NOTE ABOUT THE AUTHOR

Dr. D. V. Liyanage devoted over fifty years of his life conducting research and development work on coconut. In his own words his mission was to increase coconut production and productivity from coconut lands.

Dr. Liyanage commenced his research work at the Coconut Research Institute, Sri Lanka in 1945 and served the Institute upto 1966. During that period he produced two improved coconut strains, established criteria on genetics of the coconut palm and developed new concepts on planting methods and mass production of seed. He was with the Food and Agriculture Organization (FAO) of the United Nations from 1966 to 1981 and worked in Tonga Islands, Maldives and Indonesia on coconut research and development.

As the Project Leader of the UNDP/FAO Coconut Development Project in Indonesia from 1971-1981 he was tasked to implement an accelerated breeding programme to produce improved coconut strains and mass production of seed to be used in the national coconut development programme that had been already undertaken. If conventional methods were followed 20 years was required for that purpose. However a bold breeding programme was initiated and implemented resulting in the production of three improved strains and mass production of seed within 12 years.

Back in Sri Lanka he was appointed as Chairman Coconut Research Board (1984-1988). The Government of Sri Lanka in 1987 conferred Presidential Honours to him for his contributions to science.

COCONUT BREEDING AND DEVELOPMENT

BY D.V. LIYANAGE

COCONUT BREEDING AND DEVELOPMENT

BY D.V. LIYANAGE

A COLLECTION OF PAPERS ON COCONUT BREEDING AND DEVELOPMENT BY D.V. LIYANAGE

INTRODUCTION

Dr. D. V. Liyanage's involvement in coconut research and development spans over a half century, and his contribution particularly on coconut breeding is well known. His initiatives had resulted in developing a number of new high yielding cultivars which are considered as highly acceptable and successful ones.

In the course of his research and development work in a number of countries in the region, he had contributed many papers on genetics of the coconut palm, coconut breeding, seed production and sustainable agricultural practices. APCC accordingly requested Dr. Liyanage to compile them into one document to facilitate reference. The present publication is the outcome.

My thanks go to Dr. Liyanage for undertaking this compilation and Mrs. J. Suharto of the APCC Secretariat for its preparation for publication.

December 1998

P.G. PUNCHIHEWA, Ph.D
Executive Director

THE JOY AND AGONY OF A COCONUT BREEDER

Breeding coconut palms is tedious and sometimes monotonous. The long life cycle, absence of vegetative multiplication and few fruits produced aggravate the situation. Breeding an improved variety using conventional methods and mass production of seed takes about 20 years.

Coconut breeding was initiated in South and South East Asia between 1930 and 1935. During that period, as plantation sector dominated tropical agriculture, research objective was to maximise production by using high yielding varieties requiring high inputs. Later that technology was passed on to the small coconut farmers, which was inappropriate, as providing inputs was beyond their resources. Results were negative. What they needed was a coconut variety that gave satisfactory yields with low inputs.

With this objective and also to shorten the life cycle of a palm, a breeding program was initiated by the author in 1949 at the Coconut Research Institute, Sri Lanka. It culminated in the production of two new strains - **CRIC 60** and **CRIC 65** - suitable for small holder and estate sectors. Further, mass production of seed was achieved through the new technique of isolated seed gardens.

Subsequently, author spent ten years in another country and the mission was to produce an improved coconut variety together with large quantities of seed to be used in the national coconut development program already in progress. They were not prepared to wait for 20 years. It was a dilemma and a challenge.

Hence a bold, imaginative and accelerated programme was prepared and implemented. Within twelve years, three new coconut varieties were produced. Mass seed production was achieved through a unique system of seed gardens.

This programme clashed with commercial interests (foreign) who were interested in selling imported seed. They discouraged and criticised the breeding program. Criticism was so harsh and extensive, that author as leader of the breeding team experienced considerable difficulty to maintain morale and efficiency of the team. That was a period of agony.

However, these are memories of the past. The joy of producing new coconut varieties lingers on.

So many people working at the Coconut Research Institute (CRI), Sri Lanka and Industrial Crops Research Institute (LPTI), Indonesia co-operated with me to implement various research programmes, that it would be impossible to mention them all. But I must say special thanks to late Stanley de Silva and late R.W. Senaratne of CRI, who taught me the basics of coconut cultivation when I joined CRI in 1945; late Hasman Azis of LPTI who was an inspiration to me during the difficult period spent in Indonesia and R. Mahindapala who went through the draft of this book meticulously.

My thanks are also to the APCC Secretariat for encouraging me to bring out this publication.

D.V. LIYANAGE December 1998

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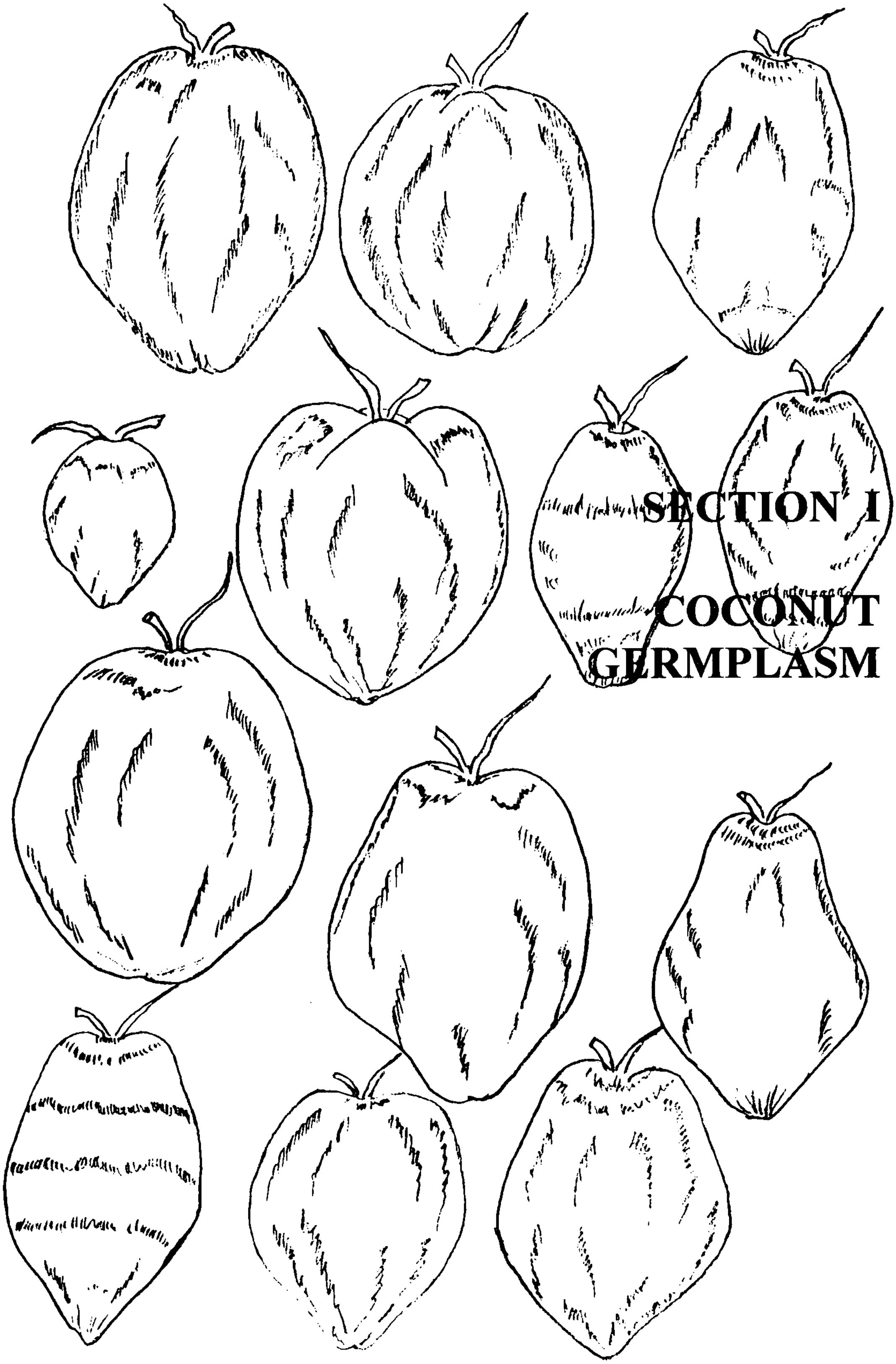
COCONUT GERMPLASM



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The Ceylon Coconut Quarterly
Vol. IX, 1958

VARIETIES AND FORMS OF THE COCONUT PALM GROWN IN CEYLON

SUMMARY

Coconut palms growing in Ceylon have been classified into three varieties: *typica* Nar. tall in habit, late flowering and predominantly out-breeding; *nana* (Griff) Nar. short in habit, early flowering and in-breeding; *aurantiaca* Liy. semi-tall in habit, late flowering, in-breeding with nuts of orange colour. Altogether 13 forms distributed amongst these three varieties are described.

INTRODUCTION

Varieties and forms of the cosmopolitan coconut palm (*Cocos nucifera* L.) have been described by different workers from time to time. Recently, Narayana and John (1949), Gangolly *et al.* *(1957)* and Menon and Pandalai (1958) have given a comprehensive list of coconut varieties. Although, a number of forms have been described by using local names, it is unlikely that the total number would be so large, if a critical analysis of varieties and forms of coconut in the world is undertaken and the terminology is standardized.

Hunger (1920) has described seven varieties of coconut palms based on the size of palm, characteristics of the nut, mainly colour and size, as follows: (1) *viridis* Hassk. - nuts green, (2) *rubescens* Hassk. - nuts gray brown, (3) - *macrocarpa* Hassk. - nuts very large, (4) *rutila* Miq. - husk very thick, of little value for copra, (5) *eburnea* Hassk. - an albino variety of no commercial value, (6) *pumila* Hassk. - early maturing dwarf type bearing green nuts and (7) *regia* Miq. - early maturing dwarf bearing golden-yellow or orange-yellow nuts. Perhaps types (1) to (5) may be more appropriately described as forms of a single variety and (6) and (7) forms of another variety.

Narayana and John (1949) have divided the species into five varieties, *viz.* (1) *spicata* Jacob - a purely female coconut palm, (2) *androgena* Nar. - a male coconut palm, (3) *javanica* Nar. - a mutant true breeding type from Java, (4) *typica* Nar. - the ordinary tall type found in all coconut growing areas of the World and (5) *nana (* Griff,) Nar. - the common dwarf variety. A number of forms in each variety has been listed. Probably, *typica* and *nana* describe appropriately two distinct varieties, but other classifications purely on sex expression are rather doubtful, since the genetical behaviour of that character has not been studied. I was unable to locate in Java, the variety described as *javanica.*

The existence of varieties of coconuts in Ceylon has been recognized from very early times. Seeman (1856) has recorded five indigenous varieties of the coconut palm: '*Thembili, Navasi, Dwarf,* another *Thembili* form with large nuts and the common tall type'. Trimen (1898) records that several varieties of coconut are recognized by growers, but mentions only two types - King Coconut and a 'very small-fruited dwarf sort (*Cocos nana* Griff.)'.

A number of forms of coconut which are distinct from one another could be identified. Considering the fact that most of the types are out-breeding and a number of variants are bound to occur, a distinct classification is rather difficult. Nevertheless, an attempt has been made in this paper to divide the indigenous types of coconut palms into groups that distinctly differ from one another and suggest a tentative classification.

VARIETIES

On a critical examination of data pertaining to morphological characters and breeding system of different types of coconut palms grown in Ceylon, three varieties could be distinguished. Using the terminology of other workers, two varieties could be described as ***typica*** Nar. *i.e.* the popular tall variety grown on a plantation scale, and ***nana*** (Griff.) Nar. *i.e.* the dwarf variety. The third variety is the group to which *King Coconut* belongs, which type is probably endemic to Ceylon. Since the bright orange colour of nut is a prominent characteristic of the variety, it is described as ***aurantiaca*** Liy.

Salient characters of these three varieties are indicated below. Girth measurements of stem has been taken 5 feet above ground level and leaf length are of 10-year old palms.

Variety *typica* Nar.

Stem - broad, mean girth 33 inches (approx.), attains a height of about 60 feet. Leaves - long, mean length is about 18.2 feet. Flowering - late, about 8 years after planting, flower production continuous. Breeding system - predominantly out-breeding due to protandry. Nuts - medium to large in size, 4,000 to 5,200 nuts per ton of copra. Copra - hard, good quality. Palms - hardy, tolerating a wide variation of soil type and climate. Under a favourable environment, economic production possible up to 60 years.

Variety *nana* (Griff.) Nar.

Stem - narrow, mean girth about 22 inches, attains a height of about 35 feet. Leaves - short, mean length 13.3 feet. Flowering - early, 3 years after planting, flower production seasonal. Breeding system - predominantly in-breeding, male and female reproductive phases of inflorescence overlap. Nuts - small, 9,000 to 12,000 nuts per ton of copra. Copra - leathery, poor quality. Palms susceptible to pests and diseases, thrive well on fertile soils with a well distributed rainfall, suffer adversely from drought. Economic production period not more than 40 years.

Variety *aurantiaca* Liy.*

Stem - semi broad, mean girth 28 inches, attains a height of about 40 feet. Leaves - short, mean length 14.0 feet. Flowering - late 6 to 8 years after planting, flower production seasonal. Breeding system - predominantly in-breeding, male and female reproductive phases of inflorescence overlap. Nuts - medium size, 8,000 nuts to a ton of copra. Epicarp of fruit orange in colour. Endosperm- thin, little value for copra production. Palms -susceptible to pests and diseases, thrive well on fertile soils with a high water table and a well distributed rainfall, suffer adversely from drought. Economic production period not more than 40 years.

* Arbor, 12 m alta, 7.1 dm. In circumferentia: fructu aurantiaca. Typus: Liyanage in Herb Peradeniya

Forms of varieties

Within each variety, a number of forms could be recognized and their salient distinguishing characters are indicated below. Variations between forms in quantitative characters of nut components are given in Tables 1 and 2, variations in size and shape of nut in Figures 1 and 2. The names used for forms are local terms, where ever possible local terms used in other countries to describe similar types are indicated. Somatic chromosome number of some forms is given.

Forms of the variety ***typica*** Nar.

Typica : Nuts generally oblong; epicarp of nut different shades of green to reddish-brown; mesocarp a good source of fibre; endosperm thick giving about 7 oz. copra per nut. This type is normally grown on a plantation scale. Chromosome number 2n = 32.

Navasi : Epicarp of nut green; mesocarp of immature nut sweet and edible; husk soft; nut water insipid. No commercial importance. Chromosome number 2n = 32. Same form described as *tamisan, taban, cayamis* in the Philippines; *kelapa tebu* in Indonesia; *kaithathali* in India; *cay dua sap* in Vietnam.

Gon-thembili : Epicarp of fruit and rachis of leaf ivory yellow; water of tender nut usually insipid; nuts fairly large, out-turn low; oil content high - 69.2%. Chromosome number 2n = 32. Same form described as *garing* in the Philippines and *kelapa kuning* in Malaya.

Ran-thembili : In immature fruits 2-3 months old the mesocarp and portion of epicarp covered with perianth lobes are pink in colour; in fruits 4-6 months old epicarp is green and chalazal region of mesocarp (basal portion) pink in colour; husk soft; oil said to be of medicinal value.

Pora-pol : Husked-nut small and elongated; endocarp exceptionally hard and very thick - about 6 mm. These nuts are used for a type of sport practised in the southern parts of Ceylon. Chromosome number 2n = 32. Same form described as *tutupaen* in the Philippines.

Bodiri : Prolific bearing palms; nuts very small requiring about 20,000 nuts to a ton of copra; each bunch carries 50-100 nuts; oil content high - 69.6%. Same form described as *coconino* and *mangipod* in the Philippines, *mapraw-puong* in Thailand.

Kamandala : Nuts large, approximately 1.5 times the size of nut of *typica* form; similar to San Ramon nuts from the Philippines, but not so globose; distribution restricted to the southern province of Ceylon. Same form referred to as *lupisan* in the Philippines, *kappadam* in India and *markam* in New Guinea.

Dikiri-pol : Commonly described as *Macapuno*; endosperm 2-3 cm thick, soft, some portions with a buttery consistency and gelatinous. Two to three nuts in a bunch are of this type, others being normal. Soft meat considered to be a delicacy. Same form referred to as *macapuno* in the Philippines and *thairu thengai* in India.

Forms of the variety ***nana*** (Griff.) Nar.

Pumila	:	Inflorescence yellowish green; epicarp of fruit green.
Eburnea	:	Inflorescence ivory yellow; epicarp of fruit yellow.
Regia	:	Inflorescence orange; epicarp of fruit apricot red.

Forms of the variety ***aurantiaca*** Liy.

Thembili or King coconut	:	Upper surface of leaf rachis, inflorescence and epicarp of fruit orange; sucrose content of tender nut relatively high - 5 to 6% - furnishing a delicious and refreshing drink. Oil said to be of medicinal value and has a peculiar characteristic of having a higher melting point than ordinary coconut oil. Breeds true to type (about 80%). Chromosome number 2n = 32. This form is popularly known as King Coconut.
Navasi-thembili	:	Uppper surface of leaf rachis, inflorescence and epicarp of fruit orange; mesocarp of tender fruit sweet and edible.

DISCUSSION

It is apparent that there is considerable variation between different coconut palms with respect to the habit of palm, vegetative characters, breeding system; size, weight and colour of fruit and its components (Tables 1 and 2, Figure 1). Strains that distinctly differ in structural or functional characters from one another, and some of which breed true to type could be distinguished. On this basis, separation of the indigenous coconut palms into three varieties is feasible. Variety *typica* is tall in habit and predominantly out-breeding, variety *nana* is short in habit and in-breeding, and variety *aurantiaca* is semi tall, in-breeding and fruits are orange in colour. Within each of these groups, there are types that differ distinctly, in relation to size and colour of fruit or its components, and they may be conveniently described as 'forms'. Size of nut is influenced by the environment, yet in some palms it is an inherent character and consequently, they could be described as 'forms' (*e.g. bodiri*).

Main commercial products of coconuts are copra, oil and desiccated coconut. In an evaluation of different forms, main emphasis should be on yield of copra or oil per unit area, which ultimately depends on nut weight and yield per palm. Statistics pertaining to these characters are available only for *typica, King Coconut* and the three *nana* forms; others are relatively few in number, and that too widely scattered amongst plantations. Yield of copra of the three *nana forms* and *King Coconut* is low, and further copra is of a low quality, that they are unsuitable for commercial planting for copra production.

Variation between forms relative to out-turns are very large, but that relative to oil content of copra is only appreciable. *Regia* form of variety *nana* has given the lowest oil value (65.2%) and *pora-pol* form of *typica* the highest value (69.7%). Out-turns have varied between 2,700 to 20,000 nuts per ton of copra; both these extreme forms belong to the variety *typica.*

Coconut palms grown in all the countries for copra production on a commercial scale belong to the variety *typica*, but between countries, there are differences particularly with regard to shape and size of fruit; Thailand type is larger than the Ceylon type, the latter being larger than Laguna type in the Philippines.

The *typica* form grown in Ceylon varies considerably with respect to colour of epicarp of fruit from various shades of green to reddish-brown - these differences are to be expected due to natural cross fertilization. There is a popular but erroneous belief that palms with reddish-brown fruits are more productive than those with green fruits. On an examination of 50 palms taken at random from the two colour types, it was found that there were no significant differences in yield of fruits between them. On the contrary, reddish-brown fruits had a distinctly thinner endosperm, requiring about 700 nuts more than green nuts for a ton of copra. This form is likely to be a hybrid with germplasm from *King Coconut,* for in controlled crosses between forms with green fruits and orange fruits, F_1 palms bear reddish-brown fruits. An important characteristic of the Ceylon *typica* palms is that they are very hardy and resistant to pests and diseases to a fair degree.

Kamandala form is characterised by having large nuts, a husked-nut weighing over 3.5 lb. giving nearly 1 lb. copra ; 2,700 nuts per ton of copra is remarkable. Each palm is said to yield 30-40 nuts a year. Distribution of this form is restricted to a portion of the Southern Province of Ceylon. Introducing it to other parts of the country may be useful, provided palms do not react adversely to a changed environment.

Bodiri is quite a remarkable form; nut size is no more than an orange, oil content is high (69.6%). *mapraw-puong* growing in Thailand is similar to this form, but more than 90% of nuts in a bunch is barren. Perhaps, these two forms are geographically isolated races and they may produce progenies exhibiting considerable heterosis when crossed with other forms.

At one time it was considered that *nana* palms would be useful for production of toddy. From a tapping trial carried out on 24 of these palms, it has been pointed out that they are not of much value for that purpose as toddy production is low; 49 and 61 litres of toddy per acre per day for *pumila* and *typica* palms respectively (Nathanael, 1951). Two characters of importance for breeding work in *nana* palms are the short habit and early flowering - 3 years. Field studies have indicated that they are adversely affected by drought; drooping of leaves and bunches unusually heavy and nut size reduced. They are generally less hardy than *typica* and are susceptible to pests and diseases.

King Coconut is probably endemic to Ceylon. It is characterised by the bright orange colour of fruits and sweetness of tender nut water due to a higher sucrose content. Because of the latter character, nut water is a popular beverage and it is grown especially for that purpose.

Forms that are useful for breeding are: *kamandala* (high nut weight), *bodiri* (prolificity in bearing, high oil content), *gon-thembili* (low out-turn, high oil content) and *pumila* (early bearing, short habit). Early bearing character of *nana* forms is partially dominant and the short habit recessive. The F_1 palms of *typica x pumila* show considerable heterosis; they combine the physiological vigour of former parent and early flowering habit of the latter to give high yield of nuts as early as the sixth year of planting.

Key for the identification of varieties and forms of coconut found in Ceylon

	Fruit Size	*Epicarp*	*Mesocarp*	*Endocarp*	*Endosperm*
Variety *typica*: tall in habit, late flowering (6-8years), predominantly out-breeding.					
Form *typica* :	large	green to brown	creamy white	thin	thick, hard
" *kamandala*:	very large	do	do	do	do
" *bodiri* :	very small	do	do	very thin	do
" *navasi* :	large	green	soft, edible	thin	do
" *ran-thembili*:	do	do	pink	do	do
" *gon-thembili*:	do	ivory yellow	creamy white	do	do
" *pora-pol*:	do	green	do	very thick	do
" *dikiri-pol* :	do	do	do	thin	very thick, soft, jelly-like
Variety *nana*: short in habit, early flowering (3-4 years), in-breeding.					
Form *pumila*:	small	green	creamy white	very thin	thin, hard
" *eburnea*:	do	ivory yellow	do	do	do
" *regia*:	do	apricot red	do	do	do
Variety *aurantiaca*: semi-tall in habit, late flowering (6-8 years), in-breeding, fruits orange in colour.					
Form *King coconut*:	large	orange	creamy white	very thin	thin, hard.
" *navasi-thembili*:	do do	soft, edible	do	do	

ACKNOWLEDGEMENTS

Thanks are due to J.E. Senaratne, Systematic Botanist, Department of Agriculture, Peradeniya, for reading through the draft and making many valuable suggestions; W.R.N. Nathanael, Chemist, Coconut Research Institute, Lunuwila for determination of oil content of copra and A.P.J. Perera, Lunuwila for the illustrations.

REFERENCES

Gangolly, S.R., Satyabalan, K. and Pandalai, K.M. 1957. Varieties of coconut. *The Indian Coconut Journal*, X: 3-28.

Hunger, F.W.T. 1920. *Cocos nucifera*, Handboek voor de kennis van den *Cocos* in Nederlandesh - Indie, Zinjne Geschiedenis, Beschrijving, cultuur en production. Groes & Nijhoff, Amsterdam.

Menon, K.P.V and Pandalai, K.M. 1958. The Coconut - A Monograph. Indian Central Coconut Committee, S. India.

Narayana, G.V. and John, C.M. 1949. Varieties and forms of coconut. *The Madras Agricultural Journal,* 36: 349-366.

Nathanael, W.R.N. 1951. Annual Report of the Coconut Research Board of the Coconut Research Institute for 1951: 12-13.

Seeman, B. 1856. Popular history of palms and their allies. Lovelle Reeve, London: 146-180.

Trimen, H. 1898. Handbook of the flora of Ceylon, Part IV. Dulan & Co., London: 337.

Table 1. Quantitative characters of fruit components of forms of coconut found in Ceylon

	Fruit			Husked-nut		Endocarp		Thickness
	Length (in.)	Width (in.)	Volume (c c)	Volume (c c)	Weight (oz.)	Thickness (mm.)	Weight (oz.)	endosperm (mm.)
Variety ***typica***								
Form *typica* -	8.6	7.0	3200	870	25	3	5.6	15
navasi -	8.9	7.6	3175	877	22	3	6.0	13
gon-thembili	8.9	6.5	2535	787	24	3	7.0	13
ran-thembili	8.6	7.6	3728	857	29	3	7.0	14
pora-pol -	9.0	6.5	1870	683	19	6	8.0	13
bodiri -	4.5	3.8	606	218	7	2	1.8	10
kamandala	10.6	8.9	5922	1760	56	3	11.4	14
dikiri-pol -	not recorded							
Variety ***nana***								
Form *pumila* -	7.8	5.4	1457	367	10	2	2.5	11
eburnea -	7.5	5.8	1591	474	15	2	3.1	12
regia -	7.7	4.9	1140	334	10	2	2.0	11
Variety *aurantiaca*								
Form *King coconut*	8.2	5.3	1394	559	14	2	6.0	12
navasi-thembili	7.6	5.7	1573	525	16	2	3.5	12

Table 2. Some economic characters of forms of coconut found in Ceylon

	No. of nuts examined	Weight per husked-nut (lb.)	Copra per nut (lb.)	Nuts per ton copra	Oil content (dry basis) (%)
Variety *typica*					
Form *typica*	100	1.53	7.52	4750	68.95
navasi	19	1.34	6.32	5675	69.54
gon-thembili	55	1.53	8.15	4400	69.20
ran-thembili	19	1.83	7.79	4600	68.46
pora-pol	20	1.18	5.00	7150	69.73
kamandala	45	3.54	13.33	2700	67.65
bodiri	20	0.43	1.80	19,900	69.58
Variety *nana*					
Form *pumila*	52	0.63	4.00	8950	69.65
eburnea	100	0.95	3.96	9050	65.49
regia	90	0.61	3.07	11,675	65.23
Variety *aurantiaca*					
Form *King coconut*	100	0.88	5.00	7150	65.62
navasi-thembili	21	1.02	4.95	7250	68.10

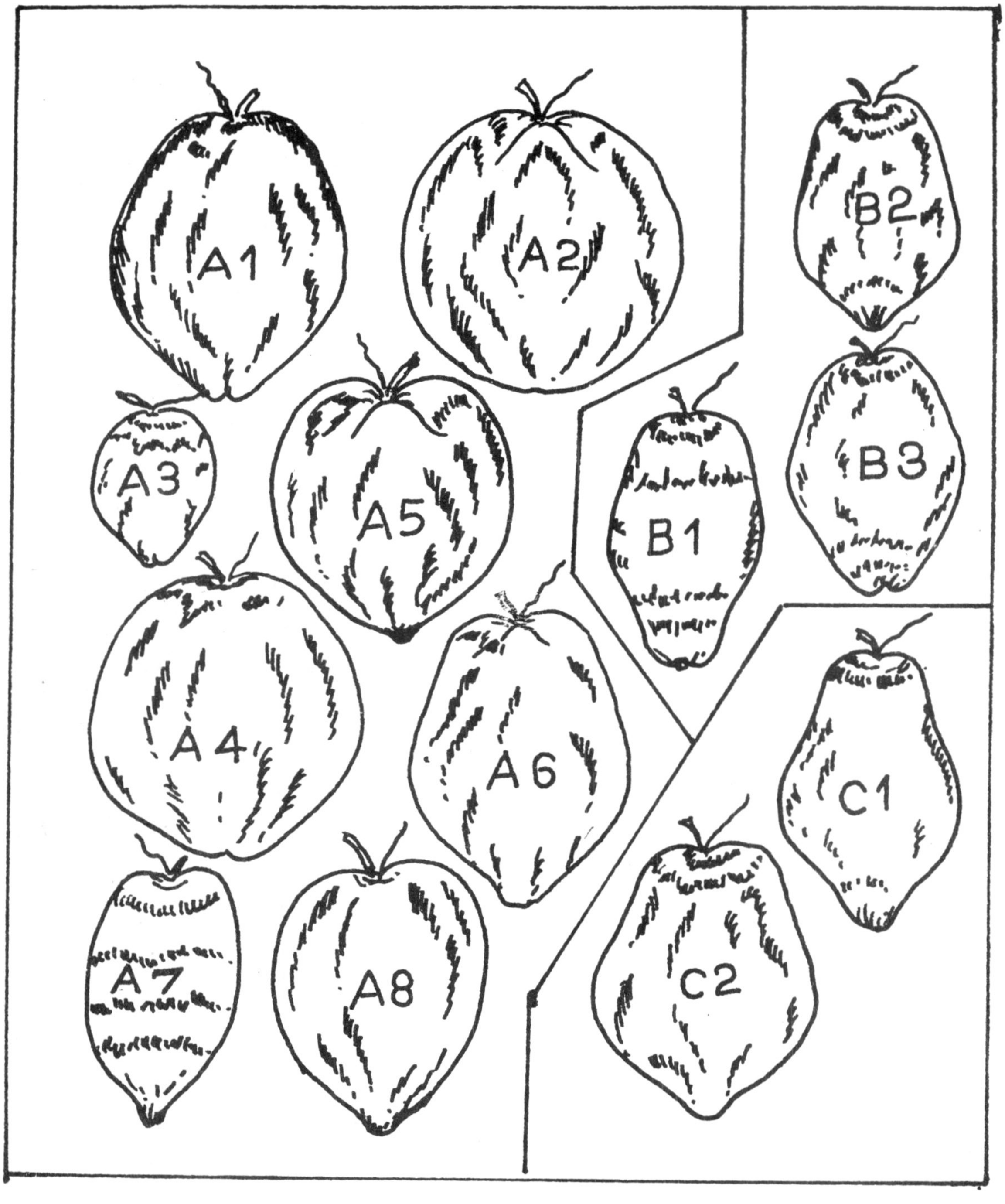

Fig. 1 Shape and size of forms of coconut found in Ceylon

Forms of variety *typica*: A1 - *typica* A2 - *kamandala* A3 - *bodiri* A4 - *navasi* A5 - *ran thembili* A6 - gon thembili A7 - *pora pol* A8 - dikiri pol.

Forms of variety ***nana***: B1 - *pumila* B2 - *eburnea* B3 - *regia*

Forms of variety ***aurantiaca***: C1 - *thembili (King coconut)* C2 - *navasi thembili*

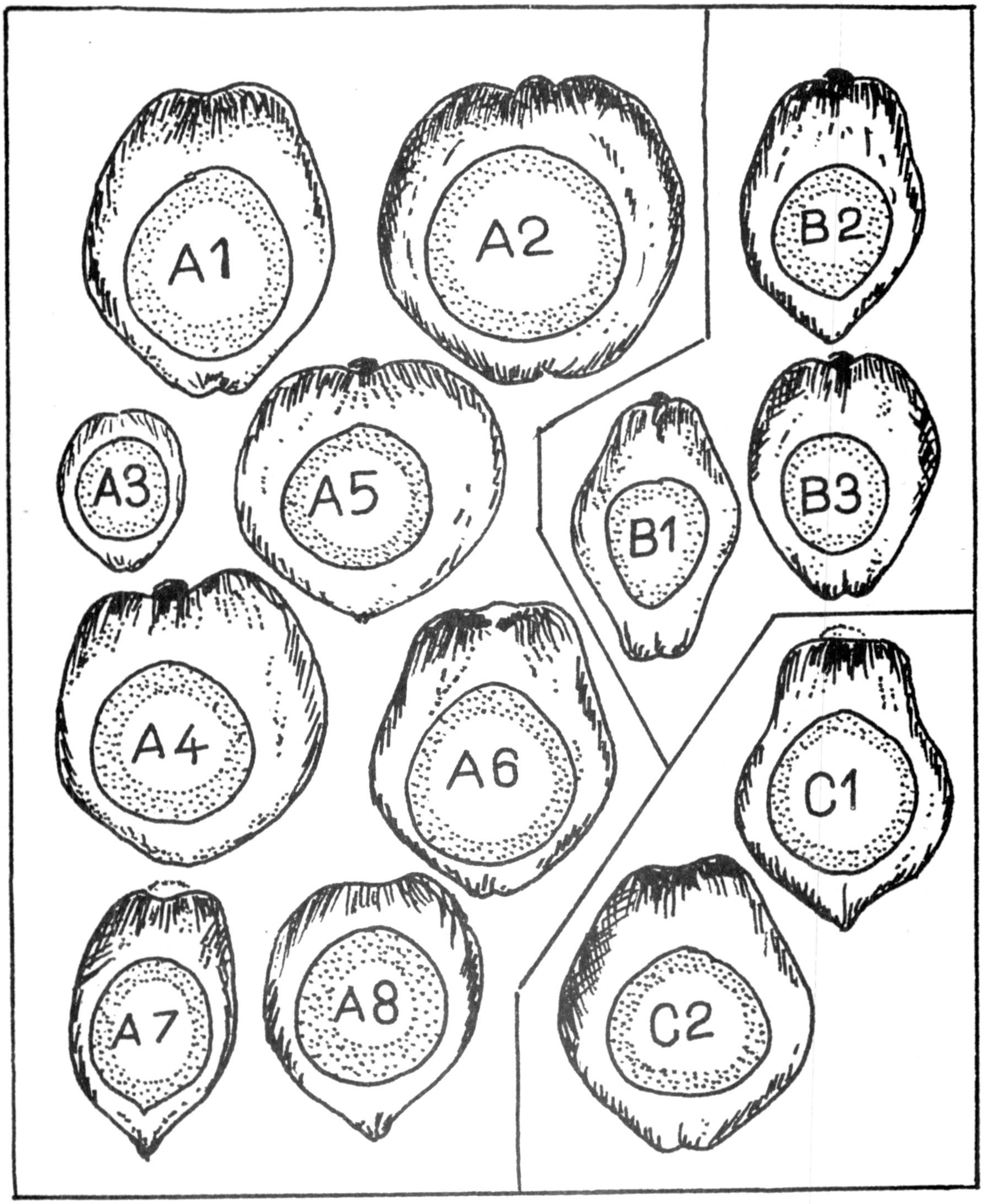

Fig. 2 Longitudinal section of fruits illustrated in Fig. 1

Forms of variety ***typica***: A1 - *typica* A2 - *kamandala* A3 - *bodiri* A4 - *navasi* A5 - *ran thembili* A6 - *gon thembili* A7 - *pora pol* A8 - *dikiri pol.*

Forms of variety ***nana***: B1 - *pumila* B2 - *eburnea* B3 - *regia*

Forms of variety ***aurantiaca***: C1 - *thembili* (King coconut) C2 - *navasi thembili*

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Fourth Session, FAO Technical Working Party
on Coconut Production, Protection and Processing
Kingston, Jamaica. 1975
Jointly with Ch. P. Corputty

COCONUT GERMPLASM IN INDONESIA

SUMMARY

A survey of coconut germplasm in selected areas of eleven provinces in Indonesia was carried out. The main objective of the survey was to identify suitable forms of coconut palms to be planted in seed gardens and to select desirable types to be included in the breeding programme.

