

Due to the heterozygosity and exclusively seed propagated nature of the crop, we are not able to use palms with exceptionally high yield or other desirable attributed like disease resistance for large scale production of good planting material. This handicap can be overcome by tissue culture, which will ensure production of large number of 'true to type' progenies. Though tissue culture work on coconut has been in progress at many laboratories (Banton and Blake, 1983; Pannetier and Buffard-Morel, 1982) there are no reports of differentiation from the callus. Raju *et al* (1984) from Central Plantation Crops Research Institute, Kasaragod reported clonal plantlets through direct somatic embryogenesis from leaf explants. For this, they used the lowermost 10 cm. segment of tender leaves from two year old seedlings. They found that upto 48 embryoids develop from a single leaf explant. These embryoids at the end of 45-60 days maturation period got detached from the parent tissue. They were found to increase in number by a process of adventitious budding from the existing ones. Histological studies showed their origin to be directly from the vascular tissue. There was no callus formation at any stage of the development which is advantageous. Further work is in progress at C.P.C.R.I. to refine the medium and standardise the technique to transfer the plantlets to soil media which when succeed will open new vistas in utilisation of superior coconut genotypes.

REFERENCES

Bavappa, K. V. A. and Nampoothiri, K. U. K. 1974. Recent trends in coconut breeding. *SABRAO*, 34 A: 58-65.

Branton, R and Blake J. 1983. A lovely clone of coconut. *New Scientist*. 98: 554-557.

C. P. C. R. I. 1980. Annual report.

C. P. C. R. I. 1984. Mycoplasma diseases of coconut with special reference to root (wilt) disease. C. P. C. R. I. Techn. bull.

Harland, S. C. 1957. Improvement of the coconut palm by breeding and selection. Bull. No. 15. Coconut Research Institute, Ceylon.

Iyer, R. D., Rao; E. V. V. B., Sukumarn C. K. and Jacob Mathew P. 1981. Towards an ideal plant type concept in coconut. Proc. *PLACROSYM* IV: 29-37.

Lakshmanachar M. S. 1959. A preliminary note on the heritability of yield in the coconut. *Ind. Coconut J.* 12 65-68.

Liyanage, D. V. 1955. Planting material for coconut. *Ceylon Coconut Quart.* 6: 75-80.

Liyanage, D. E. 1972 Production of improved coconut seed by hybridisation. *Oleagineux.* 27: 597-699.

Liyanage, D. V. and Abeyawardena. 1957, Correlation between seed nut, seedling and adult palm characteristics in coconut. *Trop. Agric.* 113: 326-340.

Liyanage, D. V. and Sakai, K. I. 1960. Heritabilities of certain yeild characters of the coconut palm. *J. Genet.* 57: 245-252.

Menon, K. P. V. and Pandalai K. M. 1958. The coconut palm.* A monograph. publ. Ind. Cetr. Coc. Comm.

Nampoothiri K. U. K., Satyabalan K. and Jacob Mathew 1975. Phenotypic and genotypic correlation of certain characteristics with yield in coconut. FAO. Techn. Wkg. Pty. Jamaica.

Ninan C. A. and Satyabalan K. 1964. A study of natural, self and cross (Dwarf x Tall) Progenies of dwarf cocounts 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.

Pannetier C. and Buffard-Morel J. 1982. First results of somatic embryo production from leaf tissue of coconut, *Cocos nucifera. Oleagineux.* 37: 349-354.

Patel J. S. 1937. Coconut breeding. *Proc. Ass. Econ. Biol. Coimbatore.* 5: 15-16.

Raju C. R., Kumar P. P., MINI C. and Iyer R. D. 1984. Coconut plantlets from leaf tissue culture. *J. Plant. Crops.* 12: 75-78.

Rao E. V. V. B. and Jacob Mathew 1981. An index for evaluation of coconut germplasm in the nursery. *Proc. PLACROSYM* IV. 200-205.

Sukumaran C. K. Narasimhayya G. and Vijayakumar G. 1981. Path coefficient analysis in coconut *Proc. PLACROSYM* IV. 191-199.

Swaminathan M. S. 1983. Coconut research; the next phase. Coconut Research and development. pp. 1-11.

Thankamma Pillai P. K., Vijayakumar G. and Ravindran P. N. 1983. Cytology of coconut. in Coconut Research and Development Wiley Eastern Ltd. pp. 62-70.