Twenty five samples of coconuts were collected from typical coconut groves and from those that were of particular interest. The samples represented a wide spectrum of populations, some exposed to selection pressure. A number of measurements of each fruit from each sample were recorded.

The *eburnea* form of *nana* (yellow dwarf) growing in Nias island is a unique population, which is suitable to be used as basic material in genetical trials. Palms are high yielding giving about 170 g copra per nut. Their first generation progenies are early bearing and homogeneous.

'Bali' form growing in Bali and in Beji estate is quite remarkable amongst the *typica* samples analyzed. Fruits are large and more or less spherical, each giving over 300 g copra, with a low husk/fruit ratio (25.6%) and a high endosperm/fruit ratio (33.2%). Besides, Tenga (North Sulawesi) and Bangga (Central Sulawesi) strains are of interest. These two strains and the Bali form are suitable to be used as male parents in seed gardens. Homogeneous populations of the three types exist from which desirable palms could be selected.

Varieties/ forms of coconut that are of interest for genetical trials are: *eburnea* form from Nias and Bali, *pumila* from Nias, Bali form from Bali and Beji estate, Tenga and Paslaten strains from North Sulawesi, Bangga strain from Central Sulawesi, Padang Tikar from West Kalimantan and Tacome form from Maluku.

The populations of palms studied have been classified into two varieties, *typica* and *nana,* with four forms for the former and three for latter.

Shape of fruit and nut varied considerably between the samples collected. A round fruit with a flat bottomed nut has given 20 g copra per nut more than the other combinations of fruit and nut shape.

INTRODUCTION

A survey of coconut germplasm was carried out in selected areas of eleven provinces in Indonesia. Palm populations were studied, fruit samples collected and a number of measurements recorded. Objectives of the survey were: to identify suitable forms of coconut to be used as male and female parents in seed gardens and to select forms to be used in the breeding programme.

Definitions of terms used

In describing varieties and forms, terms that have been used previously by Narayana and John (1949) are used in this paper. Relevant terms are:

Variety *typica* : commonly referred to as the Tall variety. Those palms commonly grown for copra production is the *typica* form of *typica* variety.

Variety *nana* : commonly referred to as the dwarf variety which has three forms:
pumila with green fruits,
eburnea with yellow fruits,
regia with apricot-red fruits.

Definitions of other terms used:

Fruit - whole fruit complete with husk, described as round (A), oblong (B) and other types (C) - Figure 1.
Nut - portion of fruit that remains after husk is removed, described as round (C), flat-bottomed (D), oblong (E) - Figure 2.

Early flowering - appearance of first spadix less than four years from date of planting palm.
Late flowering - appearance of first spadix more than four years from date of planting palm.
Copra per nut - calculated as 50% of the wet endosperm weight.
Yield of nuts - yield of nuts is not given in quantitative terms as data were not available, where high yield is referred to, it is at least 80 nuts per palm/yr.

Sampling method

Generally 30 to 50 ripe fruits with a brown epicarp were taken at random from heaps of coconut, depending on availability of fruits and transport facilities. Some samples had less than 30 fruits due to loss in transport, non-availability and other reasons. Populations from which samples were collected are indicated in Table 1. Following measurements of each fruit were recorded:

- shape of fruit and nut,
- weight of fruit, nut, endosperm (wet) and shell,
- thickness of endosperm (mean of three readings taken on the equatorial plane).

Data collected are presented in Tables 1, 2, 3 and 4.

DISCUSSION

Coconut palms generally grown as a commercial crop in Indonesia, could be classified as the variety *typica*. There are considerable variations within the variety particularly fruit and nut shape, size, weight and colour of epicarp. *Nana* palms are restricted to home gardens, except in Nias island where a plantation of 246 ha has been established.

Nana palms in Nias island

There are 9,000 palms remaining now out of 45,000 planted between 1927 and 1933. Four forms could be distinguished amongst them and their distribution in the population is indicated below:

Eburnea (yellow)	- 82% of the population
Pumila (green)	- 10% "
Regia (red)	- negligible
Natural hybrid	- 8% of the population

Summarizing Tables 2, 3 and 4 together with other observations, differences between *eburnea* and *pumila* are outlined below. Data of *regia* were not available as the few scattered palms were of a poor quality.

		Eburnea form	*Pumila* form
Palm characters	-	uniform	variable
Yield	-	heavy bearing	less
Fruit shape	-	oblong	variable
Fruit	-	larger, 1339 g wt., cv 2%	smaller, 898 g wt., cv 20%
Nut	-	larger, 796 g wt., cv 13%	smaller, 604 g wt., cv 20%
Endosperm	-	more, 342 g wt., cv 10%	less, 288 g wt., cv 13%
Progenies	-	more true to type	variable

Eburnea population is generally more homogeneous than *pumila*. Coefficient of variation (cv) for all the characters scored, except for husk weight, is less for the former than the latter (Table 2). *Pumila* has better husk/fruit, nut/fruit and endosperm/fruit ratios (Table 3).

Progenies (400) of the *nana* form have been planted at the Experimental Station at Teunon in 1969. Flowering commenced in July 1972 - 86% of *eburnea* has flowered against 36% of *pumila*. In bearing palms, former carried 6 to 7 bunches per palm in different stages of maturity, whereas the latter had about 3 bunches, indicating that *eburnea* has flowered earlier. Here again, *eburnea* is more uniform relative to vegetative and fruit characters than *pumila*.

Type		Percentage of total palms	Palms flowering/ bearing (%)
Eburnea	-	61	86
Pumila	-	34	36
Natural hybrids and segregates	-	5	25

The Nias plantation has been neglected over a continuous period of 30 years or so since 1938, which has resulted in a large number of casualties as given in census figures (Table 5). Assuming that *typica* and *nana* varieties were exposed to the same stress during the period of neglect, it is interesting to record the variety/environment interaction: 80% of *nana* palms have failed to survive against only 15% of *typica* (comparison between Toyolawa 2 and Toregoo only).

This confirms the view that *nana* variety is not so hardy as *typica* and does not tolerate adverse environmental conditions. The existing *nana* palms could be considered a unique population, in that through a process of natural selection weaker genotypes have been eliminated during the period of neglect.

Natural hybrids in the Nias population

It is possible that *nana* seed nuts imported to be planted in Nias island contained some seed crossed with *typica*. These have given natural hybrids and roughly 8% of the population consists of them. They could be identified from morphology of the palm (Table 6) and breeding system. They are taller than *nana* palms, showing vigorous growth, bole is rather bigger, and most of them give a high yield - 130 to 150 nuts palm/year. They do not show any signs of decline in yield, apparent in *nana*, although both groups are about 40 years old. It is obvious from these palms that F_1 of *nana* x *typica* will remain productive for over 50 years under satisfactory conditions.

***Eburnea* form in Bali**

The few *eburnea* palms growing in Sangiang estate, Bali are quite different from those in Nias as tabulated below. It seems to be a separate strain, unrelated to Nias strain and should be useful for genetical studies.

	Eburnea form in Bali	*Eburnea form in Nias*
Fruit weight (g) -	468	1339
Nut weight (g) -	312	796
Endosperm weight (g) -	201	342
Husk/fruit ratio (%) -	33.3	40.3
Endosperm/fruit ratio (%)	42.9	25.6
Endosperm/nut ratio (%) -	64.4	43.0

Variations between *typica* samples

The 22 samples of *typica* variety represent quite a spectrum of coconut populations in Indonesia. Wide fluctuations in mean values of different characters between the samples are to be expected due to the heterozygous nature of palms and diverse environmental conditions. Some samples are quite representative of mixed stands of palms, unexposed to any selection pressure previously, *e.g.* sample 4, Pangandaran; 10, Sangiang and 22, Banda Aceh. Some represent more homogeneous stands, where apparently planting material has been selected, *e.g.* sample 5, Beji; 9, Celukembawang and 11, Tenga (Table 2). Important differences between them are summarized in Table 7.

In the populations of group 1 (Table 7), where presumably unselected planting material has been planted, size of fruit is small, copra content per nut is low and the coefficient of variation for all characters very high - over 20%. Presumably, group 2 is composed of upgraded populations through selection for high fruit weight and copra content per nut, resulting in relatively lower coefficients of variation - less than 15%.

Variety *typica* form *Bali*

Out of all the *typica* populations studied, samples 5, 8 and 9 are quite distinct from the others. They are referred to locally as Bali palms, because a large acreage of palms in Bali island is of this type and seed has been introduced to other provinces from Bali. Main characters of typical Bali palms are:

- Large fruits, more or less spherical,
- nuts prominently flat-bottomed with a pointed posterior end (Fig. 2),
- copra content per nut averages 300 g,
- low husk/fruit ratio and
- high nut/fruit ratio.

Morphology of the stem and crown is similar to that of the *typica* form. Number of nuts per bunch is about 5 to 6. A comparison is made between a typical Bali sample (No. 9) and a standard one (No. 17) - Table 8. This type of palm could be described as a distinct form of the variety *typica* , viz. form *Bali.* It is said that this form originated from Celukembawang in Bali. Selected palms of *Bali* form are suitable to be used as a male parent in seed gardens and for breeding purposes.

Populations of particular interest

Besides the Nias and Bali populations already referred to, following are of particular interest - Tenga (sample 11), Bangga (15), Paslaten (13) and Padang Tikar (18). Weight of fruit components varies between them (Table 2), but they all belong to homogeneous populations. They cannot be classified as different forms, but may be considered as strains of the *typica* form.

Tenga, Bangga and Paslaten palms carried round and oblong fruits with flat-bottomed nuts. The last character indicates that they may be related to the *Bali* form. Copra content per nut is high. Tenga gives 8 to 10 nuts per bunch, Paslaten and Bangga 6 to 7 nuts. Selected palms of Tenga and Bangga populations are suitable to be used as male parents in seed gardens and for breeding.

Padang Tikar is a village in an island of the same name, situated in an estuary of a tributary of the river Kapuas in West Kalimantan. Soil is fertile alluvial clay with a high water table. Coconut yields are about 5,000 nuts per ha/yr. The growers claimed that coconuts could be harvested in the 5th year after planting. In a block of 1 ha, about 60% of palms were in bearing in the 6th year. All young coconut groves have been raised from seed collected within the island and local seed has not been planted outside that island. Thus, it was not possible to determine whether precocity for flowering is due to genetical or environmental factors.

A type of coconut palm called *Kelapa raja* (kelapa = coconut) is said to be found in Tobelo, Halmahera island, Maluku where there are about 100 palms in one block. It was not possible to examine this block. However, 5 bearing palms in Ternate said to be offspring of that type were inspected. Stem and leaf characters of these palms are similar to those of *nana* variety, self pollinated, early bearing, fruit colour deep reddish brown, quite different from the green, yellow and apricot-red forms already known. Mature fruits were not available for analysis. They belong to the *nana* variety judging by the morphology and breeding system of the palm. Since they bear fruits of a different colour and this character seems to be true breeding, could they be considered as a separate form of *nana* ? It is known that *pumila x regia* gives progeny bearing reddish brown fruits. It is necessary to study these palms in detail to determine their varietal status.

Fruit and nut shape in relation to copra weight

Generally, round fruits carry round or flat-bottomed nuts, seldom oblong nuts; oblong fruits have round, oblong or flat-bottomed nuts. Flat-bottomed nuts probably originated from *Bali* form and have been introduced to Sulawesi and Java. They were seldom found in Maluku and West Kalimantan. Samples 7, 9, 11, 12, 13, 14, 15 and 24 have different combinations of fruit and nut shape as indicated below.

Fruit shape (Fig. 1)	A	A	A	B	B	B	O
Nut shape (Fig. 2)	C	D	E	C	D	E	O
No. of nuts examined	62	95	3	53	16	12	3
Endosperm wt/nut (g.)	521	576	405	503	474	383	401

There is variation of copra content per nut according to shape of the fruit and nut. Round fruits (A) with flat-bottomed nuts (D) have given the highest copra content, 288 g per nut which is 28 g copra more than from round fruits with round nuts. This is quite a substantial difference, amounting to an additional 200 kg (approx.) of copra per ha/yr.

Inclusion of samples of *Bali* form or those of its origin, inflate the mean endosperm weight per nut, and further brings in complications due to inter action between forms, if any. Hence samples 7, 9 and 15 were not included in the analyses of variance of endosperm weight given in Table 9.

Variations between locations is highly significant and that between fruit and nut combinations significant. Endosperm of a round fruit with a flat-bottomed nut weighed 576 g, whilst that of a round fruit with a round nut was only 521 g, a difference of 55 g - significant difference being 34. Thus, it may be advantageous to breed round fruits with flat-bottomed nuts as they give more copra per nut than round fruits with round nuts.

'Banyuwangi' and 'Jepara' populations in Beji estate are probably F_2 open-pollinated progenies of the *Bali* form. The former had 80% flat-bottomed nuts and the latter 100% (Table 4). Flat-bottomed nut is a characteristic of the *Bali* form. This evidence suggests that there is dominance of this character. *Nana x typica* seed with flat-bottomed nuts could be produced, if the latter parent has that character, unless maternal inheritance is involved, which is unlikely as *pumila x San Ramon* produces nuts with the shape of male parent.

Endosperm thickness

Average thickness of endosperm of a nut from a standard mixed population is about 12 mm. In the current survey, some samples had a high proportion of nuts with a thickness of 13 to 14 mm as indicated in Table 10. It is seldom that endosperm thickness is considered in breeding programmes, it should be a useful character to be included.

Coconut varieties/forms in Indonesia

Coconut palms in the areas surveyed could be classified into two varieties, *viz.* *typica* and *nana* . A number of forms (cultivars) could be distinguished within each variety. Those of *typica* are listed below: The three forms of *nana* have been described earlier.

Forms of variety *typica*

Typica

This form is commonly grown in coconut holdings. Samples given in Table 1 except No. 1,2,3,5, 8, 9 and 21 belong to this form. Samples 11 (Tenga) and 15 (Bangga) could be considered as strains of this form.

Bali

Samples 5, 8 and 9. They are quite distinct from the *typica* form, in that fruits are larger and more or less spherical, nuts flat-bottomed tapering towards posterior end with a high copra content. These characters seem to be true breeding. Average out-turn is about 3,300 nuts per metric ton of copra.

A similar form with large fruits , but without flat-bottomed nuts are described as 'Lupisan' in Philippines, 'Kapadam' in India, 'Markam Valley' nuts in New Guinea and Kamandala' in Sri Lanka.

Tacome

Sample 21. Fruits and nuts very small requiring about 12,500 nuts per metric ton of copra. Setting of female flowers very high. Endosperm is hard and testa light brown in color.

Similar form described as *'Coconino'*, *'Mangipod'* in Philippines, *'Maprawpuong'* in Thailand and *'Bodiri'* in Sri Lanka.

Kelapa kopyor

Endosperm very soft with some portions having a buttery consistency and gelatinous. Only some fruits in a bunch have this character, others being normal.

Similar form described as *'Thairu thengai'* in India, *'Macapuno'* in Philippines and *'Dikiri pol'* in Sri Lanka.

Other types that may be considered to be forms were found scattered about coconut plantations, and were seldom found in groups of even two palms.

Review of literature on coconut varieties in Indonesia

Miguel (1856) has listed 18 varieties of coconut in Indonesia - varieties *rutila, macro carpa, sachcarina, capuliformis,* etc. A complete description of these varieties is not given. Hence it is not possible to ascertain differences between them. In a list at the Botanical Garden, Bogor, 11 varieties are mentioned - *dilie, dioica, viridis, pumila,* etc. All these varieties, except *dilie* are said to have originated from Sunda Kecil, island of Dilie.

Corputty and Budhoyo (1968) described 8 forms of the *typica* variety growing in Beji estate - *banjuwangi, jepara, pulau seribu* etc. The names indicate the places from which seed nuts were derived. A critical examination of these four populations indicates that they could be described as two forms - *Bali* and *typica.*

Soenarto (1971) observed 12 coconut varieties in Sumberjambe estate. Differences amongst them relative to important characters like habit of palm, breeding system, nut characters etc. are not very marked to classify them into separate varieties.

REFERENCES

Corputty, Ch.P. and Budhoyo, S., 1968 Some notes on coconut forms at Beji estate. Paper presented at the *Third Session of the FAO Technical Working Party on Coconut Production, Protection and Processing.*

Miguel, F.A.W. 1856. *Flora voor Nederland Indie,* Vol. 3.

Narayana, G.V. and John, C.M. 1949 Varieties and forms of coconut. *The Madras Agricultural Journal*, 36.

Soenarto, H. 1971. Beberapa tjatatan varietas dan forma pada kelapa. Mimeographed paper.

Table 1. Details of coconut samples collected

Sample No.	No. of fruits	Place collected	Remarks
Variety *nana*			
1	30	Nias island, North Sumatra	Dwarf yellow palms, 41 yr. old.
2	20	do	Dwarf green palms, 41 yr. old
3	17	Sangiang estate, Bali	Dwarf yellow, from one palm, 30 yr. old
Variety *typica*			
4	50	Pangandaran, West Java	Tall palms, heap nuts.
5	29	Beji estate, Central Java	'Bali' palms, 55 yr. old.
6	29	do	'Jepara palms, 55 yr. old.
7	30	do	'Banyuwangi', 55 yr. old.
8	15	Celukembawang, Bali	'Bali ' palms, 80 yr. old.
9	41	do	'Bali' palms, 20-30 yr. old.
10	49	Sangiang estate, Bali	Tall palms, 35-47 yr. old, seed from Banyuwangi, 70 yr. old.
11	30	Tenga, North Sulawesi	Tall palms, 70 yr. old.
12	30	Tongtalete, North Sulawesi	do
13	30	Paslaten, North Sulawesi	Tall palms, 35 yr. old.
14	30	Pandu, North Sulawesi	Tall palms, 40-45 yr. old.
15	30	Bangga, Central Sulawesi	do
16	30	Bua, South Sulawesi	Tall palms, heap nuts.
17	30	Ramayadi, West Kalimantan	Tall palms, 20-30 yr. old.
18	24	Padang Tikar, West Kalimantan	Tall palms, 20 yr. old.
19	30	Awaya estate, Maluku	Tall palms, 65 yr. old.
20	30	Tacoma village, Maluku	Tall palms, 40 yr. old
21	5	Acango, Maluku 40 yr. old.	Tacome palms, one palm only,
22	40	Banda Aceh, Aceh	Tall palms, heap nuts.
23	26	Pulau We, Aceh	Tall palms, 60 yr. old.
24	25	Serual, North Sumatra	Tall palms, 35-60 yr. old.
25	20	P. Maose, Nias, North Sumatra	Tall palms, 55 yr. old.

Table 2. Weight of fruit and its components (g)

Sample No.*		Fruit	Husk	Nut	Endos.	Shell	Endos.thick. (mm)
1		1339	540	796	342	152	11.3
	c.v. (%)	1.9	32.6	13.0	9.8	13.4	-
2		898	292	604	288	146	10.8
	c.v.	19.8	24.3	20.2	13.2	22.8	-
3		468	158	312	201	77	11.7
	c.v.	12.0	15.9	11.3	8.2	13.2	-
4		1313	471	842	387	216	12.7
	c.v.	20.1	32.9	22.2	17.8	18.9	-
5		1822	477	1385	619	282	13.3
	c.v.	13.3	20.6	13.1	12.7	12.8	-
6		1366	389	977	460	222	12.6
	c.v.	17.4	17.4	19.1	18.4	12.8	-
7		1689	493	1196	505	249	12.2
	c.v.	30.1	33.3	30.7	24.4	27.7	-
8		1781	474	1307	534	261	12.2
	c.v.	15.9	18.1	17.0	13.2	17.0	-
9		2431	842	1602	624	335	12.0
	c.v.	13.5	28.2	11.5	11.1	12.1	-
10		1533	527	1005	456	228	12.5
	c.v.	20.6	22.6	22.2	28.2	17.0	-
11		1842	633	1209	538	250	12.8
	c.v.	14.1	29.6	15.3	13.5	13.4	-
12		1392	484	908	408	220	11.9
	c.v.	17.1	26.6	20.0	18.7	18.1	-
13		2136	709	1428	594	305	12.8
	c.v.	15.5	20.9	17.5	17.2	14.9	-
14		1710	719	991	426	242	12.1
	c.v.	18.1	29.5	17.5	15.5	18.5	-
15		2005	438	1567	644	311	12.2
	c.v.	16.0	24.6	16.8	14.1	15.3	-
16		-	-	1030	440	300	11.7
	c.v.	-	-	16.8	12.5	15.8	-
17		1473	560	905	377	277	11.1
	c.v.	24.4	23.9	12.3	14.7	24.8	-
18		1786	802	984	426	253	12.2
	c.v.	17.2	24.7	16.8	17.1	15.3	-
19		1400	589	810	388	201	11.7
	c.v.	18.6	25.0	17.9	17.6	18.4	-
20		1719	712	1007	438	233	11.9
	c.v.	17.0	27.3	16.2	13.7	16.6	-
21		380	150	230	163	65	10.8
22		1430	668	762	342	203	12.4
	c.v.	23.2	33.8	23.0	20.3	20.4	-
23		1514	542	971	432	222	12.6
	c.v.	21.8	39.0	21.4	18.6	19.5	-
24		1529	579	950	410	232	12.6
	c.v.	14.2	20.5	21.6	19.9	16.7	-
25		1328	473	855	409	202	12.9
	c.v.	14.4	-	15.3	11.6	19.1	-

- as given in Table 1

Table 3. Ratios between fruit components (percent)

Sample No. *	Husk/ fruit	Nut/ fruit	Endos./ fruit	Endos./ nut	Shell/ nut
1	40.3	59.5	25.6	43.0	19.1
2	32.5	67.3	32.1	47.7	24.3
3	33.3	66.7	42.9	64.4	24.7
4	35.9	64.1	29.5	46.0	25.7
5	25.6	74.4	33.2	44.7	20.4
6	28.5	71.5	33.7	47.1	22.7
7	29.2	70.8	29.9	42.2	20.8
8	26.6	73.4	30.0	40.9	20.0
9	34.1	65.9	25.7	39.0	20.9
10	34.4	65.6	29.7	45.4	22.7
11	34.4	65.6	29.2	44.5	20.7
12	34.8	65.2	29.3	44.9	24.2
13	33.2	66.9	27.8	41.6	21.4
14	42.1	57.9	24.9	43.0	24.4
15	21.9	78.2	32.1	41.1	19.9
16	-	-	-	42.7	29.1
17	38.6	61.4	25.6	41.7	25.8
18	44.9	55.1	23.9	43.3	25.7
19	42.1	57.9	27.7	47.9	24.8
20	41.4	58.6	25.5	43.5	23.1
21	39.5	60.5	42.9	70.9	28.3
22	46.7	53.3	23.9	44.9	26.6
23	35.9	64.1	28.5	44.5	22.9
24	37.9	62.1	26.8	43.2	24.4
25	35.6	64.4	30.8	47.8	23.6

* as given in Table 1.

Table 4. Shape of fruit and nut (percent)

Sample No. *	Fruit shape			Nut shape			
	A	B	O	C	D	E	O
1	-	100	-	87	-	13	-
2	20	65	15	75	-	25	-
3	-	-	100	-	-	-	100
4	36	42	22	66	14	20	-
5	90	10	-	-	100	-	-
6	100	-	-	-	100	-	-
7	84	16	-	20	80	-	-
8	100	-	-	13	87	-	-
9	100	-	-	18	82	-	-
10	2	89	11	30	6	59	4
11	47	50	3	46	37	16	-
12	57	43	-	80	20	-	-
13	53	47	-	63	37	-	-
14	37	56	7	60	27	13	-
15	97	3	-	53	47	-	-
16	not recorded						
17	17	70	13	43	-	30	27
18	29	71	-	33	-	67	-
19	50	50	-	43	-	-	57
20	63	37	-	80	6	6	6
21	not recorded						
22	27	63	10	47	20	33	-
23	77	11	11	61	11	28	-
24	68	32	-	50	21	29	-
25	20	75	5	30	-	60	10

* as given in Table 1.

Table 5. Toyolawa estate, Nias island, North Sumatra

Division	Area (ha)	Variety	When planted	Number of palms Original stand	 Now remaining
Toyolawa 1	518	*typica*	1909-1920	53,500	40,300
Toyolawa 2	246	*nana*	1927-1933	45,000	9,000
Toregoo	190	*typica*	1927-1933	19,700	16,800
Maose	76	*typica*	1909-1920	4,800	4,000
Total	**1030**	-	-	**123,000**	**70,100**

Table 6. Stem characters of *nana* palms and natural hybrids

Type	Girth of stem above ground (cm) 10 cm	 1 m	Inter-node length (mm)	Height of stem (m)
Natural hybrid	129.0	88.7	62	12.5
Eburnea form	89.3	68.6	47	10.5
Pumila form	99.9	75.4	52	10.5

Mean measurement of 10 palms.

Table 7. Variations between some selected samples *

		Fruit wt. (gm)	c.v. (%)	Nut wt. (gm)	c.v. (%)	Endosperm wt. (gm)	c.v. (%)
Group 1.	Sample 4	1313	20.1	842	22.2	387	17.8
	" 10	1533	20.6	1005	22.2	456	28.2
	" 22	1430	23.2	762	23.2	342	20.3
Group 2.	Sample 5	1862	13.3	1385	13.1	619	12.7
	" 9	2431	13.5	1602	11.5	624	11.1
	" 11	1842	14.1	1209	15.3	538	13.5

* as given in Table 1

Table 8. Comparison between *bali* form and standard *typica* form

		Bali form (sample 9)	*Typica* form (sample 17)
Fruit weight (g.)	-	2431	1473
Nut weight (g.)	-	1602	905
Endosperm weight (g.)	-	624	377
Husk/fruit ratio (%)	-	34.1	38.6
Nut/fruit ratio (%)	-	65.9	61.4
Fruit dimensions			
Polar vertical length (cm.)	-	23	-
Equatorial diameter (cm.)	-	21	-
Polar circumference (cm.)	-	72	-
Equatorial circumference (cm)	-	69	-

Table 9. Analysis of variance for endosperm weight

	df	Mean square	F - value
Between locations	4	74193.73	13.91 **
Fruit and nut shape	1	30282.82	5.68 *
Error	67	5334.54	

* significant at P = 0.05   ** significant at P = 0.01

Table 10. Frequency distribution of endosperm thickness

Sample number *	Mean thickness endosperm (mm)	Thickness of endosperm (mm)*			
		11	12	13	14
		Percentage of palms			
5	13.3	11	3	38	48
9	12.0	20	61	20	0
11	12.8	7	30	43	20
13	12.8	10	23	46	20
15	12.2	20	46	26	7

* as given in Table 1

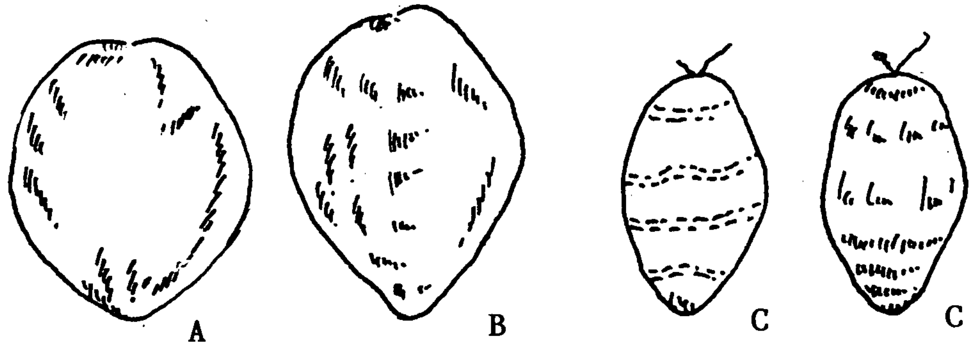


Fig. 1 Shape of fruit A - Round B - Oblong C - Others

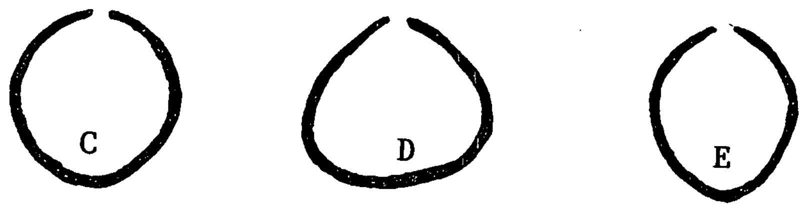
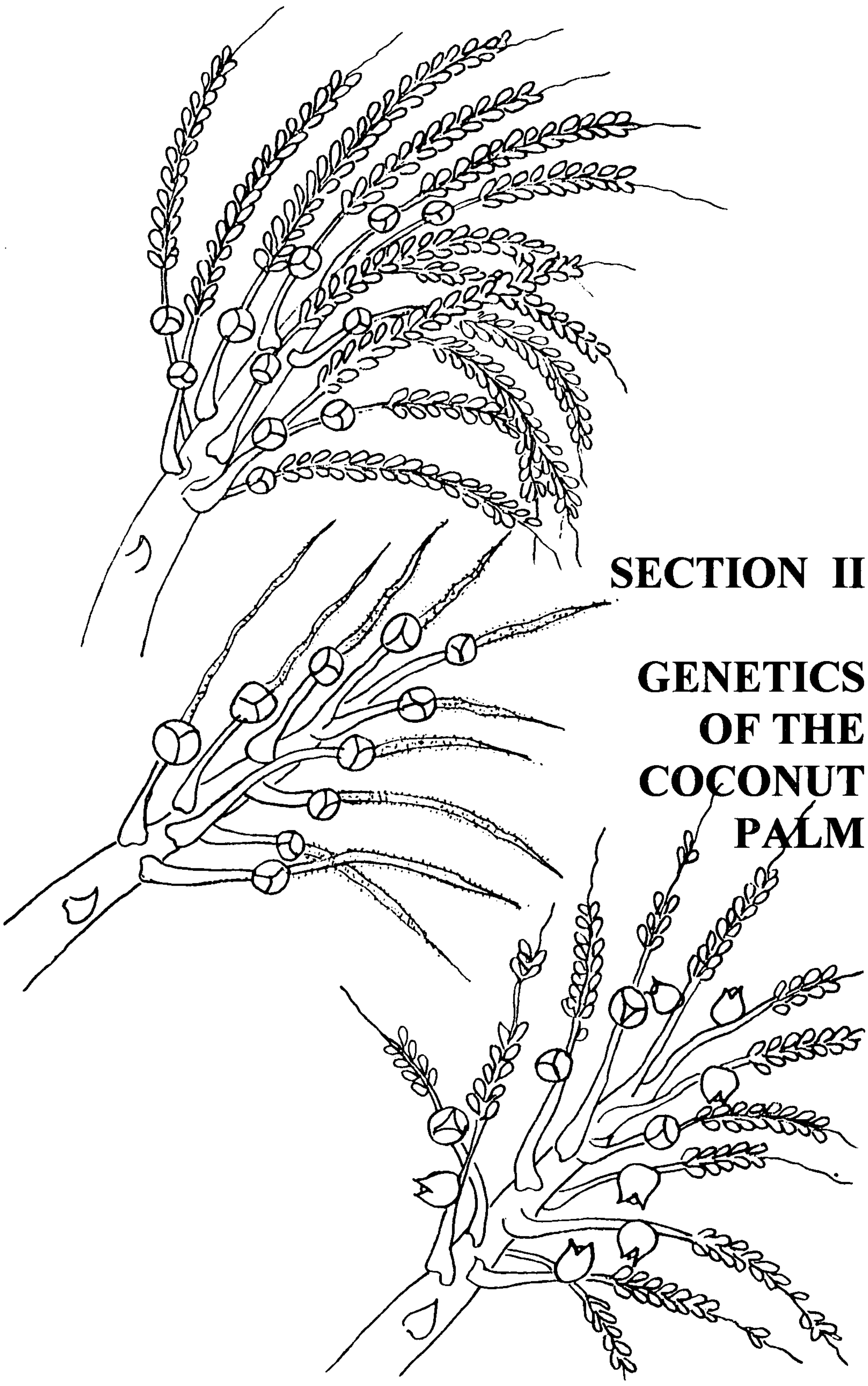


Fig. 2 Shape of nut C - Round D - Flat bottomed E - Oblong



SECTION II

GENETICS OF THE COCONUT PALM

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Tropical Agriculturist
Vol. CXIII, 1957
Jointly with V. Abeywardena

CORRELATION BETWEEN SEED NUT, SEEDLING AND ADULT PALM CHARACTERS IN COCONUT

SUMMARY

Correlation coefficients between 14 characters pertaining to seed nut, seedling and adult palm characters in coconuts have been worked out in order to ascertain whether any of the young progeny characters predispose towards economic qualities of the adult palm. Besides, criteria already considered in selection of seed parent, it is desirable to select palms with large and heavy nuts that give a low sprouting period. Early sprouting of a seed nut, early flowering and high initial yield of a young palm are reliable characters of a high yielding adult palm.

INTRODUCTION

In a perennial crop like coconut, *Cocos nucifera* L. where the only known method of propagation is by seed, any morphological characters either of seed nut or seedling, that demonstrate yield potential of young or adult palm, are of considerable economic value. The importance of such an assessment cannot be over emphasized, since available planting material is so heterozygous that even after years of careful crop husbandry a number of palms in a plantation tend to be unproductive.

Correlation studies made so far by different workers regarding coconuts have been limited to characters of adult palms, *e.g.* correlation between number of leaves on the crown and yield of palm. These studies are useful, in selection of suitable seed parents, but do not indicate behaviour of their offspring.

The present study was undertaken to determine, whether any young progeny characters predispose towards high yield of nuts or copra in adult palms.

MATERIAL AND METHODS

A field trial was planted in 1939 to study methods of mass selection of the coconut palm (var. *typica*). Altogether 576 seedlings have been planted, and out of them, there were 144 plants whose seed parents are known with at least 4 progenies per family, *i.e.* per seed parent. These 144 progenies that have been planted amongst the other plants, were used for present study. Seed material has been collected from 20 selected high yielding palms under open pollination, planted in a nursery and subsequently transplanted. Following data have been collected during different stages of the experiment:

Seed nut : Weight and volume of un-husked nut and date of sprouting. Sprouting period is taken from date of planting seed to emergence of sprout from the husk.

Seedling : Height, leaf and root numbers eight months after planting seed nuts. Vegetative weight is total weight of seedling, less weight of un-husked nut.

Adult palm : Date of initial flowering, total yield of nuts and weight of husked nuts during the 16th and 17th years after planting. Yield of copra has been calculated as 32% of the husked nut weight.

The correlation coefficients between and within families of the characters listed above, and in some instances partial coefficients keeping one or two factors constant have been worked out. Their significant levels are given below.

			Between *r*	Within *r*
P = 0.01 (denoted with *** in the text)		*r* =	0.5466	0.2324
	Partial	*r* =	0.5591	0.2324
P = 0.05 (denoted with ** in the text)		*r* =	0.4316	0.1778
	Partial	*r* =	0.4434	0.1778
P = 0.1 (denoted with * in the text)		*r* =	0.3680	0.1497
	Partial	*r* =	0.3774	0.1497

RESULTS

Seed nut volume

The volume of a seed nut has no bearing at all on sprouting period, height and root number of seedling or yield of copra of the adult palm.

Within a family, *i.e.* seed nuts taken from the same mother palm, larger ones produce seedlings with a heavier weight and more leaves and they flower relatively late. The high positive correlation between seed nut volume and seedling weight is presumably due to common seed nut weight; yet when vegetative weight is correlated with volume, high significance is retained, indicating that larger seed nut promotes better vegetative growth (Table 1).

There is a high negative correlation between families only, for volume of seed nut and yield of nuts of progeny, suggesting that seed parents with above average nut size have progenies with fewer nuts. Even if flowering period is kept constant same relationship holds, indicating that it is valid irrespective of bearing age.

Seed nut weight

Weight of a seed nut has no bearing on sprouting period, vegetative weight and root number of a seedling, or flowering period of progeny. A heavy seed nut gives a heavy seedling, but since there is no significant relationship between seed nut weight and vegetative weight, it is apparent that former correlation is purely due to common seed nut weight. A heavy seed nut shows a tendency to produce more leaves in the seedling, but since between correlation is not significant, it does not follow that a seed palm bearing heavy nuts would necessarily give progenies with more leaves.

Weight of a seed nut has no significant bearing on the nut weight of its progeny. The partial coefficient between these two factors, keeping flowering period constant, is significant only for between parents. Therefore, although there is nothing to be gained by selecting heavy seed nuts within parents, it does help to an appreciable extent, if seed palms that normally give heavy seed nuts are selected.

The weight of a seed nut has no bearing on nut production in its progeny, but between parent correlation is negative and significant, *i.e.* parents that normally bear heavy nuts give progenies with fewer nuts (Table 2).

Seed nut weight per unit volume

The weight per unit volume of seed has no significant bearing on sprouting period, height and root number of seedling, weight per nut, yield of nuts and copra of the adult palm. Within families, nuts with high weight per unit volume tend to inhibit vegetative growth and promote early flowering (Table 3).

Sprouting period

Early sprouting promotes seedling height, leaf and root number. This may be largely due to higher physiological age of seedlings that sprout early, rather than to other causes.

Within a family, one cannot expect seed nuts that sprout early to produce palms that flower early and *vice versa*, but between families correlation is highly significant and positive, showing that a family with a low sprouting period will have a low flowering period.

Sprouting period has no significant bearing on nut production, but when flowering is kept constant, within correlation is highly significant and negative. The position then, is that early sprouting, in spite of bearing age will bring about a higher nut production (Table 4).

Seedling height

Seedling height has a significant bearing on seedling weight and same relationship holds when sprouting period is kept constant, *i.e.* seedling age is the same.

If seedlings from the same parent are considered, taller ones have more leaves. But when sprouting period is kept constant, this correlation disappears, indicating that this relationship is merely a reflection of seedling age.

If seedlings are from same parent, seedling height has no bearing on the flowering period, but significant negative correlation suggests that seed parents that normally give tall seedlings will find their offspring flowering early. However, if sprouting period is kept constant, this association disappears (partial for *between* r= - 0.1235, *within* r = - 0.0227) and in effect seedling height by itself can be considered to have no bearing on flowering period of palms.

Within same parent, seedling height has no effect on weight per nut and yield of nuts or copra of the adult palm. The significant correlation between height of seedling and weight per nut for between parents disappears when sprouting and flowering are kept constant. (Table 5).

Seedling weight

Weight of a seedling has no influence on its leaf or root number, and flowering period of the palm. The same pattern holds even when sprouting period is kept constant.

Within a family, seedling weight has no effect on weight per nut or yield of nuts. But between parents, correlation of seedling weight per nut is suggestive, and it is so (- 0.3986) even when sprouting period is kept constant. But it is highly significant (- 0.5534) when both sprouting and flowering periods are kept constant.

Thus, if effect of sprouting and flowering periods is eliminated, a heavy seedling tends to give heavy nuts in the bearing palm. The suggestive between correlation with regard to seedling weight and yield of nuts disappears when both flowering and sprouting periods are kept constant. This indicates that a weight of a seedling by itself, has no influence on number of nuts produced by the adult palm (Table 6).

Seedling leaf number

There is a highly significant positive correlation between leaf and root numbers in a seedling, and same pattern holds when sprouting period is kept constant. Besides, this factor there are no relationships between leaf number of a seedling and flowering period or yield of the adult palm (Table 7).

Seedling root number

Number of roots in a seedling has no bearing at all with any of the palm characters, *i.e.* flowering period, weight per nut, yield of nuts and copra (Table 8).

Flowering period

Period taken for flowering of a palm is negatively correlated, both between and within parents, with weight per nut, yield of nuts and weight of copra of the adult palm, *i.e.* a palm that flowers early will give a higher yield of copra and nuts than those that flower late. These relationships hold irrespective of the sprouting period (Table 9).

Initial yield

Initial yield is the mean of harvests gathered during second and third years of bearing. First year of bearing has not been considered, as invariably during that year only a few harvests have been collected. All correlation coefficients listed in Table 10 are highly significant. If a palm during the second and third years of bearing gives a high yield, it will continue to be a high yielding subsequently.

DISCUSSION

General

Sprouting period of a seed nut and flowering period of a palm are two important physiological stages in development of the life cycle of a coconut palm. Former seems to influence growth of a seedling and latter the yield (Fig. 1, 2). Size or weight of a seed nut apparently has no effect on period taken for its sprouting, but early sprouting promotes height, weight and leaf number of the seedling, probably due to higher physiological age.

Considerable care has to be taken in the definition of term 'early sprouting'. Germination of a seed nut depends on its genetic constitution and environment - particularly soil moisture. Seed nuts planted at different seasons may have varying sprouting periods, purely due to different climatic conditions as illustrated in Table 11, which has been prepared from data collected by the senior author in implementing a program of in-breeding work. Age of seed nuts has been calculated from date of opening of the inflorescence to date of planting of ripe nuts from that inflorescence. It is seen that age of seed nuts from different palms is practically the same. Yet there are two marked differences: variations in the means between families and sprouting periods of nuts within families.

Seed nuts of some families have sprouted more or less together, where as in others, period between first and last to sprout has been considerable. In families 34, 66 and 315, range is less than 16 days, but in families 35 and 196 it is 61 and 49 days respectively. Since this is inbred material, it is clear that degree of heterozygosity relative to sprouting period of seed varies between families.

Mean sprouting period of two families 72 and 315 planted in one season is extremely low, whereas that of 196 and 290 planted in another season is high (Table 11). These differences may be due to seasonal effects; it does not follow that nuts of palms 72 and 315 sprout earlier than those of 196 and 290. Hence the term 'low sprouting period' cannot be defined precisely, but in selection work, seed nuts that sprout early from a heap of nuts picked together could be selected from nursery beds.

Sprouting and flowering periods are significantly correlated (r = + 0.5468) for between parents only, *i.e.* palms that give seed nuts with a low sprouting period will have progenies with a relatively low flowering period. Although sprouting period is not directly correlated with yield, within coefficient is significant and negative when flowering is kept constant (Table 4). Thus, it is an advantage to select seed nuts for early sprouting , as it brings about a higher nut production, besides early flowering.

Flowering period of a palm is negatively and significantly correlated with weight per nut, yield of nuts and copra in the adult palm (Fig. 1 & 2). That is, a palm that flowers early would be more productive than one that flowers late. This correlation is of considerable significance, since bearing age of a palm which is normally one year more than flowering period, is an important economic consideration. Further, yield in second and third years of bearing has a relation to yielding capacity of the adult palm (Table 10). All palms, except one, that have flowered in less than 102.5 months and have given an initial yield of 40 or more nuts per palm/year have given more than 70 nuts per year during 16th and 17th years (Fig. 3).

Thus, flowering period and initial yield of a coconut palm are criteria of considerable value in thinning out unproductive palms in a plantation, a practice which would materially benefit the industry. With a mean initial yield of 30.7 nuts per year and a standard deviation of 18.7, palms giving an initial yield of 12 or less nuts per year (*i.e.* mean less standard deviation) are suitable for thinning out stands. On a basis of mathematical probability, about 16% of the stand would be in this yield group.

Unfortunately, current system of planting coconut seedlings in a symmetrical manner at the corners of a geometrical figure, is not conducive to rouging. Main draw back being that, when (say) eight year old palm shows poor growth and has to be uprooted, a new seedling has to be supplied, thereby losing eight years. To overcome this factor, the senior author has suggested a system of *Hedge Planting*, where about 25% more seedlings are planted than necessary, so that after thinning unproductive palms, required density is maintained. In the present material, if palms flowering later than 9 years and those with an initial yield of 12 or less nuts per year were thinned, 25% (approx.) of the stand would have been rejected.

Optimum yield of palms

Four adult palm characters in the present study are flowering period, weight per nut, yield of nuts and copra. Last three factors represent harvests gathered from palms during the 16th and 17th years after planting, *i.e.* current age of plantation. How far is it justified to take the yield of these two years as optimum or mature yield of a coconut palm?

The variety of coconut palms grown in Ceylon on a plantation scale flowers initially in 6 to 8 years and remains productive for over 50 years depending on soil, climate and crop husbandry. After initial flowering, yield of nuts increases every year, until an optimum yield is attained, which is continued thereafter depending on the environment, Unfortunately, there is no data available to ascertain when optimum yield of a palm is attained. Figure 4 exemplifies this point to a certain extent.

Curve A (Fig. 4) gives yearly yield of nuts per acre of a 12 acre block from the 6th to 17th year after planting. Present correlation coefficients have been worked out from this population. Curve B presents yield of nuts acre/year from a 5 acre block from the 6th to 19th year after planting. Yield of both blocks for subsequent years is not available.

Soil in block A is laterite gravel and in B clay. Total rainfall over both blocks is practically the same, but B has a more erratic distribution than A. Yearly yield fluctuations of B are due to the latter factor combined with a less favourable soil.

Yield of block A has been increasing progressively from 6th to 16th year and in the 17th year there has been a drop, largely due to a severe drought previous year. Considering soil and climatic conditions, 4000 nut acre/year in block A is reasonably good. It is not possible to say definitely whether palms in this block have reached optimum yield until further data are collected; yet it could be reasonably stated that they are in full bearing.

The pattern of curve B is different. Yield has progressively increased up to 10th year and thereafter fluctuations have been considerable; every alternate year yield has been low. Maximum production of 4500 nuts acre/year has been obtained in 19th year. It may be that, if climatic conditions were more favourable, 4500 nuts acre/year would have been possible much earlier.

It is not possible to conclude from above evidence , that optimum yield of a coconut palm is derived in the 16th and 17th years; but it is clear that at this age a reasonable yield is possible. Further, yield of the 16th and 17th years are representative of total harvests gathered from 6th to 17th years, *i.e.* first 12 years of bearing in a plantation, as the following correlation coefficients are significant.***

	Between *r*	Within *r*
Yield of nuts in the 16th and 17th years x total yield of nuts from 6th to 17th year	+ 0. 9507***	+ 0.9277***

Re-assessment of selection criteria

It is necessary to ascertain the relevance of present study on current standards of selection of planting material in coconuts. Current practice is to collect seed nuts from high yielding mother palms or high yielding blocks. Mother palms are selected on the following criteria: trunk straight and stout with leaf scars placed closed to each other; fronds short and well dispersed on crown; bunch stalks short; nuts medium sized, extra large nuts to be avoided; weight of husked-nuts to be high; bearing should not be seasonal; total yield to be over 100 nuts with at least 50 lb. copra per palm/year.

In the other category of seed selection, *i.e.* block nuts, a high yielding block giving about 4000 nuts acre/year is selected, all palms within it are harvested, and heavy or medium sized nuts selected from the heap, irrespective of variations between palms in that population. Obviously, such a method of seed selection is not sound genetically.

Seed nuts are planted in a nursery and seedlings are selected on early sprouting and vigour before transplantation. Vigour is rather a relative measurement and is an expression of rate of growth and sturdiness of the seedling (Coconut Research Institute, Leaflet No. 1, 2, 14).

Some pertinent factors that are overlooked in selection of seed palms are apparent from Fig. 1. A palm having large or heavy seed nuts tends to give offspring with fewer nuts, but since total yield of copra is not affected, it is not a disadvantage. On the other hand, it is an advantage if nuts are large and heavy, since fewer nuts are required for a ton of copra, thereby reducing cost of production.

The volume of seed nuts used in the present study has varied between 1349 and 4165 cc. with a mean of 2684 cc. A nut of volume 4000 cc (approx.) which is ideal for seed purposes, both in shape and size is illustrated in Fig 5.

Further, a seed parent that gives progenies with a low sprouting period, other characters being satisfactory, will produce early bearing progenies. Therefore, after preliminary selection of seed parents as pointed out earlier, it is advantageous to select those with a low sprouting period of seed, provided seedlings are vigorous. There is another advantage due to selection of families in this manner. It is the experience of the senior author, that some palms give a higher percentage of vigorous seedlings than others - in some instances 80 to 85% - so that if a large number of such palms could be selected, quantity of rejected seedlings would be negligible. The current rate of rejection is about 50 to 60%.

Nut size and weight within a family have a bearing on seedling characters: seedlings of larger nuts have more leaves, those from heavier nuts are taller (Fig 2). Since vigour is an expression of leaf number, height of seedling, *etc.* as pointed out earlier, it is an important criteria for seedling selection: nuts should be selected for their larger size and weight within families.

Thus, in selection of seed palms, besides the morphological characters, it is desirable to select those giving heavy nuts with about 4000 cc volume, sprouting early and producing a high percentage of tall and vigorous seedlings.

ACKNOWLEDGEMENT

Our thanks are due to W.V.D. Peiris, former Geneticist, Coconut Research Scheme, who planted the field trial in 1939, from which data presented in this paper have been collected.

REFERENCES

Liyanage, D.V. Hedge planting for coconuts. *Ceylon Coconut Quarterly*, 6, 1955.
Coconut Research Institute, Leaflet No. 1, 2 and 14.

Table 1. Correlation coefficients between volume of seed nut and other characters

	Between r	Within r
Seed nut volume x seed nut weight	+ 0.8703***	+ 0.6625***
" x seed nut weight per unit volume	- 0.3788	- 0.7015***
" x sprouting period	- 0.0247	- 0.0134
" x seedling height	+ 0.1762	+ 0.1083
" x seedling weight	+ 0.8547***	+ 0.4893***
" x seedling vegetative weight	+ 0.3640	+ 0.3069**
" x seedling leaf number	- 0.0146	+ 0.2163**
" x seedling root number	+ 0.0266	+ 0.1086
" x flowering period of palm	+ 0.3019	+ 0.2206**
" x weight per nut of palm	+ 0.2904	- 0.0571
" x yield of nuts of palm	- 0.5598***	- 0.1117
" x yield of copra of palm	- 0.3597	- 0.0974
<u>Partial coefficients keeping flowering constant</u>		
Seed nut volume x weight per nut of palm	+ 0.5631***	+ 0.0421
" x yield of nuts of palm	- 0.4955**	- 0.0376

Table 2. Correlation coefficients between weight of a seed nut and other characters

	Between r	*Within* r
Seed nut weight x weight per unit volume of seed nut	+ 0.1158	+ 0.0166
" x sprouting period	+ 0.0955	- 0.0715
" x seedling weight	+ 0.8672***	+ 0.5012***
" x seedling height	+ 0.0193	+ 0.1875**
" x seedling vegetative weight	+ 0.1913	+ 0.0840
" x seedling leaf number	+ 0.0460	+ 0.2093**
" x seedling root number	+ 0.0191	+ 0.1182
" x flowering period	+ 0.2865	+ 0.0804
" x weight per nut of palm	+ 0.3032	+ 0.0220
" x yield of nuts of palm	- 0.5351**	- 0.0581
" x yield of copra per palm	- 0.0422	- 0.0374
<u>Partial coefficients keeping flowering period constant</u>		
Seed nut weight x weight per nut of palm	+ 0.5660***	-
" x yield of nuts of palm	+ 0.4724**	-

Table 3. Correlation coefficients between weight per unit volume of seed nut and other characters

	Between r	*Within* r
Weight per unit volume		
of seed nut x sprouting period	+ 0.2870	- 0.0989
" x seedling height	- 0.3562	+ 0.0457
" x seedling weight	- 0.1159	- 0.2894***
" x seedling vegetative weight	- 0.4040	- 0.3418***
" x seedling leaf number	+ 0.0717	- 0.0857
" x seedling root number	- 0.1267	- 0.0561
" x flowering period	- 0.0166	- 0.2260***
" x weight per nut of palm	- 0.0736	+ 0.0916
" x yield of nuts of palm	+ 0.1276	+ 0.1303
" x yield of copra of palm	+ 0.0961	+ 0.0999

Table 4. Correlation coefficients between sprouting period of a seed nut and other characters

		Between r	*Within* r
Sprouting period	x seedling height	- 0.9348***	- 0.8110***
"	x seedling weight	- 0.0378	- 0.0891
"	x seedling vegetative weight	- 0.2192	- 0.0671
"	x seedling leaf number	- 0.2768	- 0.3529***
"	x seedling root number	- 0.2756	- 0.3758***
"	x flowering period of palm	+ 0.5468***	- 0.0271
"	x weight per nut of palm	- 0.3429	- 0.0145
"	x yield of nuts per palm	+ 0.0026	- 0.1545*
"	x yield of copra of palm	- 0.1777	- 0.1411
Partial coefficients keeping flowering constant			
Sprouting period	x weight per nut of palm	- 0.0694	-
"	x yield of nuts of palm	+ 0.3762	- 0.2706***

Table 5. Correlation coefficients between height of a seedling and other characters

		Between r	*Within* r
Seedling height	x seedling weight	+ 0.2472	+ 0.2599***
"	x seedling vegetative weight	+ 0.4575**	+ 0.2115**
"	x seedling leaf number	+ 0.3336	+ 0.3463***
"	x seedling root number	+ 0.2974	+ 0.4155***
"	x flowering period	- 0.5478***	+ 0.0353
"	x weight per nut of palm	+ 0.4586***	- 0.0264
"	x yield of nut of palm	+ 0.0039	+ 0.0821
"	x yield of copra of palm	+ 0.0205	+ 0.0075

Table 6. Correlation coefficients between seedling weight and other characters

		Between r	*Within* r
Seedling weight	x seedling leaf number	+ 0.2535	+ 0.1108
"	x seedling root number	+ 0.2120	+ 0.1400
"	x flowering period of palm	+ 0.1588	+ 0.0477
"	x weight of nut of palm	+ 0.3872*	- 0.0963
"	x yield of nuts of palm	- 0.3838*	- 0.0165
"	x yield of copra of palm	- 0.1780	- 0.0231

Table 7. Correlation coefficients between seedling leaf number and other characters

		Between r	*Within* r
Seedling leaf number	x root number	+ 0.6637***	+ 0.5761***
"	x flowering period	- 0.0159	+ 0.0914
"	x weight of nut of palm	+ 0.1613	+ 0.0075
"	x yield of nuts of palm	- 0.0534	+ 0.0704
"	x yield of copra of palm	+ 0.0196	+ 0.0834

Table 8. Correlation coefficients between seedling root number and other characters

	Between r	*Within* r
Seedling root number x flowering period of palm	- 0.0953	+ 0.0618
" x weight per nut of palm	+ 0.0864	+ 0.0293
" x yield of nuts of palm	+ 0.0120	+ 0.0347
" x yield of copra of palm	+ 0.0316	+ 0.0013

Table 9. Correlation coefficients between the flowering period and other characters

	Between r	*Within* r
Flowering period x weight of nut of palm	- 0.5375**	- 0.4268***
" x yield of nuts of palm	- 0.4957**	- 0.6348***
" x yield of copra of palm	- 0.6236***	- 0.5525***
Partial coefficients keeping sprouting period constant		
Flowering period x weight per nut	- 0.4450**	- 0.4276***
" x yield of nuts of palm	- 0.5938***	- 0.6470***

Table 10. Correlation coefficients between initial yield of nuts and yield in 16th and 17th years

	Between r	*Within* r
Initial yield x yield of nuts in 16th and 17th years	+ 0.8861***	+ 0.7369***
" x yield of copra "	+ 0.9216***	+ 0.7389***
Partial coefficients with flowering period constant		
Initial yield x yield of nuts in 16th and 17th years	+ 0.8699***	+ 0.6856***
" x yield of copra "	+ 0.9299***	+0.7119***

Table 11. Sprouting periods of inbred seed coconuts

Cross	*Age seed nuts(mth)*	*Frequency of seed nuts sprouting in the following periods (days)* 75-89	90-104	105-119	120-134	135-149	> 150	*Germination of seed nuts (days)* *Non*	*Mean*	*Range*
Seed nuts planted in September 1956										
34 selfed	14.1	1	7	-	-	-	-	1	97	15
37 selfed	14.6	-	8	3	-	-	-	0	101	27
35 selfed	14.3	1	3	1	-	2	1	0	113	61
198 selfed	14.9	3	2	2	-	-	-	0	96	37
21 selfed	15.1	1	4	2	1	-	-	1	101	42
402 selfed	14.3	2	5	-	-	1	-	0	101	54
15 selfed	14.2	-	3	3	-	-	-	0	104	23
66 selfed	14.4	-	1	5	-	-	-	0	105	14
290 selfed	14.1	-	3	4	3	-	-	0	113	29
196 selfed	14.5	-	1	1	3	1	-	0	86	10
Seed nuts planted in April, 1957										
72 selfed	-	-	9	1	-	-	-	0	81	24
315 selfed	-	-	6	1	-	-	-	0	86	10

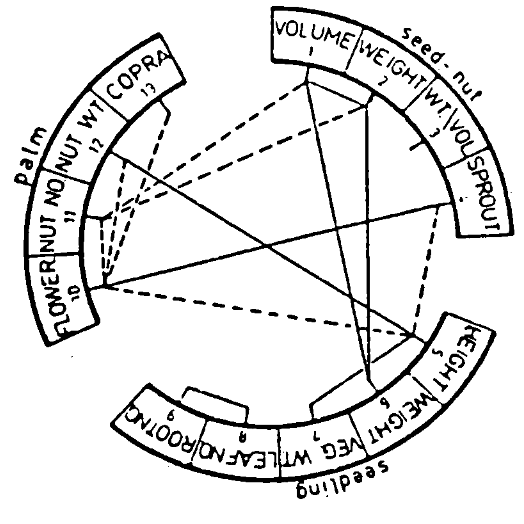

Fig. 1 The significant correlations between parents.

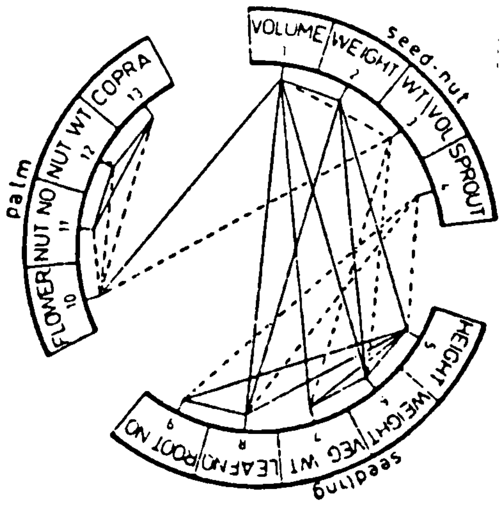

Fig. 2 The significant correlations within parents

(All correlations are significant at least at 5 percent . level. A continuous line joining two characters indicates a positive correlation and a discontinuous line a negative correlation.)

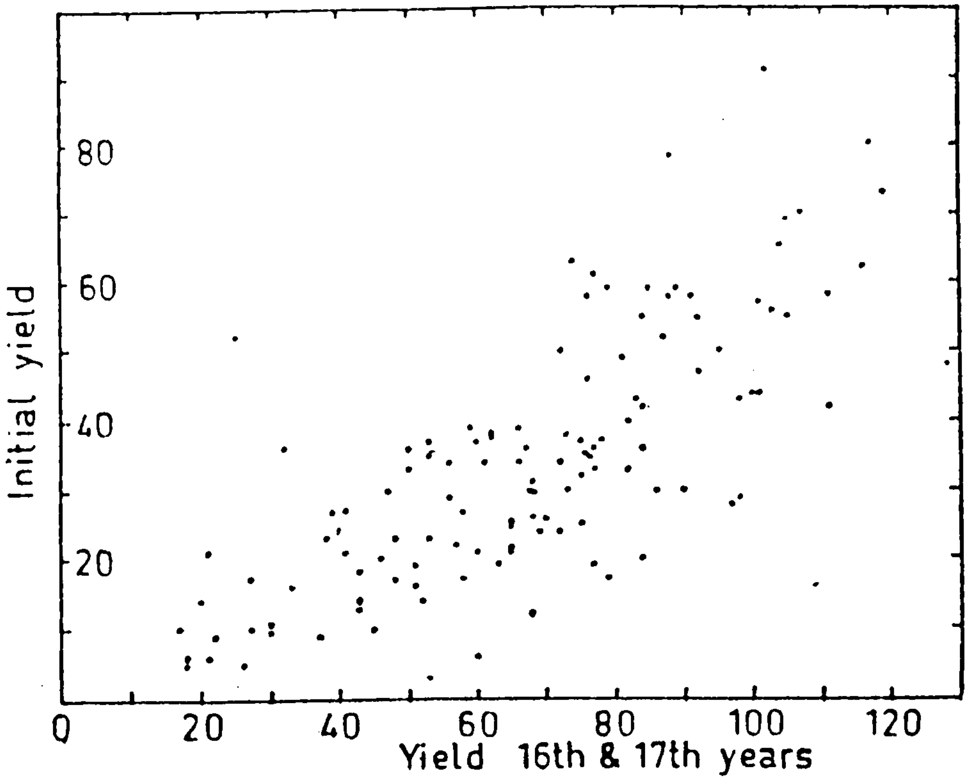

Figure 3. Mean yield of nuts per year in the 2nd and 3rd years of bearing (initial yield) and the 16th and 17th years after planting.

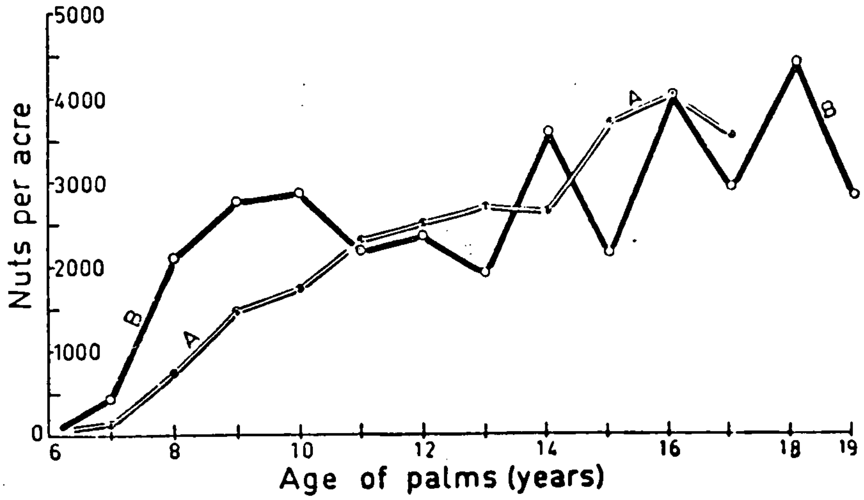

Fig. 4 - The yield curves of two populations of coconut palms.

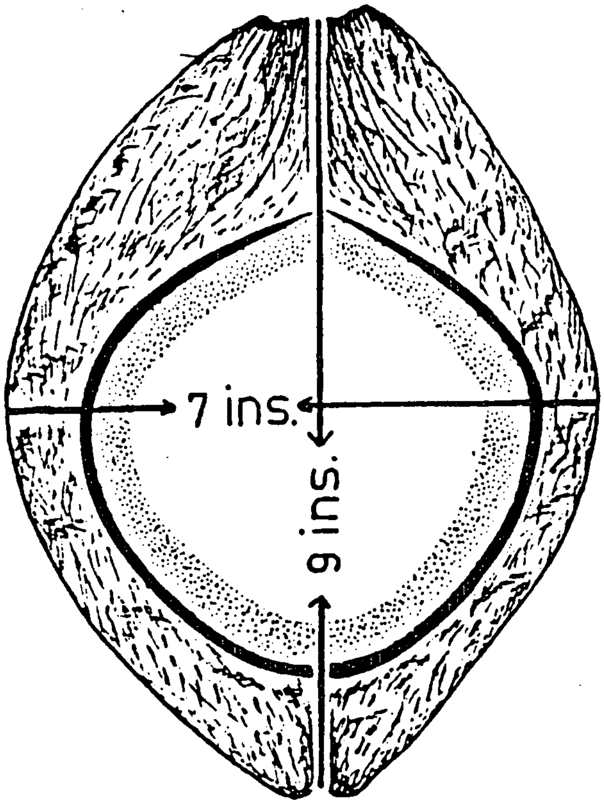

Fig. 5 - An ideal form of seed- coconut, approximately 4000 c.c. in volume.

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Journal of Genetics
Vol. 57, 1960
Jointly with K.I. Sakai

HERITABILITIES OF CERTAIN YIELD CHARACTERS OF THE COCONUT PALM

SUMMARY

Heritability values for the flowering period, yield of nuts, yield of copra and weight per husked-nut of the coconut palm, have been estimated. Genetic correlations between these four characters have been ascertained. The heritability values for yield of copra and weight per husked-nut are high, for yield of nuts intermediate, and for flowering period low. Genetic correlation between yield of nuts and copra is high and negative. 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.

INTRODUCTION

In the genetic improvement of an economic character like yield, it is necessary to understand the contribution of environment and genotype to the phenotype of an individual. Concept of heritability which is a ratio of genetic variance to phenotypic variance is useful in evaluating the genetic value of a desired character and consequently an appropriate program for selection (Lush, 1949).

Selection of high yielding coconut palms (*Cocos nucifera* L.) for seed collection has been a common practice in most coconut growing countries. Different authors have listed a number of criteria for selection of seed bearers, and in most cases these characters have been taken on an empirical basis. *e.g.* Prudhomme, 1906; Jack, 1930. In the absence of progeny trials or similar studies, it would not have been possible to give a fair assessment of selection criteria.

Pieris (1934, 1937) has worked out correlations between 10 characters of the coconut palm including yield, and has specified standards for selection. According to him, size of seed nut is not important, provided large numbers are present, a medium sized nut is the best, palms with extra large nuts to be avoided; weight per husked nut should be high. Number of nuts per palm and their weight provide the best standards of selection.

Object of the present study is to assess heritability of four important characters of the coconut palm, their genetic correlations, and study their relative importance in a selection program. The characters concerned are (i) flowering period, (ii) yield of nuts (iii) yield of copra (*i.e.* total weight of husked-nuts) and (iv) weight per husked- nut.

MATERIAL

Data presented have been taken from a progeny trial planted in 1934 with open pollinated seed nuts collected from nine high yielding mother palms of the tall variety of coconut (*Cocos nucifera).* Mother palms have been selected for high yield of copra on the lines advocated by Pieris

(1937 and seed nuts or seedlings taken from them have not been selected before transplantation. There are altogether 278 progeny in the 9 families, number of seedlings per family has varied between 10 and 64. Design of trial is full randomization with un-equal replications.

Four characters, *viz.* flowering period, nuts per palm, total weight of husked nuts and mean per husked- nut were recorded. Flowering period is the time taken from transplanting a seedling to appearance of the first spathe. Other characters represent harvests gathered during 4 years, 16th to 19th after planting. Yield of copra per nut has been calculated as 32% of total weight of husked nuts (Pieris, 1935).

METHODS AND STATISTICAL ANALYSIS

The tall variety of coconut palms grown on plantation scale in Ceylon is predominantly out breeding. On the assumption that random pollination takes place in a population of coconut palms, mean squares and mean products are partitioned into within and between family components, and the genetic and non genetic variances and covariances are estimated. Analysis of variance and covariance and partitioning into within and between family components are shown in Table 1.

Table 1. The expected components of variances and covariances

Source	Degrees of freedom	Variances		Variances .	
		Mean squares	Expected components	Mean products	Expected components
Total	$\sum_{i=1}^{x} y_i - 1$				
Between families	x - 1	M_1	$\sigma^2_w + k\,\sigma^2_B$	P_1	$\sigma_{wxw} + k\,\sigma_{BxB}$
Within families	$\sum_{i=1}^{x} (y_{i-1})$	M_2	σ^2_w	P_2	σ_{wxw}

In the above table, x stands for the number of families, y_i number of individuals in the i-th family and k is a coefficient related to y. If the number of individuals in family is the same, then $k = y$, but since it varied from family to family in this experiment, k is computed by using Crump's formula (1946) as follows:

$$k = \frac{1}{x-1}\left\{ \Sigma y_i - \frac{1}{\Sigma y_i} \sum_{i=1}^{x} y_i^{\,2} \right\}$$

where x stands for number of families, y_i number of individuals in the ith family and $\Sigma\ y_i$ total number of individuals investigated.

σ^2_w and σ_{wxw} are between individuals within families variance and covariance, and σ^2_B and σ_{BxB} are between families variance and covariance.

σ^2_w or (σ_{wxw}) is expected theoretically to include environmental variance (or covariance between two characters) and three quarters of the genetic variance (or covariance) assuming that dominance deviations are negligible, σ^2_B (or σ_{BxB}) on the contrary, is expected to include only one quarter of genetic variance (or covariance)

$$\sigma^2_w = \sigma^2_E + 3/4\ \sigma^2_G \qquad (1)$$
$$\sigma^2_B = 1/4\ \sigma^2_G$$

$$\sigma_{wxw} = \sigma_{ExE} + 3/4\ \sigma_{GxG} \qquad (2)$$
$$\sigma_{BxB} = 1/4\ \sigma_{GxG}$$

The heritability value has been computed as in the usual manner:

$$h^2 = \frac{\sigma^2_G}{\sigma^2_E + \sigma^2_G} = \frac{4\ \sigma^2_G}{\sigma^2_w + \sigma^2_B}$$

The genetic correlation between i-th and j-th characters has been computed by using the following formula:

$$r\, G_i G_j = \frac{\sigma\, G_i \times G_j}{\sigma G_i \cdot \sigma G_j}$$

RESULTS

Mean yield data of the 9 families is given in Table 2, and performance of progenies of the two best seed parents is indicated in Appendix 1. Results of analyses of variance and covariance of data obtained for the flowering period, yield of nuts, yield of copra and weight per husked-nut; environmental and genetic variances and covariances, heritability values and genetic correlations are presented in Tables 3 to 6.

Table 2. Yield and other data of the progenies of nine selected palms

Family No.	Number of progenies	Flowering period (months)	Mean yield per palm per year		
			No. of nuts	Weight of husked-nuts (lb)	Weight per husked-nut (lb)
1	57	65.0 (6.78)*	73.3 (20.42)	99.3 (28.63)	1.35 (0.06)
4	11	65.1 (9.17)	84.1 (20.04)	126.7 (27.86)	1.53 (0.08)
6	22	67.7 (8.04)	64.3 (12.93)	100.5 (16.20)	1.58 (0.08)
16	19	67.1 (9.18)	49.3 (15.51)	75.8 (23.59)	1.56 0.07)
17	64	69.5 (7.17)	67.4 (20.55)	88.7 (26.65)	1.33 (0.07)
22	12	65.9 (8.97)	69.1 (16.83)	107.0 (27.34)	1.55 (0.05)
23	41	68.2 (9.63)	64.8 (22.35)	79.4 (28.37)	1.22 (0.07)
26	42	68.6 (7.42)	61.9 (18.35)	91.6 (25.97)	1.49 (0.08)
43	10	59.7 (5.31)	82.3 (23.55)	116.4 (22.51)	1.45 (0.07)

* Standard deviation. Age of palms 16 to 19 years

Table 3. Variance of four characters together with estimated values of within and between families components

	Degrees of freedom	Mean squares			
		Flowering period	No. of nuts	Copra	Weight per husked-nut
Between families	8	172.8	1910.3	4790.7	0.475
Within families (σ^2_W)	269	61.7	385.4	695.9	0.048
(σ^2_B)		3.8	52.0	139.5	0.015

Table 4. Expected values of genetic and environmental variance components together with heritability values

		Flowering	No. of nuts	Copra	Weight per husked-nut
	σ^2_G	15.2	208.0	558.0	0.60
	σ^2_E	50.3	229.4	277.4	0.003
Heritability	h^2	0.23	0.48	0.67	0.95

Table 5. Covariance between any two of the four characters: yield of nuts (N), of copra (C), weight per husked-nut (W) and flowering period (F)

	Degrees of freedom	N x C	N x W	N x F	C x W	C x F	W x F
Between families	8	2413.0	- 6.4	- 338.6	19.9	- 590.0	- 1.6
Within families (σ_{WxW})	269	442.6	- 0.76	- 41.7	1.8	- 42.9	0.06
σ_{BxB}	-	67.1	- 0.19	- 10.1	0.62	- 18.6	- 0.06

Table 6. Expected values of genetic and environmental covariance components, genetic and environmental correlations between any two characters out of those listed in Table 5

	N x C	N x W	N x F	C x W	C x F	W x F
σ_{GxG}	268.4	- 0.76	- 40.4	2.5	- 74.1	- 0.24
σ_{ExE}	241.3	- 0.19	- 11.4	- 0.06	12.9	0.24
r_G	0.79	- 0.22	- 0.72	0.43	- 0.81	- 0.25
r_E	0.96	- 0.23	- 0.11	- 0.07	0.12	0.62

DISCUSSION

As the analysis of yield figures presented in this paper is based on four years grouped yield data, it is necessary to examine the agreement of numbers of the same character in the years which are averaged. Normally, repeatability value is used to ascertain reliability or consistency of yield data over the years. But, since yield of palms in this experiment has shown wide seasonal fluctuations, repeatability value would be necessarily low - 0.38 for yield of nuts - and a study of the pattern of variation between palms would give a more appropriate answer.

The rank correlation for yields between ranks for four years mean yields and the rank for each year, would give a fair estimate of reliability of the data. If rank correlation is high, it shows that the yield pattern between different palms has been consistently so over the years, in spite of seasonal fluctuations. In this situation, it is reasonable to expect that any type of statistical analysis involving different groupings of the individual yields will give similar results in any single year or over a group of years. The rank correlation coefficients (Spearman's) for yield of nuts are as follows:

		Rank correlation coefficient
16th year Vs. 4 years average:		+ 0.99
17th year Vs.	"	+ 0.97
18th year Vs.	"	+ 0.99
19th year Vs.	"	+ 0.97

The correlations are of a very high order, and therefore analysis of data of four year groups would not show a significant difference from results obtained from data of a single year.

Two of the characters dealt with in this study have shown generally high heritability values, weight per husked-nut 95% and yield of copra 67%. Yield of nuts have given an intermediate value 48% and flowering period 23%. Since the heritability value measures efficiency of selection, so far as the selection of individuals is conducted under the same conditions as of this experiment, selection of seed parents in coconuts with regard to weight of copra and weight per husked-nut would be highly effective. Selection for number of nuts may also be effective, while selection for early flowering will not be effective.

From a general analysis of data of a selection experiment conducted by the Coconut Research Institute of Ceylon (1953, 1956), it has been shown that there are no significant differences in yield of progenies whether open-pollinated seed is taken from mother palms selected for high yield of copra or heap nuts (*i.e.* nuts selected for medium size and high nut weight from a heap of nuts harvested from a number of palms), indicating that selection of parents has not been effective. These results are contrary to the conclusions drawn from the estimates of heritability. On a critical examination of the planting material used for the selection experiment, it was found that all selected mother palm seed nuts and half the quantity of heap nuts have been taken from one population of palms and remaining heap nuts from another distinct population. There is evidence to indicate that collection of seed nuts for different treatments from two separate populations has masked results of the selection experiment. This is clear from a comparison of yield data of progenies of high yielding mother palms and heap nuts taken from the same population (Liyanage, unpublished).

Table 7. Mean yield per palm per year of progenies of selected high yielding palms and heap nuts

	Age of palms 11 to 14 years		Age of palms 15 to 18 years	
	Nuts	Husked-nuts weight (lb.)	Nuts	Husked-nuts weight (lb.)
Progenies of selected mother palms -	57.6	87.6	75.7	120.4
Progenies of heap nuts	46.0	71.7	64.1	107.6
Percentage increase -	25.2	22.2	18.1	11.9
't' value -	3.24 **	2.42**	2.62 **	1.52

** Significant at $P < 0.01$

Data given in Table 7 are of 80 progenies of selected mother palms and 53 progenies of heap nuts that could be identified in the field. The former group has given considerably higher yields over those of the latter, showing that selection of seed parents is effective at least during the juvenile age of palms.

In a selection programme, genetic correlations between different productive traits of the coconut palm that have been estimated (Table 6) would be of considerable importance. Since yield of nuts and yield of copra are highly correlated positively ($r_{g} = + 0.79$), and flowering period and yield of copra are highly correlated negatively ($r_g = - 0.80$), selection of seed parents for early flowering and number of nuts tends to increase yield of the progeny population with respect to copra production.

These findings suggest that a number of characters could be considered in the selection of seed palms. It is necessary to ascertain which trait would be most useful for this purpose or what progress in the genetical constitution for yield could be attained if selection is made on each of these characters.

Assuming that intensity of selection is constant, say 5% of the most favourable individuals being selected, the genetic progress expected in yield of copra could be computed by using the following formula:

$$\Delta G_B = r_{GAGB} \frac{\sigma_{GB}}{\sigma_{GA}} (i)\ \sigma_A\ h^2_A$$

Where ΔG_B is the expected genetic process in yield, σ_G is the genetic standard deviation, i is a constant for a given intensity measured in a standard unit, and σ_A is the standard deviation of a selected character. Results of computation are given in Table 8.

Table 8. Relative efficiency of four criteria for selection of seed parents

Selected criteria of seed parent	$r G_A G_B$	σG_B	σG_A	i	σA	h^2A	Expected genetic progress in yield copra (lb.)
Yield of copra (lb.)	1.00	23.62	23.62	1.64	28.53	0.67	31.4
Yield of nuts	0.79	23.62	14.12	1.64	20.72	0.48	21.1
Flowering period	0.81	23.62	3.90	1.64	8.06	0.23	14.9
Weight per husked-nut	0.43	23.62	0.24	1.64	0.24	0.95	15.8

The relative importance of the four characters listed in Table 8 has been in the following order of merit:

(i) yield of copra,
(ii) yield of nuts,
(iii) weight per husked-nut,
(iv) flowering period.

Expected genetic progress in yield of copra in progenies would be more, if the seed parent is selected on high yield of copra and nuts rather than on the other two criteria. From the standpoint of practice, efficiency of selection should be considered taking into account other factors, besides yield of copra and nuts.

ACKNOWLEDGEMENTS

We are greatly indebted to (i) Mr. W.V.D. Pieris, former Geneticist, Coconut Research Scheme, for planting the progeny trial, (ii) Mr. V. Abeywardane, Biometrician for statistical analysis of data, and (iii) Messrs. H.L. de Mel & Co. Ltd., Colombo for maintaining the progeny trial.

REFERENCES

Crump, S.L. 1946. The estimation of variance components in analysis of variance. *Biometrics Bulletin. 2:7-21.*

Jack, H.W. 1930. Improvement of coconut crop by selection. *Malayan Agricultural Journal.* 18: 30-39.

Lush, J.L. 1949. Heritabilities of quantitative characters in farm animals. *Proc. 8th Int. Congr. Genet.* (Stockholm). Supplementary volume of *Heriditas.*

Pieris, W.V.D. 1934. Studies on the coconut palm - I. *Tropical Agriculturist*, 82 : 75-97.

__________________. 1935. Studies on the coconut palm - II. On the relationship between weight of husked-nuts and the weight of copra. *Ibid.* 85: 208 -220.

__________________.. 1937. Seed selection. *Coconut Research Institute (Ceylon), leaflet No. 1.*

Prudhomme, E. 1906. *Le Cocotier*, Augustin Challamel, Paris.

Coconut Research Institute. 1939. *Ceylon Sessional Paper* VIII - 1940. Report and accounts of the Coconut Research Scheme for 1939, 6-7.

____________________ 1953. *Ibid.* XXV - 1955, 27-28.

____________________ 1956. *Ibid.* VI - 1958, 33 -34.

Appendix 1. Statement of yields of the best two seed parents 4 and 43.

Progeny No.	Flowering period (mth.)	Mean per year No. of nuts	Wt. of husked-nuts (lb.)	Wt. per husked-nut (lb.)
Progeny of seed parent No. 4				
81	65	65.0	126.5	1.95
85	63	131.4	173.7	1.32
95	56	80.4	126.3	1.57
105	55	100.3	145.4	1.55
180	54	60.5	71.1	1.18
182	73	91.5	146.3	1.60
191	73	91.5	150.2	1.63
208	71	65.0	116.9	1.80
291	74	63.8	112.9	1.35
292	78	76.5	127.6	1.67
111	54	78.5	96.4	1.23
Progenies of seed parent No. 43.				
62	53	114.0	147.9	1.30
64	55	81.5	105.4	1.29
68	59	84.3	119.3	1.42
82	58	71.3	125.7	1.76
90	72	63.5	108.7	1.71
145	61	131.0	150.1	1.15
150	57	82.8	101.3	1.22
176	63	54.3	73.5	1.35
193	62	64.8	109.9	1.70
199	57	75.5	121.1	1.60

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Expt. Agric.
Vol. 3, 1967

IDENTIFICATION OF GENOTYPES OF COCONUT PALMS SUITABLE FOR BREEDING

SUMMARY

Results of progeny testing of 104 unselected coconut palms are presented. Progenies of the best 5% of the parents, selected on their phenotypic values, gave yields 14% above the progeny mean, indicating that mass selection is effective. Breeding values varied between seed parents. A higher frequency of genotypes could be isolated when parents are selected on yield of copra, rather than when they are taken at random. Prepotency of coconut palms is discussed. Leaf production of young palms within a family during the first 40 months of their growth, was correlated with the breeding value of a parent.

INTRODUCTION

The variety of coconut palms (*Cocos nucifera* L. var. *typica*) grown on a plantation scale in Ceylon is predominantly out-breeding and consequently, existing stands are highly heterogeneous. Mass selection that is generally practised for seed production is a fairly efficient method, since the heritability for yield of copra per palm and weight of husked-nut, which are important criteria in selection are high (Liyanage and Sakai, 1960). Limitations for a selection programme for rapid genetic progress per unit of time are: long life cycle of the palm, small number of nuts produced per year and absence of known methods of vegetative multiplication.

The current practise of isolating desirable genotypes is by progeny testing, which takes at least 12 years for a provisional classification, as coconut palms do not bear fruits until 6 to 8 years after planting, and an optimum yield is not obtained until palms are about 15 years old. The only redeeming feature of slow progress of a breeding programme is that, once good genotypes are identified, they can be used for a long period, as coconut palms remain productive for about 60 years.

A field trial was planted in 1948 to study variation in breeding values of the *typica* variety and to isolate palms suitable for breeding purposes. Results of this experiment are presented, together with methods of accelerating identification of desirable genotypes.

MATERIAL

The progeny trial was planted in 1948 with unselected, open pollinated seedlings of 104 palms taken at random from a block of 292 palms. Design of the trial was a cubic lattice (5^3), with progenies of 21 palms duplicated, bringing total number of hypothetical parents tested to 125. The lattice has three replications, with three progenies of each seed parent per plot.

Two characters are discussed in this paper: (a) total number of leaves produced per plant within each family during 40 months after transplanting seedlings, referred to as *leaf production* in the text, and (b) mean weight of husked-nut when progenies were 13 to 16 years old. In both cases adjusted values derived after analysis of lattice data are given.

Parental population consisted of unselected offspring of unselected high yielding palms. The weight of husked-nut of parental population 16 to 19 years old is presented. Parent and progeny populations have been in different districts, with considerable soil and climatic variations. Consequently, no comparisons have been made between parent and offspring with respect to absolute values.

Whenever yield data and phenotypic values are referred to, unless otherwise stated, represent weight of husked-nuts, and yield of copra will be about one-third of that weight. Breeding value of a palm has been taken as twice the deviation of mean of its progenies from the mean of the entire progeny population, in respect of weight of husked-nuts. Since progeny has not reached optimum bearing stage, suggestions given herein are tentative.

RESULTS

Analysis of variance of weight of husked-nuts and leaf production are given in Table 1. The difference between treatments with respect both characters was significant, former at P = 0.01 and latter at P = 0.05.Other statistics pertaining to the design are:

	Weight of husked-nuts	Leaf production
Efficiency of design relative to corresponding randomised block	110 percent	137 percent
Coefficient of variation	20.6 percent	6.2 percent
Average standard error of a difference between two adjusted values	12.5	1.29

DISCUSSION

Mass selection

It is possible to assess the effect of selection of seed parents on the performance of their progeny. As parents were taken at random, their yields have been variable, with a mean weight of 106 lb. (SD ± 25.0) per palm/year, and a coefficient of variation of variation of 23.6%. Performance of progeny of seed parents selected from the two extreme ranges , *i.e.* best 15% and worst 15% of palms in the population, based on weight of husked-nuts is indicated in Table 2.

When the selection is increased on an upward basis, response of progeny increases. For instance, the best 5% of parents have given progenies with a yield of 14.4% higher than population mean, against an increase of only 7.9% for progenies of the best 15% palms. With selection on a downward basis, worst 5% of parents gave progenies whose phenotypic value was much inferior to those of the worst 15%. This indicates that there is response to selection of coconut palms as parents, when they are selected on a basis of high husked-nut weight.

It has been shown previously that selection of seed parents on a basis of high yield of copra and weight per husked-nut, would be highly effective, since their heritability estimates are high: 0.95 and 0.67 respectively (Liyanage and Sakai,1960). Thus, selection of parents on lines advocated above, would assist in upgrading progenies in the first generation.

Breeding value of a palm

Since breeding value of a palm is determined by the average effects of genes, and not by the genotype, progeny testing is an important phase in coconut breeding programmes. Breeding value of

104 palms tested has varied between + 59.6 and - 62.1. These variations are to be expected, as parents are heterogeneous and taken at random. The best 10% of the parents based on breeding values are listed in Table 3.

Although, palm 248 had a low phenotypic value, its breeding value was fairly high, apparently a case where a good genotype placed in a poor environment produced a low yield. Since there were only 9 progenies of each parent, a high phenotypic value of a few progenies within the family could inflate family mean, resulting in a high false breeding value. To eliminate such errors, it is necessary to study records of individuals in each family. For instance breeding values of palms 55, 141, 179 and 248 were similar, difference being statistically significant, yet there was a high variation in the performance of progenies, as reflected in their coefficients of variation (Table 3). In family 55, none of the progenies gave a yield less than the population mean (79.8 lb), whereas in 248 one out of eight, in 141 two out of eight and in 179 three out of nine plants have given yields less than the population mean. High progeny means of families of 55 and 248 were probably due to additive effects of genes of parents rather than to non-additive effects.

Harland (1967) has pointed out that certain palms are able to transmit the high yielding character to their offspring in spite of open pollination, and described them as *prepotent* palms. Apparently palm 55 is such a case: both phenotypic and breeding values are high, its open pollinated progenies are consistently high with a low coefficient of variation (Table 3). Further, agronomic characters of that palm are of a high standard. Only one percent palms tested in the trial could be classified as prepotent, others falling short of the required standards in some characters.

As pointed out earlier, only a limited quantity of seed is available from a single palm, and in the absence of vegetative multiplication, extensive use of a prepotent palm has to be on the use of pollen to pollinate female parents as is done in animal breeding. Fortunately, coconut palms produce a large quantity of pollen, *e.g.* improved techniques have enabled us to collect 5 gm of pollen per inflorescence from palm 55, sufficient to pollinate 325 palms per month.

In other perennial crops like rubber, cocoa and oil palm, isolation of palms that demonstrate specific combining ability is an important technique in the breeding programmes, but in coconuts emphasis has to be on general combining ability.

Methods of selecting palms for progeny testing

Problems associated with breeding coconut palms are: long generation interval, and large land area required for testing and labour involved in recording. Any method that could be devised to reduce these factors would be of utmost importance.

Seed parents could be taken at random or selected on their phenotypic values for progeny testing. If palms are selected on the second method, some palms of potential high breeding value may be left out. How efficient are these two methods?

In the present trial, palms of high breeding value were isolated as follows: 20% when parents were taken at random and 30% with selection on a basis of phenotypic values. Thus, there seems to be no serious disadvantage in selecting parents for progeny testing, as it contributes to isolation of a higher frequency of good genotypes.

A quick method for isolating good genotypes

There was a significant and a positive correlation between leaf production and yield of adult progenies per family (P = 0.01). Although, magnitude of the correlation coefficient was low (r = 0.385 ± 0.091) and is of little value for prediction purposes, there is good evidence of an association of leaf production of progeny and breeding value of parent. If the best 10% palms were selected on phenotypic values, magnitude of the above correlation is larger (r = 0.650 ± 0.269 at P = 0.05).

Distribution of these 10 palms relative to leaf production and yield of progenies was as follows

Leaf production range	No. of parents	Mean wt. nuts per progeny/yr (lb).
> population mean	5 out of 10	98.2 *i.e.* 123.1%
< population mean	5 out of 10	77.5 *i.e.* 97.1%
population mean	-	79.8 *i.e.* 100%

Five out of ten palms have given progenies with a higher mean leaf production than the population mean (32.2), and they have a high breeding value giving 23% increase in crop. Out of the remaining five palms whose progenies have recorded less than 32.2 leaves, one palm has given a high breeding value.

It is possible to isolate tentatively palms of high breeding value by scoring leaf production in progenies in the best 10% palms in a population selected on phenotypic values. The main advantage of this method is that, without waiting for 12 years for collection yield data from progenies, parents could be classified provisionally after 40 months, and selected genotypes could be used for breeding purposes immediately.

ACKNOWLEDGEMENTS

My thanks are due to the following, who have been associated with the field trials: Mr. W.V.D. Pieris, Dr. T.S. Raghavan, Dr. M.F. Chandraratne and V. Abeywardena for statistical analysis of data.

REFERENCES

Harland, S.C. 1957. *Bulletin* 15, Coconut Research Institute.

Liyanage, D.V. and Sakai, K.I. 1960. *Journal of Genetics*. 57.

Table 1. Variance ratios of weight of husked-nuts and leaf production

Source	d.f.	Wt. of nuts V.R.	Leaf produc. V.R.
Replicate	2	-	-
Treatment (ignoring blocks)	124	1.73 **	1.76 *
Error (r.c.b.)	248	-	-
Blocks	72	1.95	3.43
Component (A)	12	1.54	3.76
Component (B)	12	2.70	2.03
Component (C)	48	1.87	3.70
Intra-block	176	-	-

Table 2. Performance of progeny when seed parents are selected on <u>weight of husked-nuts</u>

Proportion selected	Selection differential	Increase/decrease over population mean %
UPWARDS		
The best 5% of palms	55.5	14.4
The best 10% of palms	45.7	10.1
The best 15% of palms	39.6	7.9
DOWNWARDS		
The worst 5% of palms	- 49.5	- 15.7
The worst 10% of palms	- 41.4	- 9.3
The worst 15% of palms	- 37.1	- 4.6

Table 3. The best 10% of seed parents selected on their <u>breeding</u> values

Parent No.	Phenotypic value (lb)	Breeding value	C.V. of progenies (%)
55	174.3	59.6	19.1
411	111.3	31.5	33.3
179	150.5	48.5	31.6
248	76.1	48.2	19.3
183	113.3	42.9	46.4
237	124.7	41.6	17.1
13	89.5	36.7	25.7
62	147.9	36.5	22.0
284	99.5	35.5	21.0
26	125.3	34.8	32.1

Table 4. The best 10% of seed parents selected on their phenotypic values

Seed parent			
No.	Phenotypic value	Breeding value	Leaf production in progeny
55	174.3	59.6	33.5
85	173.7	31.5	33.3
222	158.4	- 9.3	31.5
179	150.5	48.5	32.5
145	150.4	- 15.6	31.4
62	147.9	36.5	31.6
105	145.5	18.0	34.1
37	141.6	- 28.5	31.0
7	138.9	26.4	33.3
162	136.2	- 5.6	29.7

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Ceylon Coconut Quarterly
Vol. 20, 1969

EFFECT OF INBREEDING ON SOME CHARACTERS OF THE COCONUT PALM

SUMMARY

Data of inbred and open-pollinated progenies of coconut palms relative to endosperm weight, embryo weight, leaf production and flowering period are presented. There has been an inbreeding depression in all these characters, but the intensity has varied between families. There are indications that the rate of depression on endosperm and embryo weights is related to the breeding value of seed parent.

INTRODUCTION

Two genetic principles, general combining ability and specific combining ability, have been used in breeding perennial crops. In crops that are propagated vegetatively, specific combining ability has been the main theme in producing high yielding strains, *e.g.* rubber and cocoa. Remarkable advances have been made during the last 20 years or so in production of high yielding clones of rubber by using bi-parental crosses. Use of this method has rather restricted application in coconuts, as only a few seed nuts are produced per palm/year and there are no known methods of vegetative propagation. Even if successful bi-parental crosses are evolved, mass production of seed is not possible. Thus, for the time being, emphasis has to be on general combining ability in a coconut breeding programme.

The high phenotypic value for copra of a seed parent may be due to additive or non-additive effects of genes, and in the latter case genotype is likely to break down and progeny may not be true to type with respect to yield. The problem facing a coconut breeder is how to screen the latter type of palms, during a reasonable period of time and eliminate them as seed parents. A possible approach to the problem is to ascertain correlation between juvenile characters of progenies and breeding value of seed parents. Total number of leaves produced during the first 40 months per progeny within families of the best 10% palms in a block, is correlated to breeding value of the seed parent. Thus, palms of high breeding value for yield could be identified tentatively within 3.5 years against usual 12 years required on a basis of progeny testing for yield (Liyanage, 1967).

A preliminary report on the effect of inbreeding on endosperm weight, embryo weight, leaf production of young palms and flowering period is given here. The relationship between inbreeding depression on the first two characters and breeding value of seed parent has been studied.

MATERIALS AND METHODS

Experiment 1 : Eight high yielding coconut palms (var. *typica*) each giving a mean weight of over 45 lb. copra per year were selected from a population of 104 palms, whose breeding values are known. Two to three inflorescences from each palm were self pollinated and two others were left for open pollination. Every alternate inflorescence was open pollinated, taking care not to allow any inter-spadix pollination within the palm. Nuts were harvested during the 52nd week after pollination, and wet weight of endosperm and embryo was recorded on the 7th day after harvest.

***Experiment** 2* : Twenty four palms of the variety *typica* from another population of coconut palms were taken at random and pollinations were carried out as in experiment 1. Nuts were harvested 12 months after the date of pollination and planted in a nursery two weeks later. Seed nuts sprouted between November 1960 and February 1961 and seedlings transplanted without any selection in May 1961.

As all pollinations were not successful, those families without four progenies, either selfed or open pollinated were discarded. Progenies of 17 parents were transplanted in a randomized lay out in a single block. after leaving out casualties in the field, 257 progenies of 17 parents were available for analysis as indicated below.

Palm No.	No. of progenies selfed	No. of progenies o.p*	Palm No.	No. of progenies selfed	No. of progenies o.p.*
10	7	4	386	9	8
29	7	5	444	9	10
45	11	12	457	8	8
90	6	6	462	8	11
71	6	7	483	10	6
118	4	5	540	7	7
146	7	7	546	9	12
216	9	6	554	8	4
313	10	4			

* open pollinated

The total number of green dissected leaves in each palm was counted at 12, 24, 36 and 48 months age. A young leaf with more than half the leaf blade dissected was considered as a dissected leaf. Date of flowering of each palm, *i.e.* date when first spadix was visible in axil of leaf was recorded. There were five palms from each group, selfed and open pollinated, without flowering when data were analyzed. Flowering period of each of these palms was taken tentatively as 91 months.

Leaf count data were transformed to log values (x + 0.5) and flowering data to *fx* prior to analysis of variance. Phenotypic value given in Table 1 is the mean weight of copra per palm/year (lb). Breeding value has been taken as twice the deviation of progeny mean from the population mean.

DISCUSSION

Generally, there has been an inbreeding depression on all the characters studied: inbred plants carried less leaves with a longer period to flower, than open pollinated plants. But intensity of depression has varied between families, *e.g.* mean number of leaves per plant (Table 5) of family 10 was practically the same for inbred and out bred plants, whereas inbred plants of family 444 have given 30% less leaves than out- bred plants. These differences are of genetical significance.

There is considerable variation in the weight of endosperm and of embryo between and within palms: mean endosperm weight between palms has ranged from 286 to 407 g and embryo weight from 96 to 135 mg. These variations are to be expected due to natural out crossing habit of the variety of palms under consideration. If weight of either of these characters is under genic control, one could expect differential behaviour between genotypes when selfed, depending on the nature of genes involved. If it is largely due to additive effects of genes, then breeding depression may be less marked or even negligible than when it is controlled by dominance and epistasis.

Five of the eight palms taken for experiment 1 (Nos. 55, 179, 85, 62 and 105) are of good breeding value and the remaining three (Nos. 222, 145 and 37) low value (Table 1). Loss in weight of endosperm and of embryo of selfed nuts in the former group of palms has been low in relation to those of open pollinated nuts; in each case selfed weight being less than 5%, except embryo weight of palm 62 which has shown a difference of 9.4%. Two palms of low breeding value have shown a marked decrease in weight of endosperm and embryo on selfing - over 12 % in each case.

Behaviour of palm 145 is quite inconsistent: the two characters have shown no inbreeding depression, although it is of low breeding value. It is likely that high phenotypic values of palms 55, 179, 85 and 105 are mainly due to additive effects of genes rather than to other causes.

Correlation coefficient between gain/loss in endosperm weight and breeding value of palm is high ($r = 0.6935$). Thus, there is an indication that palms of high breeding value could be isolated from phenotypically superior palms (copra production), by selfing and studying the depression on endosperm and embryo weights relative to those of open pollinated nuts. In the present study, 5 palms (55, 179, 85, 105 and 145) would have been considered as desirable genotypes on the above basis; four of them have turned out to be of good breeding value and the other palm (145) of low value as judged from progeny trials. This method takes only 12 months for testing relative breeding values of coconut palms.

Coconut endosperm is composed mostly of triploid tissue (Abraham and Mathew, 1963) and the embryo of diploid. Genic balance may be unlike in the two tissues owing to double contribution of the female parent to endosperm. Yet, percentage loss in weight of endosperm and embryo has been practically the same on selfing, but coefficient of variation of endosperm weight has increased with selfing.

In palm 55, weight of 33 embryos (others being aborted) of open pollinated nuts ranged from 63 to 152 mg. with a mean of 126 mg; similar variations were common in the other palms. An interesting study of immense practical value will be to ascertain useful correlations between the weight of embryo, and vigour and yield of the resulting palm within families using embryo culture techniques. Are the heavier embryos within a family an expression of specific combining ability?

Differences between families relative to intensity of inbreeding depression on leaf production and flowering period may have some relationship as outlined for endosperm and embryo weights. But, these factors cannot be established, as breeding values of palms used in experiment 2 are not known.

ACKNOWLEDGEMENTS

This work was carried out at the Coconut Research Institute of Ceylon. My thanks are due to Dr. W.R.N. Nathanael, Director for permission to publish the data, Mr. V. Abeywardene for statistical analysis and Mr. B. Fernando for doing the pollinations.

REFERENCES

Abraham, A. & Mathew, P.M. *Ann. Bot.* N. S. 27. 1963.

Liyanage, D.V. *Expt. Agric. 3, 1967.*

Table 1. Mean weight of endosperm and embryo of eight high yielding palms (experiment 1)

Seed Parent					Endosperm weight/nut (gm)			Embryo weight (mg)		
No.	Phenotypic value	Breeding value	Pollination system	No. of nuts	Mean	Percent	C.V. (%)	Mean	Percent t	C.V. (%)
55	56	59.5	o.p. *	34	362.8	100	6.3	126	100	15.5
			selfed	20	362.8	100	10.4	122	96.8	13.0
179	48	48.5	o.p.	24	354.1	100	7.8	131	100	16.1
			selfed	19	353.0	99.7	11.7	135	103.1	12.7
85	56	31.5	o.p.	18	319.0	100	14.2	118	100	11.5
			selfed	36	325.3	102	16.9	115	97.5	13.3
62	47	36.5	o.p.	8	407.3	100	8.4	96	100	16.2
			selfed	5	394.0	96.7	12. 1	87	90.6	12.4
105	47	18.0	o.p.	27	325.0	100	9.0	107	100	15.5
			selfed	22	317.9	97.8	3.8	106	99.1	13.2
222	51	- 9. 3	o.p.	14	329.6	100	8.0	119	100	15.8
			selfed	8	287.8	87. 3	13.4	105	88.2	13. 7
145	48	- 15.6	o.p.	21	285.6	100	3.2	116	100	9.8
			selfed	15	285.4	99.9	12.1	115	99.1	8.0
37	45	- 28.5	o.p.	8	398.3	100	11.6	135	100	11.7
			selfed	5	340.0	85.4	2.7	117	86.7	2.7

* o.p. - open pollinated nuts

Table 2. Mean number of green dissected leaves per plant and the mean flowering period (experiment 2)

Age of seedlings		Open pollinated	Self pollinated
12 months	-	7.6	7.1
24 months	-	8.2	7.5
36 months	-	11.1	9.7
48 months	-	14.7	12.6
Flowering period (months)	60.7	65.1	

Table 3. Analysis of variance of leaf production (experiment 2)

	Degrees freedom	Age of palms (mth.)	Mean square	Variance ratio
Between families -	16	12	0.0034	-
		24	0.0115	1.15
		36	0.0243	2.12
		48	0.0272	2.05 *
Open pollinated x selfed -	1	12	0.0406	4.59
		24	0.1057	10.53 ***
		36	0.1775	15.51 **
		48	0.2603	19.67 ***
Females x open pollinated x selfed	16	12	0.0083	-
		24	0.0130	1.29
		36	0.0135	1.18
		48	0.0162	1.22
Error -	223	12	0.0088	-
		24	0.0100	-
		36	0.0114	-
		48	0.0132	-

Table 4. Analysis of variance of flowering period data (experiment 2)

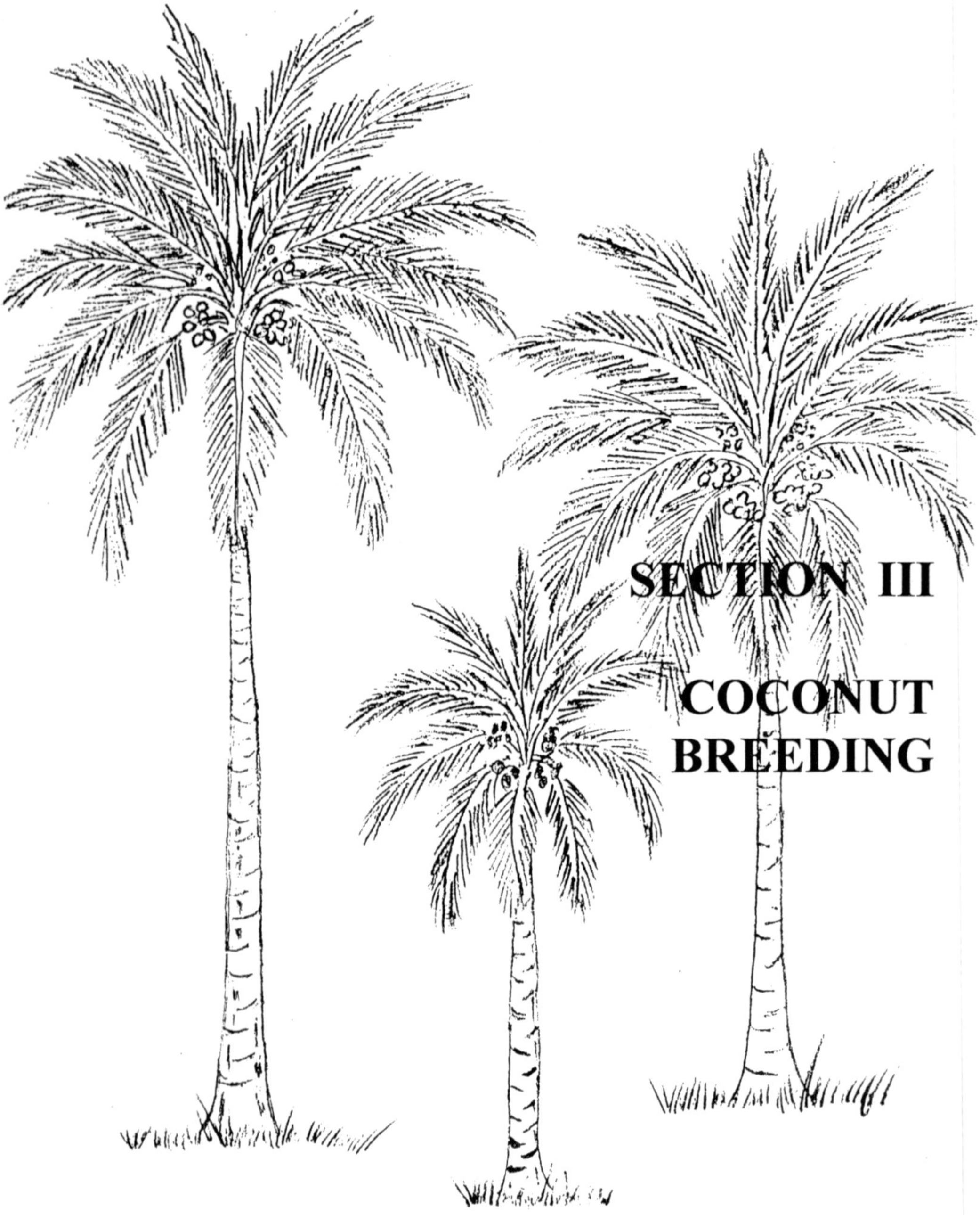
	DF	Mean square	VR
Between families	16	1.9435	2. 61 **
Open pollinated x selfed	1	4.9477	6. 64 *
Females x open pollinated x selfed	16	0. 9878	1. 33
Error	223	0. 7446	-

Significance * P = 0. 05 ** P = 0. 01 *** P = 0. 001

Table 5. Mean number of leaves when palms were 48 months old and mean flowering period on a basis of families (experiment 2)

Palm No.	Open pollinated		Self pollinated		Percent +	
	Leaves	Flowering (months)	Leaves	Flowering (months)	Leaves	Flowering (months)
10	15.3	54.0	15.7	52.3	102.6	96.9
29	16.8	53.4	18.3	51.7	108.9	96.8
45	13.3	65.4	12.8	64.0	96.2	97.9
71	15.7	56.3	14.3	64.7	91.1	114.9
90	15.7	62.3	11.2	71.0	71.3	114.0
118	14.2	59.2	11.5	61.5	81.0	103.9
146	14.1	68.4	13.7	68.4	97.2	100.0
216	16.5	60.7	12.7	73.9	77.0	121.7
313	18.3	62.0	14.6	72.6	79.8	117.1
386	16.4	59.6	16.4	55.1	100	92.4
444	15.6	62.4	10.9	74.8	69.9	119.9
457	14.6	60.0	12.1	55.8	82.9	93.0
462	14.7	62.3	13.1	65.4	89.1	105.0
483	14.8	69.3	13.1	68.9	88.5	99.4
540	14.1	54.7	11.3	75.0	80.1	137.1
546	14.5	61.8	10.7	75.8	73.8	122.7
554	15.3	59.0	11.6	66.9	75.8	113.4

+ Percent calculated by equating the respective open pollinated mean value = 100



SECTION III

COCONUT BREEDING

7

Tropical Agriculturist,
Vol, CV, 1949

PRELIMINARY STUDIES ON FLORAL BIOLOGY OF THE COCONUT PALM

SUMMARY

Tall variety palms are protandrous and generally cross-pollinated. Inter-spadix pollination is not common. In dwarf and King coconut palms male and female phases overlap and self pollination is the general rule. A suitable medium for germination of pollen grains is 10% sugar and 12% gelatin. Viability of pollen can be prolonged by storing in a desiccator with 43.4% sulphuric acid. A saturated atmosphere seems to be injurious to the viability of pollen.

INTRODUCTION

Floral biology of the coconut palm (*Cocos nucifera*) appears to have received scant attention. Considering its importance, literature pertaining to several aspects of the palm must be regarded as meager. The earliest papers dealing with some observation on floral biology of this palm are those of Aldaba (1921) and Furtado (1923). Marechal (1928) has made an investigation of the dwarf palm. Some information regarding the tall variety is given in Patel's (1938) monograph.

It is considered desirable to make some detailed observations on the commonly grown tall variety of coconut in Ceylon, and make a comparative study with reference to other varieties, mainly dwarf and King coconut. A systematic classification of varieties grown in Ceylon has not been done. Hence, a few notes on the varieties mentioned are desirable. The tall variety referred to is the palm grown on a commercial scale in the island. It takes 6 to 7 years to flower and remains productive for over 60 years. The dwarf is of Malaya origin, short in habit, and flowers in 31/2 to 41/2 years. Economical life time does not last more than 30 years. The three forms of dwarf could be distinguished mainly by colour of epicarp of the nut : green, ivory yellow and golden yellow. King coconut palm is rather tall in habit and short lived than tall variety. Epicarp of the nut is golden yellow in colour. Locally this variety is referred to as "Thembili". Observations which follow are confined to the following aspects of floral biology :

a) Duration of two sexual phases with special reference to their synchrony. This was expected to show whether a particular variety could be self pollinated

b) Studies on the viability of pollen with special reference to atmospheric humidity.

FLORAL STRUCTURE

The number and arrangement of floral parts in the different varieties of coconut commonly grown in Ceylon are more or less identical. They conform to the usual trimerous pattern of floral construction which is a common feature of monocotyledons.

Male and female phases

Duration of the female phase is herein computed on basis of stigmas. Receptivity begins when the three stigmas separate and a fluid is secreted through them. At this stage stigmas and upper area of the visible portion of ovary are whitish. First sign of loss of receptivity is change in colour undergone by stigmas from a whitish to a brownish shade; simultaneously exudation of fluid ceases. Duration of male phase is taken as that period from opening of first male flower to that of the last within a spadix. These phases are represented in Table 1.

In all the three varieties examined, male phase lasted from 18 to 22 days. Often male flowers do not remain on an inflorescence for more than one day; generally they open in early hours of the day and are shed same evening. There is no definite sequence of opening of male flowers. Those that are borne on upper half of each spikelet open earlier than those on the lower half. In tall palms a few male flowers always open soon after opening of spathe, but in dwarf and King coconut instances have occurred when the first flower bloomed only after a week of opening spathe.

The female phase lasts from 5 to 7 days in tall palms and from 10 to 16 days in dwarfs and King coconuts. In tall palms, male phase always precedes female phase and often there is an interval of one to two days between them. Thus, there can be no self-pollination between male and female flowers within a spadix in tall palms. In all the observations, only one spathe opened before completion of female phase of the previous inflorescence of the same palm. Here again female flowers were receptive only for one day, after opening of the new spathe. Chances of inter-spadix pollination of tall palms are therefore rather remote and cross-pollination is the general rule.

In dwarfs and king coconut, male and female phases overlap and consequently self-pollination is considerable : female phase begins about a week after the start of male phase and ends near completion of male phase. Marechal working on Malayan dwarfs in Fiji islands has made similar observations.

Receptive period of individual female flowers of dwarf, King coconut and tall palms varies from two to four days. Here again there is no definite order in which they become receptive. Table 2 presents duration of receptivity of individual female flowers of an inflorescence of the tall variety. Spikelets and female flowers are numbered from the base upwards.

Germination of pollen grains

Tests were carried out to determine a suitable medium for germination of pollen grains. Sugar and gelatin were used in different concentrations. Results are tabulated in Table 3. Intine protrudes through rupture of exine within half an hour after pollen grains are left in the culture solution. Maximum germination is effected by end of the first half hour and thereafter pollen tubes continue to elongate. For maximum germination, a medium containing 10% sugar plus 2% gelatin appears to be satisfactory. In higher concentration of sugar, cytoplasm of pollen tubes grain is plasmolised and germination almost nil. Marechal has obtained contrary results and has indicated that 25% saccharose showed 60% germination. In the 10% sugar plus 2% gelatin solution, dwarf and tall palms recorded 58 and 74% pollen germination.

Preservation of pollen

Pollen retains viability under atmospheric conditions for 3 to 4 days. In hybridization work connected with coconut palms, it was found necessary to keep pollen viable up to 10 days. Relative humidity (RH) of the atmosphere is a factor that changes constantly. Wilson has shown that different humidity equilibrium can be produced by using various sulfuric acid solutions in enclosed chambers.

Three desiccators were used with 18.5%, 30.4% and 43.4% sulphuric acid; RH inside them remained at a constant level of 90%, 75% and 50% respectively. Fresh pollen collected from dwarf and tall variety palms were kept in the three desiccators. Germination counts were made every other day after pollen was germinated in 10% sugar plus 2% gelatin solution. Results are given in Table 4.

On the fifth day of storage, pollen kept in the desiccator with 99% RH, showed no germination. Therefore, a saturated atmosphere seems to be injurious to viability of pollen of coconut palms. On the other hand, 40% of pollen grains from tall palms remained viable for 19 days when kept in a desiccator with 50% RH. Dwarf pollen was more short lived and after the 7th day of storage, less than 40% were viable even at 50% RH.

Marechal has obtained similar results and claimed that 50% sulphuric acid maintained a higher germination percentage. In tests on pollen stored in desiccators with calcium chloride, pollen was more short lived than atmospheric conditions.

ACKNOWLEDGEMENTS

The author thanks Dr. T.S. Ragavan, former Botanist, Coconut Research Scheme, for the encouragement and advice given to conduct these investigations.

REFERENCES

Aldaba, V.C. Philippine Agriculturist, Vol 10, 1921

Furtado, C.X Gardens Bulletin, Straits Settlements, Vol 3, 1923

Marechal, H. Agricultural Journal, Department of Agriculture, Fiji, Vol. 1, 1928

Patel, J.S. Monograph on Coconut, Government Press, Madras 1938

Wilson, R.E. Journal of Industrial and Engineering Chemistry, Vol. 13, No 4

Table 1. Duration of male and female phases

Variety	Palm No.	Male phase (days)	Female phase (days)
Tall	195	19	7
	292	21	6
	163	18	5
	204	20	5
Dwarf	488	18	10
	2649	22	14
	2647	22	15

Table 2. Period of receptivity of female flowers of a spadix from a tall variety coconut palm

Spikelet No.	No. of female flower	Receptivity period-days	Spikelet No	No. of female flower	Receptivity period-days
1	1	3	13	1	2
	2	2		2	2
	3	*	14	1	3
	4	*	15	1	3
	5	*	16	1	2
	6	*		2	2
				3	2
2	1	2		4	*
3	1	4	17	1	3
4	1	*			
5	1	*	18	1	2
6	1	3	19	1	2
	2	3	20	1	2
7	1	3		2	*
8	1	3		3	*
9	1	*		4	2
	2	2	21	1	2
10	1	*	22	1	+
11	1	3	23	-	
	2	3	24	1	2
	3	3		2	*
	4	*	25	1	*
	5	3	26	1	2
12	1	3	27	1	3
	2	*	28	1	2

* fallen   + not developing

Table 3. Germination of pollen grains (%)

Time	Dwarf pollen			Tall palm pollen		
	A	B	C	A	B	C
After half hour	0	0	0	30	32	0
" one "	26	58	0	62	74	0
" two "	38	53	0	56	75	0

A- 5% sugar + 2% gelatin B - 10% sugar + 2% gelatin C - 15% sugar + 2% gelatin

Table 4. Germination of pollen grains kept in desiccators with varying concentrations of sulfuric acid

Age pollen (days)	Tall germination (%)			Dwarf germination (%)		
	A	B	C	A	B	C
2	58.5	59.4	54.2	38.6	51.4	59.8
3	15.6	41.7	56.4	9.6	38.9	46.8
5	nil	50.6	43.4	nil	48.7	48.9
7	nil	61.6	59.7	nil	52.1	40.0
8	nil	42.9	71.8	nil	20.6	36.2
10	nil	36.1	56.7	nil	19.2	40.5
12	nil	8.3	67.0	nil	5.6	46.0
14	nil	nil	44.9	nil	nil	20.4
16	nil	nil	44.2	nil	nil	36.0
19	nil	nil	40.6	nil	nil	9.9
21	nil	nil	20.6	nil	nil	nil
24	nil	nil	5.8	nil	nil	nil

A - 90% RH B- 75% RH C - 50% RH

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Ceylon Coconut Quarterly
Vol. V, 1954

CONTROLLED POLLINATION OF COCONUT PALMS

ABSTRACT

Parent palms were selected on a basis of vigour and production. On the 17th day after opening of a spathe in the tall variety, each spikelet was cut about three inches above female flowers and the whole inflorescence was enclosed in a bag. Pollinations were done from the 22nd day for two or three days, early morning or late evening. Bag was removed on 3rd day after the last pollination and also the remaining non-receptive female flowers.

INTRODUCTION

The variety of coconut palms (*Cocos nucifera*) that is commonly grown on a commercial scale in Ceylon is largely cross pollinated. This is brought by the male phase preceding female phase in an inflorescence; further the next one generally opens after female flowers of the older one have passed receptivity. Sometimes, the younger inflorescence opens during receptive stage of female flowers in the older one, thereby making inter-spadix or self-pollination possible.

Coconuts can be propagated only with seed and there are no known methods of vegetative multiplication. In any given stand of palms, there is considerable variation in yield between palms. If quality of seed nuts is to be improved, controlled pollination is necessary so that both parents are from known types. Quality of seed nuts from high yielding mother palms under natural pollination could be erratic as male parent is unknown.

Breeding work started at the Institute in 1949. Since then a number of estate owners have been interested to carry out their own pollination programmes. The main purpose of this article is to describe methods used for their guidance.

Inflorescence

The coconut inflorescence is a massive structure, about 36 inches long and 34 inches across. Towards upper half of the central axis there are a large number of spikelets with male and female flowers (Fig. 1). Female flowers are the spherical bodies situated towards base of each spikelet and above them are a large number of male flowers closely arranged. Generally there are only one to two female flowers per spikelet.

Inflorescences open successively at intervals varying from 22 to 30 days, depending on age of palms and environmental conditions. From 2nd to 19th day after opening of an inflorescence, male flowers open, liberate pollen and fall off. During most of that time, female flowers remain closed and become receptive about on the 22nd day. When they are receptive, ovary has protruded through perianth lobes, upper end is whitish in colour with three furrows running into the tissue. Further, furrows are wet with nectar secreted through nectarines. Receptive stage lasts for two to three days in each female flower.

Selection of parents

Parent palms should be selected as advocated in Coconut Research Institute Leaflet No 1. Selected palms should yield consistently more than 100 nuts/50 lb. copra palm/year. The ideal would be to use 'proved' parents: those that are known to give high yielding progenies through progeny tests. But for immediate work this would not be possible, as progeny testing with coconut takes decades, which could be overcome to a certain extent, in that yield depends on genotype and environment. If good yielding palms are selected under satisfactory environmental conditions, chances are that at least some high yield potential is due to germplasm.

Preparation of parents

Husks are tied to the stems of parent palms at intervals of about two feet, to assist pollinator to climb the palm. As selected palms are heavy bearers, one or two bunches from the lowest whorl may have to be removed to assist pollinator to get to the crown. A record has to be kept of dates of opening of inflorescences in each palm. Date of opening is taken as the day when sheath (spathe) enclosing flowers bursts open.

Bags and bagging

Bags are made of cheap gray cloth with a transparent plastic window (Fig. 2-A). Dimensions are given in Fig. 2. Cloth should be of sufficient texture so that foreign pollen would not pass through. Below the transparent window on one side of the bag is placed a narrow pouch (Fig. 2-B) through which a glass tube can be introduced. For our own experimental work, when different crosses are done on the female flowers of a single inflorescence, miniature bags are used to enclose each of them. For mass pollination work, it is sufficient if the inflorescence is enclosed in a large bag.

Seventeen days after opening of a spathe, each spikelet is cut about three inches above the female flowers and any remaining male flowers removed - generally all of them would have fallen by that time. Bag is now introduced, a layer of cotton wool is spread over stalk of inflorescence and it is tied gently over cotton wool with twine.

Pollen and pollen storage

Collect pollen from 3rd to 8th day after an inflorescence opens. At other times only a little pollen is available as male flowers are premature or old. Spikelets are cut above female flowers preferably in the evenings. They are dipped in test tubes containing water, mounted on a stand and left in an inclined position over black cartridge paper. Spikelets are completely covered with a box made of a wooden frame, 22x19x13 (height) inches with brown paper pasted over all sides, except the bottom. A large quantity of pollen will be fallen on the black paper by about 10.00 am next morning.

Pollen grains are collected with a fine camel hair brush and stored in vials plugged with cotton wool. Collection of pollen should be done inside a closed room to avoid contamination. Apparatus used, including paper, has to be sterilized with 10% formalin before they are used again.

Pollen remains viable only for two days under atmospheric conditions. It is often necessary to keep them for 12 to 15 days for pollination work. For longer duration of viability, store pollen in a desiccator with 43.4% sulphuric acid at room temperature . Then even on the 15th day of storage, viability was around 50%. The same effect was observed when pollen samples were stored in a refrigerator at 3°C.

Pollination

Pollen from selected male is introduced to the female flowers when they are receptive. Receptivity can be recognized by examining female flowers through the transparent window of the bag enclosing inflorescence. Receptivity of each female flower lasts two to three days and begins about the 22nd day after opening of spathe. All female flowers are not receptive together; the time gap between the first and last is generally five to six days.

Apparatus used for pollinating female flowers are: 6x1 inch test tube with a two holed rubber cork to fit it; glass tubing with a diameter of 5 mm and 18 ins long; another glass tube about 7 mm diameter bent at right angle with rubber tubing 12 ins long attached to it. They are assembled as shown in Fig. 3.

The vial containing pollen sample is placed inside the test tube and cork is replaced after adjusting lower end of glass tubing to touch pollen grains. Plug mouth of vial with cotton wool. Above apparatus should be assembled inside the pollen collection room and taken to the crown of palm for pollination. Introduce long tube to the bag through pouch, bring narrow end close to receptive area of female flower and blow gently through rubber tube. Pollen grains are carried through glass tube and spread over the wet stigmatic surface. After pollinating each female flower in this manner, withdraw tube and seal pouch.

Pollinate during early hours of morning or late evening on two or three occasions depending on duration of receptivity. Remove bag on the third day after last pollination and attach a label. Nuts will be ready for harvesting 11 to 12 months later.

Fig. 1 Coconut inflorescence of a *typica palm.*
Note female flowers are receptive and insects are engaged in pollination.

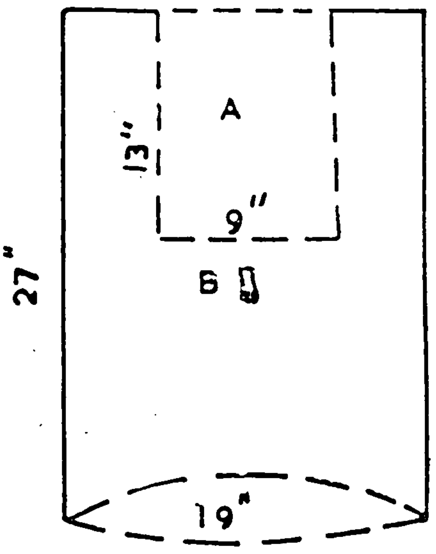

Fig. 2 Cloth bag used for pollination work

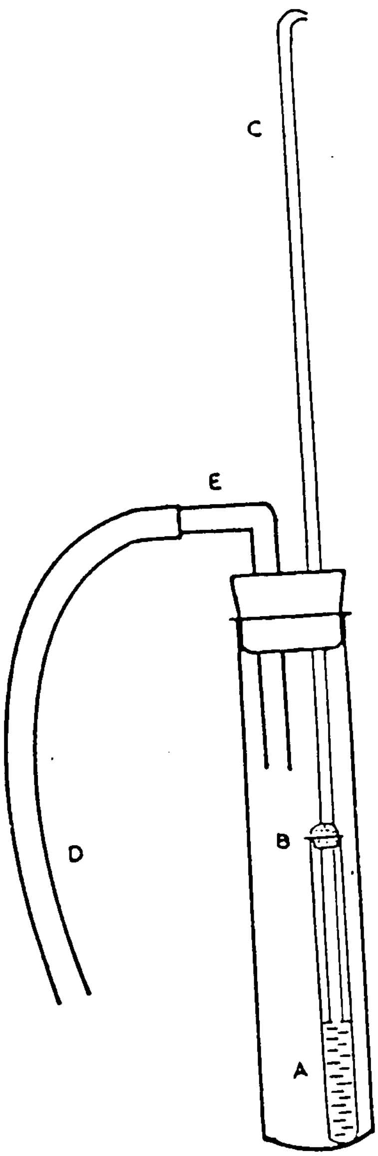

Fig. 3 Apparatus used for pollination

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Coconut Research Institute, Ceylon
Bulletin No. 5. April 1956

INTRA-SPECIFIC HYBRIDS IN COCONUTS
PRELIMINARY REPORT ON CROSSES BETWEEN *TYPICA* AND *NANA* VARIETIES

SUMMARY

This is the first of a series of interim statements on breeding in progress at the Institute. Performance of progenies between *typica* and *nana* forms of coconut during the first five years of growth is described. They have shown hybrid vigour with respect to leaf production and stem formation. They are early flowering and do not show periodicity in flower production as found in *nana*. Cross fertilisation mechanism of *typica* is dominant in the progeny and also other characters like large nuts and good quality copra.

INTRODUCTION

Considering that coconut palms (*Cocos nucifera)* have been cultivated for over a century, the number of improved strains is relatively small. This has been due to a lack of systematic and sustained breeding work, largely because of long life cycle of the palm, difficulties involved in pollination and absence of any known methods of vegetative propagation. Hitherto, method of breeding has been limited to mass selection: collection of illegitimate seed from selected palms. Current practice is collection of seed nuts from palms that conform to certain desirable agronomic characters and selection of seed from them.

In an out-breeding species like the coconut palm and with a mixed stand composed of both desirable and undesirable palms, collection of open-pollinated seed is not an efficient method, unless the pollen parent is controlled. Evidence collected so far, indicates that there are no significant differences in yield of progenies, whether open-pollinated seed nuts are taken from individual high yielding palms or high yielding blocks. There is a significant response to selection of seedlings on a basis of early sprouting and vigour (Liyanage, 1953). Besides, there is scope for evolving improved strains by hybridisation of selected varieties that exhibit useful characters.

Narayana and John (1949) have listed five varieties of coconut as follows : tall type commonly grown on a plantation scale as variety *typica* and early bearing dwarf as *nana.* Variety *javanica* is said to be a true breeding mutant from Java. Two other types have been given varietal status purely because of sex suppression: *androgena,* male coconut palm and *spicata,* female type. There are a number of forms within each variety. These are essentially agricultural varieties and forms.

Copeland (1941) has named 14 types of coconut found in the Philippine islands, two important types being San Ramon and Laguna. Both are tall in habit, former with large nuts -3,270 nuts per ton copra - and latter with smaller nuts - 6,000 to a ton. Various varieties and forms have a number of characters useful for breeding.

Two types of intra-specific hybrids have been described in literature. In Fiji islands, Malayan dwarf has been crossed with Niu Leka. Both parental types are early flowering and short in habit. Niu Leka is sometimes referred to as Fijian dwarf which as a group is said to be distinct from Malayan dwarf (Marechal, 1928). In the hybrid, Niu Leka characters dominate and there is considerable variation between progenies. Some progenies are high yielding and have been " much sought after during the past years" (Surridge, 1932; B.E.V.P., 1953).

A cross between the Indian tall and dwarf has been described by John and Venkatanarayana (1943). First generation palms exhibit hybrid vigour and combine the desirable early flowering nature of the dwarf parent with the economic nut character of tall parent.

A programme of hybridisation work was started in 1949 at the Coconut Research Institute, Ceylon. Initially *typica* and *nana* varieties were chosen as parent types. Main purpose in crossing these two varieties was to study first generation progenies in relation to, (a) expression of high hybrid vigour, (b) expression of the two useful characters of early flowering and short habit of dwarf palms and general behaviour of hybrid palms with a view to economic exploitation.

There are 30 first generation palms derived from crosses involving nine *typica* and six *nana* palms. Seed nuts were first planted in a nursery and eight-month old seedlings were selected on vigour and transplanted in the field in November, 1950 with a spacing of 28 x 28 feet.

DESCRIPTION OF PARENT PALMS

Typica variety

This variety of coconut palms is grown on a plantation scale in Ceylon for copra production. Palms thrive over a wide range of soil and climatic conditions and are hardy being resistant to pests and diseases to a high degree. They remain economically productive for about 60 years under favourable conditions and attain a height of 40 to 60 feet.

Typica palms flower initially in six to eight years after planting. Thereafter, inflorescences are produced successively varying between 25 to 30 days. Generally about 14 inflorescences are produced in a year. Flowers are unisexual and monoecious, cross fertilised by a timing mechanism - male phase precedes female on the same inflorescence. Receptivity of a single female flower lasts about two days and that of the whole inflorescence not more than four to five days (Liyanage, 1949). Nuts are generally round and large, endosperm thick, giving about 8 oz copra per nut. Copra is of good quality, hard and crisp - with about 68 percent oil (dry basis).

Altogether 9 *typica* palms about 50 years old have been used in the crosses. They have been selected on a basis of desirable vegetative characters, high yield and good size and weight of nuts as specified by Peiris (1936).

Nana variety

Commonly known as the Dwarf variety and thriving mostly on fertile soils with a good distribution of rainfall. Palms do not tolerate marginal or semi - marginal conditions and are susceptible to drought, pests and diseases. Stems are narrow, short and delicate attaining a height of about 20 feet. The palms do not remain productive for more than 30 years.

Palms flower initially in about 3 to 31/2 years and have periodicity in bearing - yield of nuts low in alternate years. Flower structure is similar to *typica* type, but male and female phases on the same inflorescence overlap resulting in self pollination. Nuts are small, endosperm thin with about 3 oz copra per nut. Copra is leathery, soft and generally classified as a low grade. Oil content 68% (dry basis).

TECHNIQUE OF POLLINATION

Typica inflorescences were emasculated and bagged on the 17th day after opening of the spathe. Female flowers were pollinated on two days, generally between 22nd and 24th days. *Nana* inflorescences were emasculated and bagged on the 5th day after opening of the spathe. Pollination was done on three alternate days depending on receptivity of female flowers, with an insuffalator introduced into the bag through a narrow pouch without removing the bag. Bag was removed on the 4th day after last date of receptivity. Nuts were harvested 12 months later.

The best period for collection of pollen was from 3rd to 18th day after opening of an inflorescence. Spikelets were cut above female flowers, preferably in the evenings and were dipped in test tubes containing water, mounted on a test tube stand and left in an inclined position over black cartridge paper. Thereafter, spikelets were completely covered with a box to prevent contamination with wind-borne pollen.

Pollen grains were collected in vials 10 to 12 hours later, plugged with cotton wool and stored in a desiccator with 43.4 percent sulphuric acid at room temperature (30 °C approx). It was found that about 50 percent of the pollen grains remained viable on the 15th day with this method of storage (Liyanage, 1954).

RESULTS

F_1 progenies of *typica* (female) x *nana* (male)

Vegetative characters

Measurements of vegetative characters recorded in November 1954, *i.e.* at the end of 4th year are given in Table 1. Those of the respective parents at that age are not known, instead, for comparative purposes, those parental types of identical age grown under the same environmental conditions are presented.

Leaf production was higher in the F_1 progenies and differences with either of the parental types were significant at 5% level. The high rate of leaf production may be due to hybrid vigour.

Stems of *typica* palms are broad, being nearly twice the girth of *nana* palms, and those of the F_1 progenies are like the former parent. Differences in girth of stem between F_1 and *nana* are highly significant (P= 0.01), but that between former and *typica* are not significant. Thus, in early stages of growth, F_1 palms combine the higher rate of leaf production character of the *nana* variety and broad stem formation of *typica*.

Breeding system

As stated previously, *typica* palms are largely cross fertilised with a timing mechanism. Male phase precedes female phase on the same inflorescence, and when the next inflorescence opens receptivity of female flowers of the previous inflorescence is over. An exception to this rule is that certain young and vigorously growing palms throw out inflorescences more frequently during some seasons making inter-spadix pollination possible. In *nana* variety, as male and female phases overlap in the same inflorescence, self pollination generally takes place.

In F_1 progenies of *typica x nana,* the out-breeding system of the former parent is completely dominant. However, due to extra vigour of these progenies in leaf production, inflorescences are produced at shorter intervals - one every 23 days - so that selfing is possible through inter-spadix pollination. Duration of various floral phases is illustrated in Fig. 1 - data have been compiled from 60 inflorescences taken from five palms within each category.

Flowering age

Parental types differ widely in this aspect : *typica* is late flowering and *nana* early flowering. Frequency distribution of these two varieties and their hybrids is given in Table 2. Flowering age has been calculated as the period from date of sprouting of seed nut to emergence of the first inflorescence. Since most of the *typica* palms grown with hybrids are not in flower yet, data relating to these palms have been taken from an adjacent block with the same soil conditions, but planted earlier.

The *nana* variety is early flowering - 38.0 months from date of sprouting seed nuts, *typica* late flowering - 74.3 months, and their F_1 progenies early flowering - 48.6 months. Within the first four years, 88 percent of *nana* and 61 percent of the hybrids were in flower , against none of *typica.* One serious disadvantage of *nana* palms under Ceylon conditions is periodicity in flower production, after producing 10 to 12 inflorescences, palms generally rest for about six months. Hybrids do not show any periodicity in flower production.

Yield of nuts

Nuts were ripe and ready for harvesting eleven months (approx.) after fertilisation of female flowers. As most of the palms flowered in latter half of 1954, not more than four to six bunches were harvested the following year. Consequently, it is premature to consider yield of nuts and copra at this stage. However some useful data have been collected regarding size and weight of nuts and quality of copra of the first generation palms of *typica x nana* which are presented below.

Mean weight per husked-nut	..	1.62 lb.
No. of nuts required per ton of copra	..	4,320
Percentage of No. 2 and 3 copra	..	8.3 %
Oil content, dry basis (%)	..	67.1 %

Above data have been collected from 448 nuts harvested in 1955. In *typica* palms grown under estate conditions, husked-nut weight was 1.5 lb (approx.) with an out-turn of 4,600 nuts per ton of copra.

Nuts of *nana* palms being much smaller require 8,000 to 11,500 per ton of copra depending on the environment. They produce about 25% low grade copra due to the presence of many leathery pieces; in *typica* it is not more than 7.5%. Thus, initial harvests gathered from hybrid palms compare favourably with *typica,* with regard to size and weight of nuts, quality and quantity of copra. In fact, nuts of the hybrid palms show an increase in size and weight over *typica;* it is too early yet to offer any conclusions.

***F_1* progenies of *nana* (female) x *typica* (male)**

Although, a number of reciprocal crosses were made, *i.e.* with *nana* as the female parent, only seven progenies are now available, as a severe drought was experienced at the station where the crosses were made, resulting in pre-mature nut drop. Further, some progenies turned out to be purely of the female parent type; their vegetative characters and breeding system being similar to dwarf palms. Probably, there has been some pollen contamination at the time of pollination. These palms have been rejected from the present analysis.

The remaining seven palms are similar to hybrids of *typica x nana* in vigour, stem and leaf formation, breeding system, size and weight of nut. Flowering period was eight months more, with an average of 56.0 months from date of sprouting of seed nut, against 48 months for the reciprocal cross.

DISCUSSION

Main economic products of the coconut palm are oil, desiccated coconut and fibre. According to world trade, oil is the primary consideration. Therefore, any breeding programme should aim at getting the maximum quantity of oil from a unit area, without altering the output of other subsidiary products. Since oil is extracted from copra, quantity of oil per unit area depends on two factors, *viz* oil content and yield of copra. Both these factors vary considerably between varieties of palms; the second factor varies even within forms of a variety. Therefore, yield of oil could be increased by breeding palms with nuts having a higher oil content or by increasing copra yield per unit area. Latter aspect has been the main theme in the present study, as both parent types have an oil content of 68% (approx.).

It is premature yet to draw conclusions based on material available now, on possibilities of economic exploitation of hybrid palms (*typica x nana*) as they are still young and eventual yield potential is not known. However, their performance in vegetative growth during the first five years has been satisfactory and compares favourably with the *typica* form with added advantage of extra vigour and early flowering.

There was an expression of hybrid vigour in vegetative growth during the fourth year (Table 1). Rate of leaf production was significantly higher than in either of the parent types, which is an important economic factor, if it is maintained in subsequent growth, for in each axil of a leaf there is an inflorescence resulting in more nuts.

Progenies are early flowering like *nana* palms (Table 2). Within the first four years after planting, 74% of them were in flower against none from *typica*. Variations in flowering age between families are indicated in Table 3. Some of these variations, other than those due to environment, maybe due to the fact that flowering age of palms used in the original crosses was not known and may have been variable.

Hybrids do not show two of the marked defects of dwarf palms, *viz.* susceptibility to pests and diseases and periodicity in flower production. Tammes (1955) has recorded that "In the island of Halmaheira (Indonesia), an estate of dwarfs lost nearly all its pure dwarf types after the first year of production, but the hybrids of which there were a great many proved to be as vigorous as the ordinary coconut".

Judging by the nuts collected from progenies during their first year of bearing, yield potential seems promising. Confirmatory evidence is available from work done in India. According to John and

Venkatanarayana (1943), "Hybrid progenies (Tall x Dwarf) gave definitely higher initial setting percentage and produced more nuts. These were like nuts of the tall variety in size, thickness of kernel, quality and out-turn of copra".

Natural hybrids

Natural hybrids of *nana x typica* occur in nature. A number of them exist in a ten acre dwarf palm plantation opened in 1939. They can be easily recognised in the field from the dwarf due to their extra vigour in growth and the breeding system. Further, they are taller than dwarf palms and inter-node length is intermediate compared to parents. Mean yield during 12^{th} to 15^{th} year after transplantation was 68 nuts per palm/year. Unlike progenies of controlled crosses, there is considerable variation between palms with regard to yield.

No doubt, that variations between these natural hybrids are related to parental material. These may be reduced in controlled crosses by judicious selection of parents; yet some variation is likely to occur as one of the parents is heterogeneous. Performance of these fairly mature hybrids indicates the possibilities for economic exploitation.

SEED PRODUCTION

One of the main difficulties associated with coconut breeding is the absence of any methods of vegetative propagation. In the multiplication of *typica x nana* hybrids, seed has to be derived by hand pollination which is rather a laborious and expensive process. Further, it may not be possible to meet the demand, if large quantities are required.

A feasible approach to the problem is to have mixed plantations of *typica* and *nana* forms, with an isolation barrier round the entire block to keep out pollen from coconut palms in the neighbourhood. If *typica* (female) x *nana* (male) hybrids are required, inflorescences of the female parent should be emasculated, and vice versa if the reciprocal seed is required. One advantage of having dwarf as female parent is that hybrid seedlings could be recognised in the nursery.

It may be possible to use male sterile *typica* palms in the mixed plantation, so that emasculation could be eliminated, provided progenies are satisfactory. There are two types of such palms : inflorescence is without spikelets and female flowers carried on its central axis, in the other type spikelets are very short with female flowers on them.

ACKNOWLEDGEMENTS

My thanks are due to Mr. F.C. Cooke, Director, Coconut Research Institute for encouragement given in various stages of this work; Mr. W.R.N. Nathanael, Chemist, for analysis of oil content of copra; Mr. R.W. Senaratne, Senior Field Assistant for yield recording.

REFERENCES

Copeland, E.B. 1941. The coconut. Mac Millan & Co., London.

B.E.V.P. 1953. A new variety of coconut palm. *Agricultural Journal,* Fiji, 24.

John, C.M and Narayana, G.V. 1943. Improvement of coconut palm by cross breeding. Madras Agric Journal. 17.

Liyanage, D.V. 1949. Preliminary studies on the floral biology of the coconut palm. *Tropical Agriculturist* (Ceylon), 55.

---------------- 1953. Annual Report of the Coconut Research Institute (Ceylon) for 1953.

---------------- 1954. Controlled pollination of coconut palms. *Ceylon Coconut Quarterly,* 5.

Marechal, H. 1928. Observations and preliminary experiments on the coconut palm with a view to developing improved seed nuts for Fiji. *Agricultural Journal,* Fiji, 1.

Narayana, G.V. and John, C.M. 1949. Varieties and forms of the coconut. *Madras Agricultural Journal,* 36.

Pieris, W.V.D. 1936. Seed selection. Coconut Research Institute (Ceylon), Leaflet No. 2.

Surridge, H.R. 1932. Malayan dwarf cross by Niu Leka *Annual Bulletin of Divisional Reports of the Department of Agriculture*, Fiji.

Tammes, P.L.M. 1955. Review of coconut selection in Indonesia. *Euphytica, 4.*

Table 1. Mean leaf number per palm and girth of stem

	Typica	*nana*	*Typica x nana*
Leaves produced during 4th year	11.7 ± 2.21	13.4 ± 1.49	15.8 ± 0.83
Girth of stem (ft.)	4.8 ± 0.50	2.8 ± 0.35	5.4 ± 0.25

Table 2. Frequency distribution of flowering age of palms

Flowering age (months)	Frequency distribution		
	Nana	Typica	Typica x Nana
31 - 36	10	-	-
37 - 42	4	-	1
43 - 48	1	-	13
49 - 54	1	1	4
55 - 60	2	-	3
61 - 66	-	3	1
67 - 72	-	3	-
73 - 78	-	1	-
79 - 84	-	5	-
85 - 90	-	3	-
Total	17	16	22
Average (mth)	38.0	74.3	48.6

Table 3. Initial flowering period from sprouting of seed nut

Cross Typica x Nana	F1 palms (No)	Flowering period (mth)	Range (mth)
139 x 2646	4	47.0	45.4 to 57.2
273 x 2646	1	44.9	-
218 x 1713	5	45.6	42.6 to 47.5
390 x 1713	5	50.3	43.8 to 50.2
360 x 1712	5	47.7	45.6 to 50.8

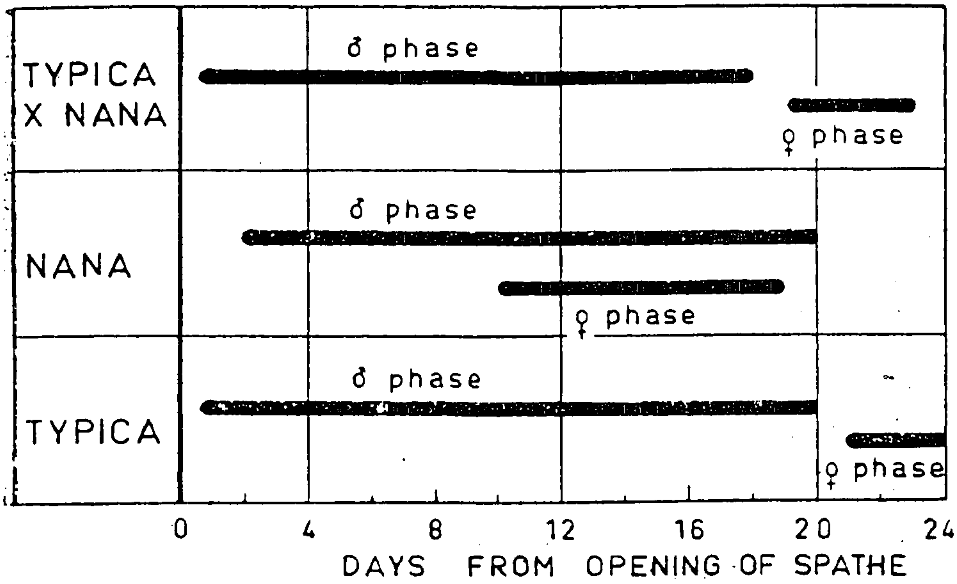

Fig. 1 Duration of male and female phases in *typica, nana* and their F_1 palms

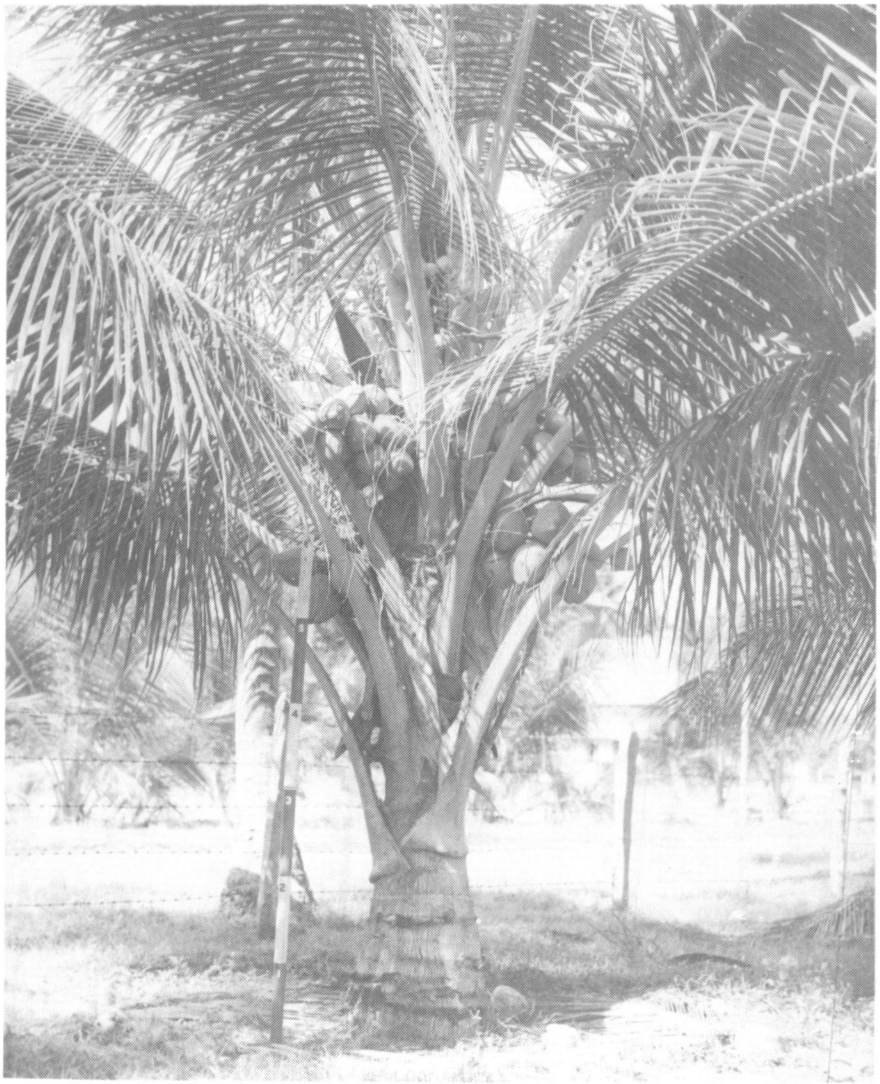

Fig. 2 *Typica x nana* palm, 5 yrs 4 mths old (Photo taken in Sept. 1965)

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Oleagineux
Vol. 27, 1972

PRODUCTION OF IMPROVED COCONUT SEED BY HYBRIDIZATION

INTRODUCTION

The tall type of coconut palm (variety *typica*) grown for production of copra is predominantly cross pollinated, and consequently existing stands are highly heterogeneous. Hitherto, mass selection *i.e.*. collection of seed from high yielding palms, has been practised to raise planting material. Since heritability values for weight of copra and weight per husked nut are fairly high (Lakshmana Char, 1959; Liyanage and Sakai, 1960), selection of seed parents on these characters will bring about some genetic progress in the progenies.

Response of progeny increases when the selection differential is increased on an upward basis. Yield (copra) of progenies of the best 5 p. 100 palms in a population is 14 p. 100 more than population mean, whereas those of the best 15 p. 100 gave an increase of only 8 p. 100 - parents being selected on a basis of yield of copra. With selection on a downward basis, yield of progenies of the worst 5 p. 100 palms in a population is inferior to that of the worst 15 p. 100 (Liyanage, 1967). Thus, although there is a response to selection in open pollinated material, increase in yield in progeny is not sufficiently high.

In order to obtain progenies with higher yields, one has to resort to controlled pollination, which is an easy technique adequately described in literature. Certain difficulties limit the full exploitation of this technique. Generally, a coconut palm produces only a small quantity of nuts per year (80 to 125), and when the inflorescences are hand pollinated still fewer nuts are obtained. Further, as there are no known methods of vegetative propagation of coconut palms, production of planting material in large quantities is a difficult task.

Two genetical principles could be used in the production of improved planting material with controlled pollination: (a) prepotency or general combining ability, and (b) hybrid vigour or specific combining ability. remarkable advances have been made in the recent past, in production of high yielding clones by using the latter technique, in plants that could be multiplied vegetatively.

PREPOTENCY

Palms that are able to transmit the high yielding character to their progenies, in spite of having being indiscriminately pollinated by miscellaneous male parents are described as *prepotent* palms. Harland (1957) has pointed out that just as the progeny of such a single female parent may be superior, whatever the nature of male parent, the reverse situation holds good, *i.e.* pollen of male transmitters could be used on high yielding female parents.

The first step is to identify a sufficient number of prepotent palms. Progeny testing is the best known method: open-pollinated progenies of known female parents are grown, and subsequently their yield of copra is calculated on a family basis, making it possible to pick out the superior female parents. *Typica* palms take 6 to 8 years to bear fruits and an optimum yield is not obtained until they are 12 to 15 years old. Thus, identification of desirable palms will take at least 12 years.

Seed parents could be taken at random from a block of palms for progeny testing, or selected on their high phenotypic value (copra). There appears to be no serious disadvantage in selecting parents for progeny testing, and it would contribute to the isolation of a larger number of transmitters within a limited area available for testing. The best 10 p. 100 of palms could be selected on the basis of yield of copra and desirable agronomic characters.

Quick methods of identifying superior palms for breeding have been devised. There is a significant and a positive correlation between the total number of leaves produced per plant within a family during 40 months after transplanting seedlings, and mean yield of progenies per family when they are 13 to 16 years old ($r = 0.385 + 0.091$, $P = 0.001$). Although, the magnitude of this correlation coefficient is low and is of little value for prediction purposes, there is good evidence of an association between leaf production in the young progeny and breeding value of parent. Magnitude of the above correlation coefficient was much larger when the best 10 p. 100 palms were selected for progeny testing. Desirable genotypes for breeding could be identified provisionally after 40 months by using this technique (see Paper No. 5).

Open pollinated progenies are grown as for progeny testing, and the number of leaves produced in each palm is scored at six monthly intervals until they are 40 months old. The families with a high number of leaves per plant will indicate the prepotent parents.

Another method of identifying good genotypes is by studying inbreeding depression on endosperm and of embryo weight of nuts. If the weight of either of these characters is under genic control, one would expect differential behaviour between genotypes when selfed, depending on the nature of genes involved. If it is largely due to the additive effects of genes, then inbreeding depression may be less marked or even negligible than when it is controlled by dominance and epistasis.

In an experiment carried out in Ceylon, eight high yielding coconut palms (variety *typica*) each giving a mean yield of 20 kg copra per year were selected from a population of 104 palms, whose breeding values are known. Successive inflorescences of each of the selected palms were self pollinated and open pollinated, care being taken not to allow inter-spadix pollination within each palm in the latter case. Nuts were harvested 12 months after the date of receptivity of female flowers, and wet weight of endosperm and embryo of each nut was recorded. Results of this experiment are recorded in Paper No. 6.

Mean weight of the wet endosperm per open-pollinated nut varied from 286 to 407 g between palms and that of the embryo from 107 to 135 mg. Five of the eight palms (No. 55,179, 62, 85 and 105) are of good breeding value and the remaining three palms (No. 22, 145 and 37) are of low value. Loss in weight of endosperm and embryo of self-pollinated nuts of the former group of palms has been low relative to those of open-pollinated nuts of the same palm. Two palms of low breeding value have shown a marked decrease in weight of these two characters on selfing, whilst behaviour of the third palm (No. 145) is quite inconsistent with these results.

Correlation between gain/loss in endosperm weight due to selfing and breeding value of the palm is high ($r = 0.6935$). Thus there is a possibility that palms of high breeding value could be isolated from phenotypically superior palms by selfing them and studying the depression on endosperm and embryo weight per nut relative to those of open-pollinated nuts from the same palm. This method takes only 12 months to test the relative breeding value of a palm, against 12 years required by the progeny testing technique.

In the above example, if 5 p. 100 is allowed as maximum loss in weight of wet endosperm and embryo per nut due to selfing, then palms 55, 179, 85, 105 and 145 would have been taken as of good breeding value. All of them, except 145 have been proved to be so. In normal practice palm 145 would not be taken for testing as nuts are of a small size, each giving only 286 g of wet endosperm. Desirable palms identified by using the above technique could be crossed, and most of the resulting progeny could be expected to be high yielding due to the cumulative effects of additive genes.

HYBRID VIGOUR

It is known that when plants are crossed in pairs, certain combinations produce progeny exhibiting hybrid vigour. Inter- and intra-varietal crosses of coconuts have given progenies superior to either of the parents: Solomon Island Tall x Malayan Tall (Duff, 1967), Tall x Dwarf (Satyabalan, 1956; Liyanage, 1956). The latter hybrid gives more copra per palm per year during the juvenile period and also bearing period is shorter than that of the Tall parent. Further, optimum yield is attained much earlier than that of the tall type. Longevity of the palm is not known, but natural hybrids (Dwarf x Tall) 30 years old growing in Ceylon are productive without showing any signs of senility. Following data extracted from the Annual Reports of the Coconut Research Institute for 1962 and 1969 indicate the performance of hybrids. *Typica* refers to the common tall type and *pumila* to green dwarf.

	Palms in flower	
	Age - 31/2 years	Age - 41/2 years
Typica x Pumila (193 palms)	87 p. 100	95 p. 100
Typica x Typica (72 palms)	19 p. 100	50 p. 100

Considerable work on the Dwarf x Tall hybrid is in progress in Ceylon, India and Ivory Coast. It is generally accepted that this hybrid is far superior to planting material raised from Tall open-pollinated seed. But, it is not clear whether it is superior to Tall x Tall (both parents selected) in production of copra per unit area. Freemond *et al.* (1971) have pointed out the commercial possibilities of Dwarf x Tall hybrids and that the yield potential to be 4 tons copra per ha/yr. Currently , Dwarf green is used as one of the parents in Ceylon and Dwarf yellow as the female parent in Ivory Coast and Jamaica, in production of Dwarf x Tall hybrid seedlings. Dwarf yellow is said to be tolerant to lethal yellowing and also carries a genetical marker so that pure dwarfs arising from hybrid seed could be isolated in the nursery stage. On the other hand, Dwarf green palms grown in Ceylon are earlier flowering and produce better copra with a slightly more oil content than the other two colour types. Mean yield per progeny of experimental material is given below:

Typica x Pumila		*Typica x Typica*
Year after planting	No. of nuts per palm	No. of nuts per palm
5th	23	nil
6th	68	22
7th	86	52
8th	65	65
9th	103	84
10th	108	88
11th	129	121
12th	146	161

Further, in Dwarf x Tall hybrids being produced , only the male parent is selected. It is possible that certain combinations of genotypes between these two varieties may show considerable heterosis. These combinations have to be isolated and parents multiplied for the production of a strain that may outyield present hybrids.

MASS PRODUCTION OF SEED

Thus, it is possible to produce high yielding planting material in coconuts by exploiting prepotency and hybrid vigour. But, difficulties arise in mass production of seed, particularly due to the limited quantity of seed available from each palm each year, and the absence of methods of vegetative multiplication. Only a few seed nuts could be produced by artificial pollination, which will be sufficient to meet only a fraction of the requirements of each country. In Ceylon with a well organized pollination unit, 11 836 hand pollinated seedlings were issued in 1969, against a demand of about 1.5 million seedlings a year - less than 1 p. 100. A feasible approach to the problem for mass production of seed is the use of seed gardens.

There are two possible methods in the production of Tall x Tall seed. Select the best 5 p. 100 palms from a number of blocks of coconut palms, on a basis of high yield of copra per palm and desirable agronomic characters - leaves well orientated on the crown; short leaf and bunch stalks; non-seasonal bearing; nuts large, round or oblong, each husked-nut weighing at least 680 g. Plant the selected seedlings taken from these palms in a seed garden, and subsequently test for prepotency by using one of the techniques described earlier. Thereafter, remove all the progenies of non-prepotent palms from the seed garden, so that seed collected are crosses between prepotents.

The second method is to test prepotency of the best 5 p.100 palms selected from each block and cross those identified as prepotents. Plant seed raised in this manner in a seed garden and again check for prepotency. Most palms within that seed garden will be of good general combining ability, and they will cross freely amongst themselves to produce seed nuts of high genetic value. It is important to avoid any chances of inbreeding occurring in the seed garden.

However, for immediate use selected high yielding palms could be pollinated with pollen from prepotents to provide good planting within a short period. If only a few prepotents are available, pollen collected from them could be increased four to five fold by mixing with lycopodium powder or talc, so that a larger number of palms could be pollinated.

Again in production of Dwarf x Tall seed one has to resort to seed gardens. In this instance, Dwarf and Tall variety palms are planted together in a block to form a mixed stand of palms. Dwarf palms should be regularly emasculated, so that they get naturally crossed with the Tall palms giving Dwarf x Tall seed. There is no data relating to the proportion of the two types of palms to be planted within seed garden, probably a composition with about 40 p.100 of total stand with the Tall type may suffice.

REFERENCES

Duff, A.D.S (1967) - Hybrid vigour between two tall varieties of coconut in the Solomon Islands. S.P.C. *Technical meeting on coconut production* at Rangiroa, French Polynesia.

Fremond, Y. and de Nuce de Lamothe, M. (1971) - Paper presented to the *Coconut Symposium* held in Kuala Lumpur, Nov. 1971.

Harland, S.C. (1957) - The Improvement of the coconut palm by breeding and selection. *Bulletin 15, Coconut Research Inst.,* Ceylon.

Lakshmana Char, S. (1959) - A preliminary note on the heritability of yield in the coconut. *Indian Coconut J.,* 12.

Liyanage, D.V. (1956) - Intra-specific hybrids in coconuts. *Bulletin* 7, Coconut Research Inst., Ceylon.

- (1967) - Identification of genotypes of coconut palms suitable for breeding. *Expt. Agric.,*

- (1969) - Effect of inbreeding of some characters of the coconut palm. *Ceylon Coconut Quart.,* 20.

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

Satyabalan, K. (1956) - Hybridization in coconut improvement. *Bull. Indian Centr.Coconut Committee,* 9

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Cord
Vol. 10, No. 2, 1994

DEVELOPMENT OF KHINA SERIES COCONUT VARIETIES IN INDONESIA

INTRODUCTION

A project for coconut development in Indonesia was initiated in 1972 with assistance from UNDP/FAO, and the Research Institute for Industrial Crops (LPTI), Bogor as the Counter-part Agency. Emphasis of research was on breeding and agronomy. Production of KHINA series of coconut varieties was an accomplishment of breeders attached to the project. They were D.V. Liyanage, H. Luntungan, A. Djisbar and T. Mankey. In the initial stages, particularly during germplasm surveys, Ch. Corputty and H. Sudasrip were associated.

Research on breeding included coconut germplasm surveys in Indonesia, hybridization of selected palms within selected populations and testing progenies. That involved considerable travelling, labour and a barrage of criticism. The agony and joy, breeders experienced in production of KHINA series of coconut varieties are outlined in this paper.

Technical details regarding the breeding program, growth of progenies, flowering and production are given in references 1, 2 and 3.

Germplasm survey

A survey of coconut germplasm in selected areas of eleven provinces in Indonesia was carried out. Twenty five samples that represented a wide spectrum of populations, some exposed to selection pressure were studied in detail. They were:

Yellow Dwarf (NYD) variety from Nias island, North Sumatra. Palms early flowering, copra per unselected nut 188 g.

Tenga Tall (TT) cultivar from Tenga district, North Sulawesi. Copra per unselected nut 296g.

Bali Tall (BT) cultivar from a government estate in Central Java. Copra per unselected nut 340 g

Palu Tall (PT) cultivar from Palu valley in Central Java. Copra per unselected nut 354 g.

Selected TT, BT and PT populations were homogeneously high yielding under low levels of management, giving about 3,500 kg copra ha/yr.

Hybridization

Selected NYD palms in Nias island were taken as the female parents and TT, BT and PT as male. Small field laboratories were set up near selected Tall palm populations for pollen collection and a larger laboratory in Nias island. Headquarters of LPTI at Bogor was the focal point where pollen collected at the three field stations were re-processed, stored and later sent to Nias island. Further, the program was directed from Bogor.

Accessibility to field stations at Nias, Tenga and Palu was difficult. For example to reach Nias island, travelling included two hours by air from Jakarta to Medan, four hours by road from Medan to Sibolga in North Sumatra, overnight sea journey from Sibolga to the main town in Nias and finally three hours by speed boat to reach the field station. Sea journey sectors were always risky.

Often coconut pollen samples sent from Bogor were not viable on reaching Nias island. Consequently, that exercise had to be repeated over and over again. Yet, in spite of all these difficulties and risks, seed nuts of NYD x TT, NYD x BT and NYD x PT were produced in sufficient quantities for progeny testing.

KHINA series

Performance of the three hybrids referred to above in progeny trials was far superior to that of the respective male parents or any other coconut planting material produced in Indonesia. They were early flowering and high yielding - details given in references 2 and 3. LPTI named them as follows:

KHINA 1	- NYD x TT
KHINA 2	- NYD x BT
KHINA 3	- NYD x PT

KHINA stands for kelapa hybrids in Indonesia. KHINA 1 is planted on a large scale in commercial plantations.

DISCUSSION

Production of improved coconut varieties like KHINA 1 and others using indigenous germplasm was not an easy task. When the breeding program was initiated in 1972, a certain group, supported by two influential foreign organizations was anxious to promote cultivation of imported coconut seed in Indonesia. They discouraged and criticized the breeding programme, often reaching unethical scientific standards. Criticism emanating from them was so harsh and extensive that the author as leader of the breeding team experienced considerable difficulty to maintain morale and efficiency of the team. However, in spite of these obstructions and insinuations, the team was able to concentrate and implement the breeding programme successfully, eventually producing KHINA 1 and other coconut varieties that would be of immense value for coconut development in Indonesia.

That would not have been possible and breeding program abandoned half way through, if not for the keen support and encouragement given by an able research administrator. He appreciated the principles on which programme was based and ability of breeders to deliver the goods. He accompanied frequently the author on field trips to monitor and evaluate work in progress and attend to administrative problems as necessary.

When he examined the first hybrid palm that flowered at Parunkuda Experimental Station, West Java in 1980, 34 months after planting seedlings, he was filled with joy and tears flowed down his eyes. That was late Hasman Azis, Director of LPTI then.

REFERENCES

1. Liyanage D.V. and Corputty Ch.P. Coconut germplasm in Indonesia. Paper presented at *The Fourth Session of the FAO Technical Working Party on Coconut Production, Protection and Processing.* Kingston, Jamaica (1975).

2. ____________________, Mankey T., Luntungan H., Djisbar A. and Sufiani S. Coconut breeding in Indonesia - I *Cocos* 4 (1986).

3. ____________________, Luntungan H. and Mankey T. Coconut breeding in Indonesia -II. *Cocos* 5 (1987).

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Cocos
Vol. 6, 1988
Jointly with M. R. T. Wickramaratne
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COCONUT BREEDING IN SRI LANKA - A REVIEW

SUMMARY

Coconut palms grown in Sri Lanka have been classified into three varieties with 13 forms amongst them. Only one form *typica* (SLT) is grown on a plantation scale. Besides morphological characters, stomata density and carotenoid content are useful in classification. Varieties have a chromosome number, 2n = 32.

SLT palms are monoecious, generally cross-pollinated and therefore, highly heterozygous. Insects are the major agents of pollination. They flower initially in 52 to 72 months after planting. Optimum yield is obtained when palms are 16 to 17 years old with a crop of about 7,400 to 9,800 nuts/1,400 to 1,960 kg copra per ha/yr, with a density of 156 palms. That level is maintained with fluctuations related to environmental factors, until palms are 50 to 60 years old.

Out of the total crop (copra) for the year, about 63% is harvested between March and August and 37% in the other months.

Components of yield exhibit different levels of repeatability, with high values for setting of female flowers into fruits, copra per nut and copra per palm/year.

Heritability values for copra weight per nut and per palm are high, for yield of nuts intermediate and for flowering period low.

Genetic correlations between yield of nuts and copra is high and positive, between yield of copra and flowering period high and negative.

Genetic progress in the progenies is likely to be more, if seed parent is selected on high yield of copra and nuts, rather than on weight per husked- nut and flowering period.

When the selection differential with respect to yield of copra is increased, response of progeny increases. The best 5% SLT palms in a population have given progenies with a yield 14.4% higher than the population mean. Thus, selection of parents on the lines advocated above, would assist in upgrading the first generation.

Breeding value of 104 SLT palms in relation to yield of copra has varied between + 59.6 and - 62.1.

Number of leaves produced during the first three years of young palms on a family basis is related to breeding value of parent, giving a quick method to identify the latter.

Inbred coconut palms have shown a depression on leaf production, flowering period, endosperm weight and embryo weight: intensity varies between families.

Perhaps, palms of high breeding value could be isolated from phenotypically superior palms (copra production) by assessing inbreeding depression on endosperm and embryo weights.

Selection indices have been calculated based on economic characters pertaining to production.

Two improved coconut varieties have been developed: CRIC 60 and CRIC 65, both giving a very high production of nuts.

A seed garden was developed for mass production of improved seed.

INTRODUCTION

The Coconut Research Institute in Sri Lanka was established in 1929, under the Coconut Research Ordinance, No. 29 of 1928. There were three divisions then: technology, genetics and soil chemistry. There was only one scientific officer attached to each division. The genetics division functioned from 1930. Subsequently, the Coconut Research Scheme was upgraded and enlarged into the Coconut Research Institute (CRI) in 1951 with more divisions and scientific staff.

The present report covers work done by CRI on coconut breeding from 1930 to 1980. Those who were in charge of the division during this period is listed below. Emphasis on the nature of breeding work varied with the Head of Division: Pieris concentrated on mass selection, Raghavan on a progeny trial, Liyanage on genetic parameters, controlled pollination and production of improved varieties, Manthriratne on assessment of performance of hybrids.

W.V.D. Pieris	- from 1930 to 1946
T.S. Raghavan	- from 1947 to 1949
D.V. Liyanage	- from 1949 to 1966
M.A.P. Manthriratne	- from 1970 to 1979

In this paper statistical significance is indicated in the following manner:

* Significant at P = 0.05
** Significant at P = 0.01
*** Significant at P = 0.001

COCONUT VARIETIES IN SRI LANKA

A critical examination of data pertaining to the morphological characters and breeding systems of coconut palms grown in Sri Lanka indicated that three varieties could be distinguished (Liyanage, 1958).

Variety *typica* Nar.

The popular Sri Lanka Tall (SLT) palm grown on a plantation scale: late flowering taking 5 to 6 years after planting, flower production continuous and predominantly out-breeding, hardy palms tolerating a wide range of environmental conditions.

Variety *nana* (Griff) Nar.

Early flowering 3 to 4 years after planting, flower production seasonal, inbreeding, epicarp of nut orange in colour, grows in a restricted environment, suffers adversely from drought and susceptible to pests and diseases.

Variety *aurantiaca* Liy.

Late flowering 5 to 6 years, flower production seasonal, inbreeding, epicarp of nut orange in colour, nut water sweet, grows in restricted environment, suffers from drought and susceptible to pests and diseases.

All three varieties have a chromosome number 2n = 32.

Forms of variety *typica*

Typica, Navasi, Gon-thembili, Ran-thembili, Porapol, Bodiri, Kamandala and Dikiri-pol.

The popular Sri Lanka Tall (SLT) palm growing on a plantation scale: late flowering taking 5 to years after planting, flower production continuous, predominantly out-breeding, hardy palms tolerating a wide range of environmental conditions.

Forms of variety *Nana*

Pumila, Eburnea and Regia.

They are not grown on a plantation scale, but have been used extensively in breeding work, because of low stature , large number of nuts and early flowering.

Forms of variety *aurantiaca*

King coconut (thembili) and Navasi thembili.

King coconut has nut water with a higher sucrose content. Hence grown on a large scale for drinking purposes.

Variations between the forms in quantitative characters are given in Table 1 of Paper 1, and shape and size in Fig. 1 and 2 of Paper 1. The *typica* forms have more copra per nut and heavier shells than the others, except *bodiri.* Oil content of two *nana* forms and *king coconut* is less than that of *typica.*

Forms that are useful for breeding are *typica* (low out-turn and high oil content), *kamandala* (high copra/nut), *pumila* (early bearing, short habit, high oil content), *pora-pol* (high shell weight). Early bearing character of *nana* appears to be partially dominant and short habit recessive. The F_1 palms of *typica* x *pumila* exhibit heterosis in growth.

The chances of inter-spadix pollination are remote in most of the *typica* forms, except when palms are young and vigorous. Potential for self pollination depends on the length of male and female phases and chances of overlap within and between spadices (Fernando, 1976).

Stomata density is a variety character. Variations due to environment were negligible. All three forms of the self-pollinating *nana* variety had more stomata (31) per mm^2 when compared with varieties *typica* (24) and *aurantiaca* (25). Stomata density may prove to be a useful marker for identification of *typica x nana* hybrids, for they have an average of 27 stomata per unit area, which is the mid parental value for the character (Manthriratne and Sambasivam, 1974).

By chromatography techniques, it was observed that green and brown forms of *typica* have similar carotenoids. The three colour forms of *nana* have carotenoids which have similar Rf. values, which differ from Rf. value for *typica.* In the three hybrids between *typica* and *nana* (3 colour forms) carotenoid characters of dwarf appear to be greater (Jayasekara, 1979).

An attempt has been made to separate pollen proteins of coconut by electrophoresis for variety identification. The method is reported, but not the results (Manthriratne, 1977).

Abbreviations used for coconut varieties/forms in the following pages are:

SLT	:	Sri Lanka Tall palms (*typica*)
GD	:	Green Dwarf palms (*pumila*)
YD	:	Yellow Dwarf palm (*eburnea)*
RD	:	Red Dwarf palm (*regia*)
KC	:	King Coconut palm (*aurantiaca*)

SRI LANKA TALL PALMS

SLT palms are the mainstay of the coconut industry in Sri Lanka, providing a variety of food and industrial goods. They are hardy, tolerate a wide variety of environmental conditions, ranging from marginal lands in the dry zone to more favourable areas in intermediate and wet zones. Consequently, production varies between locations.

SLT palms are monoecious. They are largely cross fertilized with a timing mechanism. Male phase precedes the female phase on the same inflorescence, and when the next inflorescence opens receptivity of female flowers of the previous one has lapsed. Sometimes vigorously growing young palms produce inflorescences more frequently, allowing inter-spadix pollination within the same palm.

It is predominantly insect pollinated, honey bees (*Apis indica*) and mites playing a major role. Stem is visible about the fourth year after transplanting seedlings. Its growth is continuous depending on the environment, and a 50-year old palm could attain a height of about 20 meters.

First visible inflorescence appears in an axil of a leaf when palms are 54 to 72 months old. Thereafter flowering is continuous with occasional interruptions.

SLT coconut fruit

Weight of fruit components after studying 1,000 coconuts from Bandirippuwa estate, withered for one month, is given below. The same study also showed that 30 coconuts is a reasonable optimum sample size (Nathanael, 1958).

Weight per fruit component (g)

	Wet	Dry
Whole fruit	1,053 ± 9.64	673 ± 6.09
Husked-nut	640 ± 4.50	343 ± 4.83
Husk	413 ± 7.10	330 ± 3.47
Shell	177 ± 0.88	155±0.68
Endosperm	339 + 3.15	182 + 4.53
Nut water	124 + 4.22	6 + 0.09
Copra (6% moisture)	-	182 + 4.52

(Source: Nathanael, 1958)

The respective weight of fruits could vary with environment, harvesting season and age of palms. These samples have been taken from palms over 50 years old. At that age, weight of fruits and their components decrease, *e.g.* weight of copra per fruit averages 194 g. Hence these figures may be lower, compared to those of younger palms.

Yield potential

SLT palms grown on a plantation scale remain productive for over 60 years depending on soil, climate and crop husbandry. After initial bearing, yield of nuts increases progressively every year, until an optimum is attained, which is maintained thereafter depending on environmental conditions.

Yield curves of two SLT populations are given in Fig. 4 of Paper 3.

SLT palms give a yield of about 6,200 nuts ha/yr when they are 10 to 12 years old, reaching an optimum at 16 to 18 years. Average yield varies between 7,400 to 9,880 per ha/yr, variations attributed to differences in environmental factors and management practices.

Variation between harvests

SLT palms are harvested once every two months. Variations between harvests with respect to some characters that contribute to production were studied on 972 palms over a 10- year period (Table 2).

Generally, more copra per palm/year is derived from three harvests gathered from March to August (7.14 kg), than from September to February (4.19 kg); 63% and 37% respectively of the total crop. May/June harvest alone contributes nearly 25% of the yearly total.

Components listed below have given repeatability values as follows:

Number of bunches	x^2	= *11.86**
Number of female flowers per bunch	"	= 9.31
Setting of female flowers	"	= 22.10***
Weight of copra per nut	"	= 19.31*
Weight of copra per /year	"	= 25.50***

(Source: Abeywardane and Fernando, 1963)

Biennial bearing

Most tree crops are to some extent biennial in growth and cropping. Those that exhibit a biennial rhythm, carry a heavy crop in one year and less in the following year.

Production of nuts of 300 SLT palms for a period of 10 years was examined to determine the biennial bearing tendency. There is a biennial rhythm in coconut production, but intensity of biennial fluctuations is low and of no significance in economic terms (Abeywardane, 1962).

Correlation studies

Data of 144 SLT palms whose female parents are known were used in the study. Correlation between and within families of characters listed in the first column in Table 3 were worked out. Adult palm components represent yield of data collected from palms 16 to 17 years old. The more important findings are illustrated in Figures 1 and 2 in Paper 3.

Seed parents that gave nuts above average size have progenies with fewer nuts. The same relationship holds even if flowering is kept constant. Early sprouting promotes seedling height, leaf and root number, presumably due to the higher physiological age.

A palm that flowers early, gives a higher yield both of nuts and copra , than those that flower late.

If a palm during the second and third years of bearing gives a high yield, it will continue to be very productive subsequently.

Seed nuts that sprout early, give palms that have a shorter flowering period, leading to a higher production of nuts and copra in the adult palms. These correlations are indeed very useful in selection of seedlings and rouging poor bearing palms, leading to a uniformly high yielding plantation. The ideal would be to plant about 20% more palms than the recommended number per unit area, so that after thinning out is completed, required density of palms is maintained.

Other correlation coefficients from data of 122 SLT palms are given in Table 4. Yearly leaf production from 2nd to 6th year is negatively correlated with the flowering period. Thus, in a programme of selective thinning of transplanted material, it is possible to use an index of leaf production for rouging purposes, with a view to promote early flowering of palms in the population. Leaf production and yield of 9 to 12 year old palms, both nuts and copra, are positively and significantly correlated (Liyanage, 1962).

Since SLT palms are highly heterozygous, rouging undesirable types in the nursery stage and at flowering will result in a highly productive population. Important characters to be considered for that purpose are: early sprouting of seed nuts, high production of leaves up to the 3rd year or more, early flowering of palms and initial high yield of copra.

MASS SELECTION

The initial studies at CRI were directed to identify suitable criteria for selection of SLT palms for collection of seed. Standards for their selection were outlined. They should have a short, straight stem; closely set leaf scars; short, well orientated fronds; short bunch stalks; a fair number of female flowers on the inflorescence; a large number of inflorecences carried evenly round the crown; large number of nuts, size being of no importance as long the number is large and weight of husked-nut high. Field studies indicated below were undertaken to study the efficiency of mass selection methods (Pieris, 1934).

300 palms block

A block of 300 SLT palms, already in bearing was taken for yield recording in 1931. At each pick, number of bunches harvested, fruits gathered and weight of a sample of husked-nuts were recorded (Pieris, 1932).

The study, apparently, was to relate selection standards to actual yield data. A very useful correlation has been established: ratio of copra to the weight of husked-nuts is 32% (Pieris, 1935). Subsequently, this ratio has been used widely to estimate copra weight of palms in field trials.

Ratmalagara Estate Field Trial (REFT)

The field trial started in 1939 was to compare progenies derived from high yielding palms, low yielding palms and mixed heaps of nuts, with or without selection of seedlings (Pieris, 1939).

Early attempts at analysis of data indicated that selection of seed parents was ineffective, as there were no significant differences in yield of nuts and copra of the progenies between the three sources of seed. However, there was a significant response to seedling selection (Liyanage, 1953).

A subsequent critical evaluation of the results revealed that planting material used has been from two distinct (separate) populations. Consequently, there has been a masking of the true results of this trial. More evidence on selection of parent palms for seed collection has been obtained from other progeny trials (Liyanage and Sakai, 1960).

Progeny trials of SLT palms

The first trial was planted at Marandawila Estate (MEPT) in 1934, for testing 292 open-pollinated progenies of nine selected high yielding SLT palms growing on the same estate. Un-selected progenies were planted on a fully randomized design (Pieris, 1934, 1943).

Second progeny trial was planted at Walpita Estate (WEPT) in 1948, to test open-pollinated progenies of 232 palms from MEPT. Thus, WEPT is second generation progeny testing. Seed parents, seed and seedlings were taken at random without selection. Design is a cubic lattice (Raghavan, 1948).

Third progeny trial was planted at Bandirippuwa Estate (BEPT) in 1959. It is composed of open-pollinated progenies of 125 high yielding palms growing at Bandirippuwa, Ratmalagara, Letchemy, Archchitotam and Marandawila estates. Purpose of the trial is to isolate prepotent palms. Design is a cubic lattice (Harland, 1957; Liyanage, 1959). It is unfortunate that data collected from BEPT have not been processed and analyzed yet.

Data of MEPT and WEPT has been used extensively for genetic studies, such as estimation of genetic and environmental correlations, heritability values, genetic progress due to selection and construction of a selection index.

There was no genetic information, when the mass selection programme was initiated in 1930. Hence, desirable palms for seed collection were identified, based on seven characters indicated earlier. Out of them, weight per husked-nut and yield of copra per palm have high heritability values, indicating efficiency of selection of seed parents on that basis.

Selection differential

Further, MEPT and WEPT have given very useful information on the effect of selection of seed parents on the performance of their progenies. That effect, when seed parents are selected from two extreme ranges (best 15% and worst 15% in a population) based on weight of husked-nuts is indicated in Table 2 of Paper 5.

When selection differential is increased on an upward basis, with respect to weight of husked-nuts, response of the progeny increases. Best 5% palms have given progenies with a yield 14% higher than the population mean. With selection on a downward basis, worst 5% of the palms gave progenies whose phenotypic value was much inferior to those of the worst 15%. This indicates that there is a response to selection of SLT palms, when selection is based on weight of husked-nuts (Liyanage, 1967).

Thus, there is definite evidence to prove that selection of SLT palms on certain criteria is an efficient method to collect seed. Selection of palms should be based on the following criteria:

- Short inter-node length,
- high setting of female flowers into fruits,
- high weight of endosperm weight per nut,
- high yield of copra per palm/year and
- desirable agronomic characters.

GENETIC PARAMETERS OF SLT PALMS

Breeding value

Breeding value of a palm is determined by the average effects of genes. In this study using WEPT data, breeding value of a palm has been taken as twice the deviation of the mean of its progenies from the mean of the entire progeny population, relative to weight of husked-nuts.

Breeding value of the 104 SLT palms tested has varied between + 59.6 and - 62.1. These variations are to be expected, as parents are heterozygous and have been taken at random. The best 10% of parents on a basis of breeding values are listed in Table 3 of Paper 5. Phenotypic value is the weight of husked-nuts (Liyanage, 1967).

Breeding values of palms 55, 141, 179 and 248 were similar; the differences being statistically insignificant; yet there was a high variation in the performance of progenies, as reflected in their coefficients of variation (see Table 1 in Paper 6). In family 55, none of the progenies gave a mean yield less than population mean (36.11 kg), whereas in family 248 one out of eight, in 141 two out of eight and in 179 three out of nine palms have given yields less than population mean. High progeny means of families 55 and 248 were probably due to additive effects of genes of parents, rather than to non additive effects (Liyanage, 1967).

Certain palms are able to transmit the character high yielding to their offspring, in spite of open-pollination, and these have been described as *prepotent* palms (Harland, 1957). Apparently, palm No. 55 is such a case; both phenotypic and breeding values are high, its open pollinated progenies are consistently high yielding with a low coefficient of variation (Table 6), and its agronomic characters are of a high standard. Only one per cent of palms tested could be classified as *prepotent*.

Heritability values

Data collected from MEPT has been used to calculate heritability values of a number of characters of SLT palms. The method used was to partition the mean squares and mean products of characters measured into within and between family components, and to estimate genetic, non-genetic variances and covariances. The following heritability values were obtained (Liyanage and Sakai, 1960; Liyanage, 1959, 1961).

Character		Heritability (h^2)
Girth of stem	:	0.45
Inter-node length	:	0.63
Flowering period	:	0.23
Number of bunches per palm/ year	:	0.47
Number of female flowers per bunch	:	0.52
Setting of female flowers into fruits	:	0.81
Number of nuts per bunch	:	0.50
Weight per husked-nut	:	0.95
Number of nuts per palm/year	:	0.48
Yield of copra per palm/year	:	0.67

Selection of seed parents on a basis of yield of copra per palm/year, weight per husked-nut and setting of female flowers will be highly effective. Selection for number of nuts per palm/year, number of bunches per palm/year, number of female flowers per bunch and number of nuts per bunch may be effective, while selection for early flowering will not be effective.

Genetic correlations

In a selection program, genetic correlations between the different productive traits of SLT as estimated below would be of considerable importance. Since yield of copra and yield of nuts are highly correlated positively, flowering period and yield of copra are highly correlated negatively, selection of seed parents for early flowering and number of nuts tends to increase yield of progeny population with respect to copra production (Liyanage and Sakai, 1960).

Character			Genetic correlation (r_g)
Flowering period of a palm	x weight per husked-nut	:	- 0.25
--------------------------------	x yield of nuts per palm/year	:	- 0.72
--------------------------------	x yield of copra ---------------	:	- 0.81
Weight per husked-nut	x yield of copra per palm/year	:	+ 0.43
--------------------------	x yield of nuts ------------------	:	- 0.22
Yield of nuts per palm/year	x yield of copra per palm/year	:	+ 0.79

These findings suggest that a number of characters should be considered in the selection of seed parents. It is necessary to ascertain which trait would be most useful for this purpose in relation to genetic gain due to selection.

The relative importance of characters listed above was in the following order of merit: (I) yield of copra, (ii) yield of nuts, (iii) weight per husked-nut and (iv) flowering period as indicated below (Liyanage and Sakai, 1960).

Selection criteria of seed parent		Expected genetic gain (copra)
Yield of copra (lb)	:	31.4 lb
Yield of nuts	:	21.1 lb
Weight per husked-nut (lb)	:	15.8 lb
Flowering period (mth)	:	14.9 lb

Selection index

Heritability values of, and genetic correlations between various productive traits of the coconut palm have been worked out using data from MEPT. They are of considerable importance in a selection program. Since yield of nuts and copra are highly correlated positively (r_g = + 0.79), and flowering period and yield of copra are highly correlated negatively (r_g = - 0.81), selection of seed parents on early flowering and number of nuts will tend to increase yield of the progeny with respect to copra production. As a number of characters have to be considered in the selection of seed palms, it would be generally useful to construct selection indices. An index I using three characters has been computed as follows (Liyanage, 1961).

$$I = X_1 - 14.70\, X_2 - 4.47\, X_3$$

where X_1 = number of nuts per palm/year
X_2 = weight per husked-nut
X_3 = flowering period of palm (mth)

Another selection index applicable to a particular palm as given below, has been calculated based on four characters of a palm (Abeywardena and Mathes, 1980).

$$I = \frac{(x_1 - \bar{x}_1)}{\sigma_{x1}}\, 0.5593 + \frac{(x_2 - \bar{x}_2)}{\sigma_{x2}}\, 0.4743 + \frac{(x_3 - \bar{x}_3)}{\sigma_{x3}}\, 0.3553 + \frac{(x_4 - \bar{x}_4)}{\sigma_{x4}}\, 0.5796$$

Where x_1 : girth of stem just below the crown (mean of two measurements taken 30 cm apart).
x_2 : number of opened inflorescences and bunches bearing fruits.
x_3 : number of nuts per bunch (averaged over X_2 records.
x_4 : number of green fronds present at a time.

The four characters listed above could be scored at any time. They lead to vigour of the palm, but heritability of those characters has not been reported.

Inbreeding of SLT palms

Eight high yielding SLT palms whose breeding values are known were self pollinated, and open-pollinated nuts were also taken from the same palms. Nuts were harvested during the 52nd week after pollination. Wet weight of the endosperm and of embryo were recorded , results given in Table 7 and Fig. 5. Phenotypic value is yield of copra per palm/year given in pounds (Liyanage, 1969).

There is considerable variation between palms with respect to the weight of endosperm - 286 to 407 g - and embryo weight - 96 to 136 mg - in open-pollinated nuts. These variations are to be expected due to the natural out-crossing habit of the variety of palms under consideration. If the weight of either of these characters is under genic control, one could expect different behaviour between genotypes when selfed, depending on the nature of genes involved. If it is largely due to additive effects of genes, then in-breeding depression will be less marked or even negligible, than when it is controlled by dominance and epistasis.

Five of the eight palms taken for this experiment (No. 55, 179, 85, 62 and 105) were of good breeding value, and the remaining three (No. 222, 145 and 37) were of low value (Table 9). Loss in weight of endosperm and embryo of selfed nuts in the former group of palms has been low, in relation to those of open-pollinated nuts. In each case selfed weight being less than 5%, except embryo weight of palm 62, which has shown a difference of 9.4. On the other hand, two palms of low breeding value have shown a marked decrease in weight of endosperm and embryo on selfing - over 12% in each case.

Behaviour of palm 145 is quite inconsistent: the two characters have shown no inbreeding depression, although it has a low breeding value. It is likely that high phenotypic values of palms 55, 179, 85 and 105 are mainly due to additive effects of genes rather than to other causes.

Correlation coefficient between gain/loss in endosperm weight and the breeding value of palm is high (r = 0.6935). Thus, there is an indication that palms of high breeding value, could be isolated from phenotypically superior palms (copra production) by selfing and studying the inbreeding depression on endosperm and embryo weights relative to open-pollinated nuts. In this study five palms (55, 179, 85 and 145) would have been picked as desirable genotypes on the above basis: four of them are of desirable breeding value and the other (145) of low value as judged from progeny trials. This method takes only 12 months to test the relative breeding value of a palm.

Coconut endosperm is composed mostly of triploid tissue (Abraham and Mathew, 1963). Embryo is diploid. Genic balance may be unlike in the two tissues owing to the double contribution of the female parent to endosperm. Yet, percentage loss in weight of endosperm and embryo has been practically the same on selfing, but coefficient of variation of endosperm weight has increased with selfing.

In palm 55, weight of 33 embryos (other being aborted) of open-pollinated nuts, ranged from 62 to 152 mg, and similar variations were common for other palms. It was suggested in 1969, that an interesting study of immense practical value would be to ascertain any useful correlations between weight of embryo and vigour and yield of the resulting palm within families using embryo culture techniques. Are the heavier embryos within a family an expression of specific combining ability?

CONTROLLED POLLINATION

Controlled pollination on coconut palms was initiated in 1947, with a view to introduce improved cultivars through hybridization. Initially floral biology of SLT and other varieties grown in Sri Lanka had to be studied. Therefore, pollen collection and processing, and techniques of pollination had to be developed.

In SLT, green Dwarf and King coconut male phase lasted 18 to 20 days from opening of spathe. Male flowers borne on the upper half of a spikelet open earlier than those on the lower half, They open early hours of the day and are shed same evening. In SLT female phase lasts 5 to 7 days, in Dwarf and King coconut 10 to 16 days. Male phase in SLT precedes female phase, but in the other two varieties they overlap. Thus, SLT is generally cross-pollinated and other two varieties self-pollinated (Liyanage; 1949; 1956).

Spikelets with male flowers about to open were cut and placed inside boxes dipped in test tubes containing water. They were placed in test tube racks over black paper. Pollen shed on the paper were collected next morning. Pollen germinated in a medium containing 10% sugar and gelatin, about 74% viable. This pollen stored in a desiccator with a relative humidity of 50% (desiccator containing 43.4% H_2SO_4) remained viable for 19 days. Dwarf pollen was more short lived; on the 8th day of storage, viability was less than 40% (Liyanage, 1949).

Pollen storage techniques were improved subsequently. Vials containing pollen were sealed at about 50% relative humidity and stored at a low temperature (0^0 C), remained viable for about 12 months.

Coconut pollen grains are monocolpate. Those of SLT measure 0.065 to 0.069 mm in length and 0.028 to 0.30 mm in diameter. There were no significant inter-variety differences observed in relation to size and shape of grains. Pollen production per anther has been estimated between 110,000 and 221,000 grains (Manthriratne, 1965).

A good SLT palm could give about 5 g pollen per inflorescence. Lycopodium powder is a good diluent for pollen, as it mixes well with no tendency for clumping. Mixtures containing pollen/lycopodium 1 : 10 have maintained viability for long periods.

The private sector initiated their own controlled pollination program with the assistance of CRI, who trained necessary staff and provided pollen. In order to meet the increasing demand for pollen, a *Pollen Bank* was established in 1959. Nearly 5,000 pollen samples were distributed to them each year.

In SLT palms, inflorescences are cut, emasculated and covered with a cloth bag on the 17th day after opening of spathe. Pollinations were done with an insufflator 2 to 3 times per inflorescence when female were receptive (Liyanage, 1954; Manthriratne and Liyanage, 1960). Since then these techniques have been further updated.

PRODUCTION OF IMPROVED COCONUT VARIETIES

After completion of studies on pollen processing and crossability within varieties, a program to produce intra- and inter- variety hybrids was introduced in 1949. The main objective was to develop improved varieties.

The first series of crosses

These were restricted to crosses between selected SLT (female parent) and GD palms. Seedlings were planted in 1949 in a block with a fertile loamy soil, situated in the semi wet intermediate zone. Performance of F_1 palms are outlined in Tables 8 and 9.

The F_1 palms of SLT x GD are early flowering and exhibit hybrid vigour in leaf production and stem formation as indicated below. GD has narrow stems, SLT and F_1 progenies broad stems; difference between GD and latter are highly significant (P = 0.01). Leaf production was highest in F_1 progenies, significantly more than in the parental types. GD is early flowering, SLT late and hybrid less than mid-parental value. Sixty four percent hybrids flowered in less than 42 months (Liyanage, 1956).

Character		SLT x SLT	GD	SLT x GD
No. of leaves produced during the 4th year	:	11.7 ± 2.21	13.4 ± 1.49	15.8 ± 0.83
Girth of stem (cm) measured 13 cm above ground	:	146.4 ± 15.25	85.4 ± 10.68	164.7 ± 7.63
Flowering period (mth)	:	74.3	38.0	48.6
Number of plants studied	:	16	17	22

(Source : Liyanage, 1957)

SLT palms are out-breeding, GD in-breeding and the hybrid between them out-breeding.

F_1 palms of SLT x GD started bearing fruits in the 5th year after planting, and most of them were in production in the following year. SLT x SLT progenies commenced flowering only in the 6th year. Yield data are presented in Table 8 (Liyanage, 1963).

Hybrids (SLT x GD) are more productive than the other variety during the early years of bearing. When palms were 12 years old, hybrids have given a cumulative yield of 115,000 nuts/28 tons copra per ha, against 94,000 nuts/22 tons copra from SLT x SLT, an increase of 22% nuts and 7% copra.

Hybrids start producing more than 100 nuts per palm/year from the 9th year, whereas SLT x SLT achieved that level of production in the 11th Year. When palms are 11 to 12 years old, yield differences between the two varieties disappear, each aggregating about 25,000 nuts/6,100 kg copra per ha/yr. During the second four year period, copra per nut was practically the same (242 to 250 g).

It is clear that F_1 of SLT x GD shows precocity for bearing and high production in the initial years of bearing, compared to SLT x SLT. The latter progenies have also given a very high yield of 140 nuts/36 kg copra per palm/year, when they were 11 to 12 years old. Thus, the possibility exists for development of two high yielding varieties from SLT x GD and SLT x SLT.

The second series of crosses

In this program, progenies of SLT x SLT, SLT x GD, SLT x YD (yellow dwarf form *eburnea*) and SLT x RD (red dwarf form *regia*) were studied. They were planted in 1958, 235 plants of the three hybrids and 90 of SLT x SLT. Their performance is summarized in Table 9.

SLT crossed to the three colour forms of dwarf shows precocity in bearing and is superior to SLT x SLT. Differences in production between the three types of hybrids are negligible (Mathriratne, 1971).

Copra content per nut of these three crosses is given below. The difference between reciprocals is negligible. Conversion ratio = weight of copra divided by weight of husked-nuts on a percentage basis.

Cross	No. of nuts sampled	Copra per nut (g)	Conversion ratio (%)
SLT x GD	952	193	32
GD x SLT	1224	180	32
SLT x RD	575	204	31
RD x SLT	1628	198	31

(Source: Manthriratne, 1971)

When SLT x GD palms were 9 to 12 years old, cumulative production of the first series of hybrids was 77,000 nuts/19 tons copra per ha, whereas those of the second series recorded only 40,000 nuts/7 tons of copra - a decrease of 63% in weight of copra. The drop in yield of copra in SLT progenies amounted to 75%.

This drastic drop in the second series could be attributed to soil factors. Palms of both series were planted in two separate blocks of the same estate; first series in a loamy, fertile soil and second in heavy clayey soil, subject to cracking in dry weather.

A comparison of fruit components of CRIC 60 and CRIC 65 is given below. Latter gives a lower weight of husk and shell when compared to the former.

	CRIC 60	CRIC 65 (mean weight g)	Percent +
Fruit	1517	1327	87
Husk	748	640	86
Husked-nut	769	687	89
Shell	204	173	85
Kernel	378	348	92

Source : Wickramaratne, 1987 + CRIC 60 figure is taken as 100%

Other crosses

KC x GD : former has orange red nuts, latter green nuts and their F_1 reddish brown nuts which are smaller in size, giving about 100 nuts per palm/year with 160 g copra per nut. The hybrids are less hardy than SLT palms and more susceptible to pest damage. They are not suitable for cultivation on a commercial scale (Liyanage, 1957).

San Ramon x GD : 34 progenies gave a mean flowering period of 50.6 months, yielding 68 nuts in the 9th year with 250 g copra per nut. This is a cross that should be studied further as high copra content per nut is a useful character.

Improved varieties

CRIC 60 : Derived by crossing selected SLT x SLT palms. Late flowering (55 to 70 months), out-breeding, hardy palms tolerating a wide variety of environmental conditions. It is capable of producing over 110 nuts palm/year with about 225 g copra per nut, under rain-fed conditions with a satisfactory environment combined with good management. Recommended for planting in areas suitable for coconut cultivation in Sri Lanka. Released to the industry in 1960.

CRIC 65 : Derived by crossing selected GD and SLT palms. Early flowering (36 to 45 months), out-breeding and tolerates only a restricted environment. Production over 120 nuts per palm/year with about 210 g copra per nut. Recommended for planting in home gardens and under irrigation. Released to the industry in 1965.

Thus, the coconut breeding program has been very successful, culminating in the production of two improved varieties that will help the industry to at least double coconut production in the country, provided technology could be passed on to the growers.

Germplasm

Importance of having a germplasm collection introduced from other countries has been recognized since 1950. But unfortunately, it could not be implemented, due to the fear that new pests and diseases may be introduced inadvertently. Such fears may be justified, when one considers the large number of diseases of unknown aetiology prevalent in many coconut growing countries. Yet an effort should be made to introduce foreign germplasm.

MASS PRODUCTION OF CRIC 60 AND CRIC 65 SEED

It was realized from a study of the characters of juvenile progenies of SLT x SLT and SLT x GD, that they will be highly productive , surpassing yield of SLT palms. Sri Lanka requires about two to three million seed nuts per year. It will be quite impossible to raise this quantity of seed through artificial pollination. Hence, the concept of isolated seed gardens was developed for large scale production of seed (Liyanage, 1953, 1960, 1962).

A seed garden is a special coconut plantation, carrying palms of known identity and protected to prevent pollination of palms within the seed garden by those outside it. The first seed garden in Sri Lanka was planted in 1955, eventually covering 125 ha for production of CRIC 60 seed. Subsequently, provision was made to produce CRIC 65 seed. It is situated in the Puttalam district in the semi-dry intermediate zone.

SLT palms are cross pollinated. Principal agent of pollination is the honey bee (*Apis indica*). Wind pollination is negligible. Based on these factors, it was considered that a forest barrier 800 m deep all round the garden, would prevent pollen contamination between palms within and outside.

Seed garden was largely planted with seed derived by crossing selected SLT palms, except for two blocks where GD open-pollinated seed was planted. These palms are emasculated regularly and natural pollination takes place to produce CRIC 65 seed. SLT palms will cross naturally between themselves to give CRIC 60 seed.

Nut production for 5 years from 5,700 SLT x SLT palms growing in the seed garden under rainfed conditions and good management is given in Table 10. Year 1982 was the 27th year after planting seedlings. In 1985 production exceeded 25,000 nuts per ha as rainfall and distribution were satisfactory in the previous year. In 1984 yield dropped to 11,000 nuts per ha, due to adverse climatic conditions prevalent in 1983.

Plantations raised from seed of seed gardens may give at least 18,000 nuts ha/yr under rain-fed conditions and over 25,000 nuts with irrigation. Existing plantations in Sri Lanka that are well managed give about 9,000 nuts ha/yr. That means production could be doubled when CRIC 60 seed is used for planting.

ACKNOWLEDGEMENTS

A large number of scientists and support personnel have been involved in the establishment of trials; collecting, processing and presenting data. Our thanks are due to all of them, particularly to:

Mr. W.V.D. Pieris, former Geneticist, Coconut Research Institute.
Dr. T.S. Raghavan, former Botanist, Coconut Research Institute.
Dr. M.A.P. Manthriratne, former Botanist, Coconut Research Institute.
Mr. V. Abeywardane, former Biometrician, Coconut Research Institute.
Messrs H.L. de Mel & Co. Ltd. for maintaining the progeny trial (MEPT).

REFERENCES

Abeywardane, V. 1962. Studies on biennial bearing in coconut. *Ceylon* Coconut *Q.* 13, 112-125.

____________ and Fernando, J.K.T. 1963. Seasonal variation of coconut crop. *Ibid.* 14, 74 - 80.

____________ and Mathes, D.T. 1980. A biometrics approach for evolving a selection index for seed parents in coconut. *Ibid.* 31, 112 -118.

Abraham, A. and Mathew, P. 1963. Cytology of coconut endosperm. *Ann. of Bot.* NS 27, 505.

Fernando, W.P.B. 1976. Some observations on the reproductive pattern of varieties and forms of coconut in Sri Lanka. 1976. *Ceylon Coconut Q.* 27, 1-8.

Harland, S.C. 1957. Improvement of the coconut palm by breeding and selection. *Bulletin No.*15. Coconut Research Institute, Sri Lanka.

Jayasekare, C. 1979. Annual Report of the Coconut Research Institute (ARCRI), Sri Lanka for 1979, 38.

Liyanage, D.V. 1949. Preliminary studies on floral biology of the coconut palm. *Tropical Agric.* 105.

____________ 1953. ARCRI for 1953.

____________ 1954. Controlled pollination of coconut palms. *Ceylon Coconut Q.* 5, 135-139.

____________ 1956. Intra-specific hybrids in coconut. *Bulletin No.* 7. Coconut Research Institute, Sri Lanka, 1-13.

____________ 1956. ARCRI for 1956, 33-34.

____________ 1955. ARCRI for 1955, 40.

____________ 1957. ARCRI for 1957, 40.

____________ 1958.Varieties and forms of coconut palms grown in Ceylon. *Ceylon Cocon. Q* 9 1-10.

____________ 1959. ARCRI for 1959, 45.

____________ 1960. ARCRI for 1960, 51.

____________ 1961. ARCRI for 1961, 33.

Liyanage, D.V. 1962. ARCRI for 1962,29.

____________ 1967. Identification of genotypes of coconut palms suitable for breeding. *Expt. Agric.* 3, 205-210.

____________ 1969. Effect of inbreeding of some characters of the coconut palm. *Ceylon Cocon. Q.20, 161-167.*

___________ 1972. Production of improved coconut seed by hybridization.*Oleagineux*, 27:597-599.

___________ and Abeywardane, V. 1958. Correlations between seed nut, seedling and adult palm characters in coconut. *Tropical Agric.*, CXIII, 1-16.

___________ and Sakai, K. 1960. Heritabilities of certain yield characters of the coconut palm. *J. Genetics*, 57: 245- 252.

Manthriratne, M.A.P.P. 1965. Coconut pollen. *Ceylon Cocon. Q.*, 16: 102-110.

___________ 1971. Some results of experimentation with *typica x nana* F_1 hybrids. *Ceylon Cocon. Q.* 22, 107-113.

___________ 1975. Selective use of improved planting material for rehabilitating Sri Lanka's coconut industry. *Fourth Session of the FAO Working Party* held in Jamaica.

___________ 1977. ARCRI for 1977: 24.

___________ 1978. The choice of planting material and methods in a national replanting programme. *Ceylon Cocon. Q.*, 29: 103-112.

___________ and Liyanage, D.V. 1960. Method of artificial pollination of coconut palms. *Ceylon Coconut Planters' Review*, 2: 3-8.

___________ and Sambasivam, S. 1974. Stomata density in varieties and forms of coconut. 1974. *Ceylon Cocon. Q.*, 25:105-108.

Nathanael, W.R.N. 1958. ARCRI for 1958: 19-27.

Pieris, W.V.D. 1932. ARCRI for 1932: 1.

___________ 1934. ARCRI for 1934: 5

___________ 1934. Studies on coconut palm -I. *Trop. Agric.* 82: 75-97.

___________ 1935. Studies on the coconut palm- II. *Ibid.*, 85: 208-220.

___________ 1939. ARCRI for 1939: 7

___________ 1943. ARCRI for 1943: 7.

Raghavan, T.S. 1948. ARCRI for 1948: 17.

Wickramaratne, M.R.T. 1987. Unpublished data.

Table 1. Variations between harvests of SLT palms

Component	Jan./ Feb.	March/ April	May/ June	July/ Aug.	Sept./ Oct.	Nov./ Dec.	Repeatability value
No. of bunches/palm	1.82	2.01	2.06	1.99	2.05	1.99	*
No. female flowers/bunch	14.77	15.47	15.59	16.33	13.85	13.41	ns
Setting female flowers into fruits (%)	25.37	35.05	41.83	38.17	31.60	27.36	* * *
Wt. copra/nut (g)	217	211	206	193	183	198	* * *
Wt. copra/palm (kg)	1.39	2.16	2.69	2.29	1.52	1.30	* * *

Source : Adapted from Abeywardane and Fernando (1963)

Table 2. Flowering period and yield of SLT palms

		Correlation coefficient r		
		x flowering period	x yield of nuts	x yield of copra
No. of leaves produced in 2 year old palms	-	-0.5076 *	0.1269	0.1809 *
" 3 "	-	-0.6836 *	0.3956	0.3912 *
" 4 "	-	-0.8046 *	0.4903 *	0.5001 *
" 5 "	-	-0.7556 *	0.5618 *	0.5982 *
" 6 "	-	-0.7698 *	0.6277 *	0.6443 *
Total number of leaves produced from the 2nd to 6th year	-	-0.8560 *	0.5773 *	0.6029 *
Total number of leaves borne on the palm at the end of the 5th year	-	-0.8092 *	0.5438 *	0.5894 *
Flowering period	-	-	-0.5442 *	-0.5521 *

Source : Liyanage, 1962

Table 3. Mean yield of SLT x SLT and SLT x GD palms

Year after planting		SLT x SLT		SLT x GD	
		Per palm	Per Ha.	Per palm	Per Ha.
5th	Nuts	-	-	23	3,630
	Copra (Kg)	-	-	5.18	818
6th	Nuts	22	3,480	68	10,740
	Copra (Kg)	5.16	815	15.28	2,414
7th	Nuts	52	8,240	86	13,590
	Copra (Kg)	10.08	1,592	17.70	2,797
8th	Nuts	65	10,270	65	10,270
	Copra (Kg)	14.72	2,326	15.31	2,514
Total (A)	Nuts	139	21,970	242	38,230
	Copra (Kg)	29.96	4,733	54.07	8,543
9th	Nuts	84	13,270	103	16,270
	Copra (Kg)	18.24	2,882	21.17	3,345
10th	Nuts	88	13,900	108	17,060
	Copra (Kg)	19.11	3,019	27.04	4,272
11th	Nuts	121	19,220	129	20,380
	Copra (Kg)	30.57	4,830	32.49	5,133
12th	Nuts	161	25,440	146	23,070
	Copra (Kg)	41.31	6,527	40.91	6,464
Total (B)	Nuts	454	71,830	484	76,780
	Copra (Kg)	109.83	17,258	121.61	19,214
Total (A+B)	Nuts	593	93,800	728	115,010
	Copra (Kg)	139.79	21,991	175.68	27,757

Source : Liyanage, 1963 Yield per ha is based on 158 palms

Table 4. Performance of four types of progenies

Progeny type	Flowering period (mth)	Per palm		Per ha	
		Nuts	Copra (kg)	Nuts	Copra (kg)
SLT x GD	34.8	64	11.47	10,100	1,800
SLT x YD	37.1	67	11.61	10,590	1,830
SLT x RD	38.9	55	9.58	8,690	1,510
SLT x SLT	52.9	39	7.55	6,160	1,190

Source : Manthiratne, 1971 Yield per ha based on 158 palms. Mean yield of palms 9 to 12 years old

Table 5. Yield of nuts of the seed garden from 1982 to 1986

	1982	1983	1984	1985	1986	Mean
Nuts per ha	18,200	17,500	11,100	25,100	17,800	17,900
Total rainfall (mm)	1,236	1,209	2,389	1,305	1,014	1,431
No. of wet days	110	105	134	110	90	131

Source : Wickramarahte, 1987 Yield per ha based on 165 palms

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Cocos
Vol. 4, 1986
Jointly with T. Mankey, H. Luntungan,
A. Djisbar and S. Sufiani

COCONUT BREEDING IN INDONESIA - I

ABSTRACT

Coconut breeding work done in Indonesia from 1973 to 1983 under the auspices of UNDP/FAO Coconut Development Project is outlined.

In 1972, the Government was anxious to have improved coconut varieties and seed in large quantities within a short period, for the coconut development programme which had already commenced. Hence a bold and an imaginative programme, based on long experience of the senior author, was initiated to produce improved varieties and seed within10 years as against usual 20 years.

Four varieties/cultivars suitable for breeding were identified from a germplasm survey carried out in 11 provinces of Indonesia. They were: Nias Yellow Dwarf (NYD), Tenga Tall (TT), Palu Tall (PT) and Bali Tall (BT).

NYD was crossed with the three Tall forms to study performance of first generation progenies. Simultaneously, seed gardens were established using NYD as female parent and the three tall forms as male. They were capable of producing NYD x TT, NYD x BT and NYD x PT seed. Seed gardens were developed according to a new concept.

By 1982, F_1 palms of NYD x TT, NYD x BT and NYD x PT proved their superiority over the ordinary Tall, with respect to precocity for bearing and high production of copra. In 1983, over two million seed nuts of the improved varieties were available.

INTRODUCTION

Coconut breeding in Indonesia could be divided into three phases. Phase - I, work done by P.H.L. Tammes from about 1920 to 1935; Phase - II, work done by A.F. Innes from 1950 to 1960 and Phase -III, work done by authors of this article from 1973 to 1983. Unfortunately, breeding work has not been a continuous operation due to various difficulties. However, work accomplished in each phase is of considerable importance.

Phase - I : Tammes selected mother palms of the Tall variety from smallholdings in North Sulawesi and planted 1,400 open-pollinated progenies derived from 43 of them at Mapanget, North Sulawesi. Selfed progenies of some of these selected palms have been planted at the same station in 1933 (Tammes, 1958; Toar, 1973). Seed parents of these progenies cannot be traced now and their identity is not known. Thus, valuable information that would have been useful for development of improved varieties is lost (Liyanage, 1978).

Phase - II : Innes planted open-pollinated progenies of 13 palms from Mapanget in 1957 and 1958 in three groups, each with three replications. Out of 3,470 palms planted, 2,245 remained in 1975. This trial is of considerable importance to determine prepotency as female parents of the progenies are known (Liyanage, 1975; Toar, 1973).

A number of trials have been planted at Kima Atas Experimental Station near Manado between 1957 and 1959. They include F_1 progenies of sib-matings, paired and reciprocal crosses of palms at Mapanget.

Phase - III : The UNDP/FAO Coconut Development Project was initiated in 1972. Breeding work done from 1973 to 1983 is outlined in this paper.

THE BREEDING PROGRAMME

The Government directed that improved coconut varieties should be developed and their seed produced in large quantities quickly to meet requirements of the development plans already initiated to improve coconut industry. That was a dilemma and a challenge. Breeding and testing a variety take 12 years: three years for selection of parents, crossing them and collection of seed, one year in nursery and eight years for field testing. Multiplication of seed of improved varieties through seed garden technique requires another eight years. Thus, from the start of a coconut breeding programme to mass production of seed, at least 20 years are required. The Government was not prepared to wait so long. Hence a bold, non-conventional coconut breeding programme was carried out as the germplasm survey in Indonesia indicated availability of good genotypes.

Germplasm survey

A survey of coconut germplasm in selected areas of 11 provinces in Indonesia was carried out. Twenty five samples that represented a wide spectrum of populations, some exposed to selection pressure, were studied. That revealed 4 varieties/cultivars with desirable characters for breeding. They are (Liyanage and Corputty, 1975):

Yellow Dwarf (NYD) growing in Nias island. The population is homogeneous, palms are early bearing giving 188 g copra per unselected nut.

Tenga Tall (TT) cultivar from North Sulawesi. Copra per unselected nut 296 g.

Bali Tall (BT) from Central Java. Copra per unselected nut 340 g.

Palu Tall (PT) from Central Sulawesi. Copra per unselected nut 354 g.

Palms of the selected TT, BT and PT populations were homogeneously high yielding, giving about 3,500 kg copra per ha/yr. Weight of fruit components and ratios between them are given in Tables 1 and 2. Sample size varied from 30 to 40 nuts taken at random from heaps of nuts.

The programme

Having selected varieties/cultivars, the programme formulated is given below. In the project programme, testing varieties and establishment of seed gardens with parents that are likely to give good offspring were carried out simultaneously.

Objective of the breeding programme was to produce a variety showing precocity for bearing and high yield. Hence, NYD was selected as the female parent; TT, BT and PT as male parent.

Conventional method (yr.)	Item	Project programme (yr.)
1	Selection of germplasm and parents	1
2	Crossing selected parents and seed collection	2
1	Raising seedlings	1
8	Testing varieties and selection of varieties	8
8	Seed production in seed gardens	+
20	**Total**	**12**

+ Starts simultaneously with variety testing, hence no additional years.

A new concept for seed gardens

Hitherto, in production of Dwarf x Tall hybrid seed, practice has been to plant the female parent (Dwarf) in isolated blocks situated far from existing coconut palms. The idea is to produce seed without contamination from unknown palms. Therefore, each inflorescence produced in Dwarf palms is emasculated and female flowers are pollinated artificially with pollen collected from desired Tall parents to produce Dwarf x Tall hybrid seed. Emasculation and pollination have to be carried out practically every 24 to 28 days throughout the year.

In the new model developed in Indonesia, seed gardens are established within coconut plantations and not in isolated places. Dwarf (NYD) and male parents (TT, BT and PT) were planted within the seed garden. Four rows of Dwarf palms were followed by a row of Tall palms containing TT, BT and PT. A barrier consisting of 8 to 12 rows of these Tall cultivars surrounded the seed garden. This barrier prevents contamination of palms within the seed garden, with those outside it during process of pollination. Contamination rate was less than 3% with a 12-row barrier of palms. A total of 510 ha of seed gardens were planted between 1976 and 1978 at four locations in Indonesia based on this model (Liyanage and Hasman Azis, 1983).

Purpose of planting three Tall selections in the seed garden is as a precautionary measure. If variety tests conducted simultaneously show that a particular male parent does not combine well with the female Dwarf, then that parent could be removed from the seed garden without affecting quality of seed to be produced.

Testing hybrids

A crossing programme was carried out from 1975 to 1977, using NYD as female parents and TT, BT and PT as males. Five comparative variety trials were planted between 1977 and 1980 at five locations, on a randomized block lay out using F_1 progeny of the above crosses. Varieties studied were NYD x TT, NYD x BT, NYD x PT and open-pollinated progenies of NYD, TT, BT and PT.

RESULTS

Indonesian hybrids

Sufficient yield data were available only from variety Trials I and II, planted in January and December 1977 at Parunkuda, West Java and Mapanget, North Sulawesi respectively at the completion of UNDP/FAO project in 1983. These have been fully utilized in the present analyses. Mapanget has ideal conditions for coconut cultivation, but those at Parunkuda less favourable. These variations are reflected in growth and yield of palms.

Leaf production

Leaf production data of the five variety trials when palms were 12 to 24 months old *from date of sprouting of seed nuts* are given in Table 3. NYD has produced more leaves** than hybrids and Talls. Hybrids show dominance in leaf production and have produced more leaves** than Talls.

Leaf and stem characters

Table 4 gives eight measurements of leaf characters of the 14th leaf and two of the stem, made on palms in Trial I in order to study differences between varieties.

NYD characters, except stem length had the lowest values. Stem length was longer** than that of the three Tall cultivars and shorter* than the three hybrids.

There was no significant difference between male parents with respect to all the characters, except stem girth, where PT had a narrower* girth than BT.

Among hybrids, NYD x PT has the lowest number of leaflets, less than NYD x TT ** and NYD x BT*; differences between others were negligible.

When the three hybrids are compared to Tall male parents, hybrids have a shorter* rachis and leaf length, narrower ** and longer** stem. Leaf stalk girth and width of NYD x BT were smaller* than that of BT, but in the other two hybrids similar to Talls.

It is an advantage to have a short leaf stalk and a rachis to reduce leaf drooping, larger leaflet area to increase photosynthetic activity and a shorter stem to reduce height of palm. Three hybrids compared to Talls have shorter leaves, which is an advantage, a longer stem that is a disadvantage and practically similar leaf area.

Leaf axil of the first spadix

The first spadix appeared in 30th leaf produced after sprouting of seed nut in NYD, 46th leaf in Tall and 35th leaf in hybrid. Differences between three hybrids and three Talls were not significant. More leaves** have to be produced in hybrids and Talls to produce the first spadix; hybrids need fewer** than Talls and have taken a mid-parental value.

Hybrids have a distinct advantage over Tall cultivars with regard to the number of leaves that have to be produced in a young palm to initiate the first spadix.

Through out this paper statistical significance is given as follows: *P = 0.05, ** P = 0.05, ***P = 0.001

Precocity for bearing

There are three factors involved in precocity for bearing: initial flowering, splitting of spathe and the first harvest of fruits (Table 5). It is a cycle of events varying between varieties, a shorter period for each phase being advantageous. Duration of these phases is recorded from date of sprouting of the seed nuts, but relative data in published literature is given from date of planting seedlings in the field. To convert data presented here to the latter system, deduct 8 months from the mean value of each figure.

Initial flowering period

Average initial flowering period of the three hybrids in Trial 2 was 42 months of from date of sprouting of seed nuts and in Trial 1, it was 2.5 months later. Differences between them at each location are not significant. They have taken a shorter period** than Talls, but longer than NYD. Talls have averaged 53.5 and 61.4 months to flower at the two locations., differences between them at place being negligible. NYD has taken only 32.2 months, a much shorter period** than hybrids and Talls. Hybrids show precocity for flowering compared to Tall cultivars.

First spathe to split

First spathe to split is not necessarily the first one produced as the initial ones sometimes abort. Therefore, period taken for splitting of the first spathe is a better index than the flowering period. Hybrids in Trial 2 have taken 44 months, *i.e.* 2 months after noticing the first flower and in other trials 47 months. Differences between them at each location being not significant. Behaviour of Talls is similar, which is unusual and probably a result of efficient selection. Hybrids are at an advantage over Tall cultivars.

Bearing age of a palm

Bearing age of a palm is the period taken to harvest first bunch of fruits. It is a more economic factor than earlier definitions, as some spathes produced initially do not carry female flowers or the few produced are shed prematurely. This data for hybrids only are given in Table 5 as harvesting from some Tall palms has not started. Data are presented below as mean values:

		Bearing age from date of sprouting of seed nuts (mth)	
		Trial 1	Trial 2
Flowering period of hybrids	:	45	42
Opening of first spadix of hybrids	:	47	44
First harvest of hybrids	:	64	58

Yield of fruits and copra

Yield data for 3 years for Trial 1 (5th, 6th and 7th years after planting seedlings) and two years for Trial 2 (5th and 6th years) are given in Table 6. Unfortunately, these two trials went through a severe drought and its effect is reflected on the yield. Cumulative yield data per hectare of 147 palms for the above periods are given below:

	Trial 1		Trial 2	
	Nuts	Copra (MT)	Nuts	Copra (MT)
	(for three years)		(for two years)	
NYD x TT :	23,681	5.81	15,034	3.04
NYD x BT :	17,295	4.92	9,299	2.09
NYD x PT :	20,308	5.06	10,505	2.33
TT open pollinated:	2,657	0.73	408	0.08
BT " :	2,919	0.79	265	0.07
PT " :	2,595	0.67	798	0.19
NYD " :	24,503	3.91	-	-
LSD at 0.05 :	5,304	1.38	4,008	0.77
LSD at 0.01 :	6,571	1.71	5,069	1.08
C. V. % :	4.70	18.90	2.68	26.4

Hybrids have given more fruits** and copra** than Talls in the initial stages of bearing, differences between Talls being negligible. In Trial 1 yield of copra between hybrids is not significant, but in the other Trial NYD x TT has given more copra* than NYD x BT.

Effect of drought on hybrids

A demonstration block planted in East Java in November 1978 consists of Indonesian hybrids and the ordinary selected cultivar. Each variety was divided into blocks receiving high inputs and farmers level of inputs. This block was exposed to a prolonged drought lasting 6 consecutive months in 1982, resulting in heavy leaf drooping. The number of broken and dry leaves were counted and results are summarized below:

- Hybrids suffered more** than the Talls irrespective of management system.
- Hybrids in the intensive system suffered more** than those in non-intensive .
- Hybrids with non-intensive management suffered more** than Talls in the same system.

DISCUSSION

The coconut breeding programme carried out in Indonesia from 1973 to 1983 is non-conventional and unique. At the completion of testing new varieties during a period of 10 years, seed nuts of improved varieties were available in large quantities. This was a result of implementing the breeding programme and establishment of seed gardens simultaneously.

Germplasm survey carried out in Indonesia, indicated existence of valuable genotypes to increase copra production. The three selections TT, BT and PT turned out to be useful to produce precocious and productive hybrids in combination with NYD.

NYD x TT, NYD x BT and NYD x PT bred from intensive selections of indigenous material have grown more vigorously and showing precocity for bearing compared to the male parents. Yield of hybrids NYD x TT and NYD x PT in the 6th year after planting in Trial 1 (not exposed to drought) giving over 2.8 tons copra per ha/yr. is remarkable.

Another important character of these hybrids is that copra per nut is high. Combined cumulative yield totals for 3 and 2 years of Trials 1 and 2 respectively are:

NYD x TT	- 38,705 nuts have given 8,850 kg copra, equivalent to 229 g copra per nut.
NYD x BT	- 26,594 nuts have given 7,010 kg copra, equivalent to 264 g copra per nut.
NYD x PT	- 30,863 nuts have given 7,390 kg copra, equivalent to 239 g copra per nut.

Copra content per nut is high in each hybrid ranging from 229 to 264 g with NYD x BT at an advantage over the other two hybrids. When copra content per nut is high, cost of production of copra is proportionately less.

There are differences among the three hybrids. They could be graded as indicated below, considering characters of economic value from a Breeder's point of view, disregarding statistical significance:

Character	NYD x TT	NYD x BT	NYD x PT
Flowering period	0	0	0
Harvesting period	0	0	0
Yield of nuts	2	0	1
Yield of copra	2	0	1
Copra per nut	0	2	1
Appearance of crown	1	0	0
Tolerance to drought	0	0	0
Tolerance to pests and diseases	0	0	0
Total	**5**	**2**	**3**

0 = no advantage   1 = at an advantage   2 = at an extra advantage
Note: This comparison is between the three hybrids only.

Hybrids fall into the following order of merit according to data presented in this paper:

NYD x TT, NYD x PT, NYD x BT.

There are two unique features about the Indonesian Model of seed gardens. Male and female parents are planted within the garden. Seed is produced by natural pollination, eliminating the process of assisted pollination. As they are situated in coconut growing areas, cost of production of seed is low. Inclusion of three Tall cultivars is as a precaution. If by chance, variety trials show that a particular male combined with NYD does not give productive progenies, then that parent would be removed from the seed garden, retaining only the parents that combine well with NYD. Further, seed of high legitimacy is produced, contamination being only 2.6%.

Another advantage of this model is that Tall x Tall seed of a good quality could be produced, in addition to Dwarf x Tall seed. Since selected Tall cultivars grown within the seed garden are elite palms, cross pollination between them will produce progeny far superior to those derived through open pollination from selected 'mother palms'.

ACKNOWLEDGMENTS

Prof. Dr. Thojib Hadiwidjaja, Minister of Agriculture and Ir. Hasman Azis, Director, LPTI, Bogor were interested in this breeding programme and supported it. Had it not been for their foresight and sustained support in the face of severe criticism from vested interests, who were against implementation of this programme, it would have been aborted in the initial stages.

Success of the breeding programme was due to cooperation received from a number of staff members of the Institute for Industrial Crops (LPTI). Amongst them, particular thanks are due to Messrs. Ch. P. Corputty, A. Abdulla, Deswert, H. Sudasrip, Ausai, D. Sitepu, W.A. Baringbing, D. Hidayat, M. Mansur, M. Palilu, T. Toar and Suchawan. Also, to Prof. T.A. Davis, Coconut Agronomist of the Project, particularly for the study on effect of drought on palms in the observation plot.

REFERENCES

Liyanage, D.V. 1975. Coconut Breeding Program of the UNDP/FAO Coconut Industry Development Project. Document No. 2. Mimeographed.

__________ 1978. *Ibid.* Document No. 1. Mimeographed.

__________ and Corputty, Ch.P. 1975. Coconut germplasm in Indonesia. Paper presented at the '*Fourth Session of the FAO Technical Working Party on Coconut Production, Protection and Processing*'. Kingston, Jamaica.

__________ and Hasman Azis. 1983. A new technique for establishing seed gardens. *Cocos* 1: 01-06

Tammes, P.L.H. 1958. Review of coconut selection in Indonesia. *Euphytica*, 4 : 17-24.

Toar, T. 1973. Private communication,

Table 1. Weight of fruit and components

Variety/cultivar	Fruit		Husk		Nut		Endosperm		Shell		Endosperm thickness (mm)
	wt.	cv.	wt.	cv.	wt.	cv.	wt.	cv.	wt.	cv.	
Nias Yellow Dwarf (NYD)	1339	1.9	540	32.6	796	13.0	342	9.8	152	13.4	11.3
Tenga Tall (TT)	1842	14.1	633	29.6	1209	15.3	538	13.5	250	13.4	12.8
Bali Tall (BT)	1862	13.3	477	20.6	1385	13.1	619	12.7	282	12.8	13.3
Palu Tall (PT)	2005	16.0	438	24.6	1567	16.8	644	14.1	311	15.3	12.2
Typical Tall	1430	23.2	668	33.8	762	23.0	342	20.3	203	20.4	12.4

weight is given in grams cv. is given as a percentage endosperm thickness in mm.

Table 2. Ratios between fruit components (as a percentage)

		Husk/fruit	Nut/fruit	Endosperm / fruit	Endosperm / nut	Shell / nut
NYD	:	40.3	59.5	25.6	43.0	19.1
TT	:	34.4	65.6	29.2	44.5	20.7
BT	:	25.6	74.4	33.2	44.7	20.4
PT	:	21.9	78.2	32.1	41.1	19.9
Typical Tall	:	46.7	53.3	23.9	44.9	26.6

Table 3. Leaf production in 5 variety trials

	No. of leaves produced per plant from sprouting of seed nut								
	To 12 month age					To 24 months age			
Treatment / Trial No	I	II	III	IV	V	I	II	III	IV
NYD x TT	10.0	10.7	13.8	11.2	8.1	20.6	24.7	24.5	20.8
NYD x BT	10.5	10.5	10.5	10.2	8.2	21.9	23.0	20.6	19.4
NYD x PT	10.7	10.1	-	10.5	9.6	21.9	23.5	-	20.3
NYD x WAT	-	-	-	-	8.4	-	-	-	-
NYD x WAT	-	-	11.7	9.4	8.1	-	-	21.7	19.1
TT open pollinated	7.1	10.8	-	10.1	20.8	15.9	20.8	-	18.2
BT "	9.5	-	11.3	-	-	18.7	-	20.2	-
PT "	8.0	11.3	-	-	-	17.6	21.9	-	-
LSD at 0.05	0.8	0.7	0.6	0.4	0.9	1.1	2.0	1.3	1.0
LSD at 0.01	1.9	1.0	0.7	0.6	1.1	1.4	2.7	1.6	1.2

Trial I at Pakuwon, West Java Trial II at Mapanget, North Sulawesi Trial III at Gunung Anaga, West Java
Trial IV at Sukaraja, West Java Trial V at Segayung, Central Java

Table 4. Measurements of leaf and stem characters

					Hybrid			Hybrid Vs. male parent		
Character/Variety	NYD	TT	BT	PT	NYDxTT	NYDxBT	NYDxPT	NYDxTT	NYDxBT	NYDxPT
Stalk length (cm)	135.4	186.8	195.1	183.6	177.8	181.2	182.1	- 9.0	- 13.9	- 1.5
Rachis length (cm)	256.3	411.1	413.4	427.4	378.2	363.6	379.9	- 32.9**	- 49.8**	- 53.5**
Stalk + rachis length	480.7	597.9	608.6	626.0	556.0	546.3	556.3	- 41.9**	- 62.3**	- 69.9**
Stalk width (cm)	6.1	7.5	7.8	7.5	6.8	7.0	6.8	0.0**	- 0.5**	- 0.2
Stalk girth (cm)	9.2	12.1	12.5	12.1	11.3	11.3	11.0	- 0.8	- 1.3**	- 1.1**
Leaflet length (cm)	103.5	120.4	117.9	120.8	117.0	113.3	116.2	- 3.5**	- 4.6	- 4.6
Leaflet number	137.4	199.3	196.2	197.6	194.9	191.2	187.3	- 4.0	- 5.0	- 15.3**
Leaflet width	5.2	6.5	6.8	6.7	6.1	6.3	6.2	- 0.4	- 0.5	- 0.6
Stem girth (cm)	97.4	178.7	183.9	172.2	150.7	155.7	150.3	- 28.0**	- 28.1**	- 21.9**
Stem length (cm)	143.0	93.1	95.4	99.5	170.7	172.1	180.9	+77.7**	+ 76.7**	+ 81.5**

Notes on characters listed above: Stalk length - node to 1st leaflet. Rachis length - from 1st to last leaflet. Leaf length is stalk length + rachis length. Stalk width is the flat surface at 1st leaflet. Stalk girth is the curved surface at 1st leaflet. Leaflet length is that of the longest leaflet. Leaflet width is that of the longest leaflet. Stem girth taken 1 m above ground. Stem length is ground level to node with oldest green leaf.

Table 5. Initial flowering and harvest data of two dwarf x tall trials

Treatment	Initial flowering		Splitting of spathe		First harvest	
Trial	I	II	I	II	I	II
			Months from sprouting of seed nuts			
NYD x TT	45.3	41.2	48.0	43.1	65.1	56.1
NYD x BT	43.8	42.6	46.7	45.0	63.6	59.0
NYD x PT	44.4	42.1	46.8	43.8	64.2	57.8
TT open pollinated	63.4	56.0	65.4	57.3	-	-
BT "	59.6	52.0	61.7	54.0	-	-
PT "	60.9	52.6	63.0	54.3	-	-
NYD "	37.2	-	40.9	-	-	-
LSD (0.05)	3.67	5.78	4.32	6.11	-	-
LSD (0.01)	4.55	7.16	5.35	7.57	-	-
C.V. %	3.10	5.30	3.4	5.4	-	-

Table 6. Yield data of trials I and II

Treatment	Year	Trial I Nuts	Trial I Copra (mt)	Trial II Nuts	Trial II Copra (mt)
		per hectare		per hectare	
NYD x TT	5th	1,635	0.44	8,996	1.99
	6th	11,756	2.98	6,028	1.05
	7th	10,288	2.39	-	-
	Total	23,681	5.81	15,024	3.04
NYD x BT	5th	1,161	0.36	5,615	1.42
	6th	8,034	2.38	3,684	0.67
	7th	8,100	2.18	-	-
	Total	17,295	4.92	9,299	2.09
NYD x PT	5th	1,082	0.27	5,542	1.41
	6th	11,219	2.76	5,013	0.92
	7th	8,007	2.03	-	-
	Total	20,308	5.06	10,555	2.33
NYD open-pollinated	5th	3,339	0.60	Not included	
	6th	10,883	1.89		
	7th	10,281	1.42		
	Total	24,503	3.91		
TT open-pollinated	6th	625	0.17	408	0.08
	7th	2,032	0.56	-	-
	Total	2,657	0.73		
BT open-pollinated	6th	897	0.23	265	0.07
	7th	2,032	0.56	-	-
	Total	2,919	0.79		
PT open-pollinated	6th	422	0.11	798	0.19
	7th	2,173	0.56	-	-
	Total	2,595	0.67		

Notes : No. of nuts estimated on a basis of 147 palms per ha
Copra weight is calculated as 50% of wet endosperm weight
Weight of the endosperm of a random sample of 10% nuts harvested at each pick from each treatment plot was recorded.

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Cocos
Vol. 5, 1987
Jointly with H. Luntungan
and T. Mankey

COCONUT BREEDING IN INDONESIA - II
THE YIELD POTENTIAL OF IMPROVED VARIETIES OF COCONUT

ABSTRACT

The analysis of yield data collected from 986 progenies of Indonesian Tall x Indonesian Tall showed their high production capability: 123 nuts/32. 3 kg copra per palm/year. Six of them produced 168 nuts/58.11 kg copra per palm/year. Two families showed general combining ability and no in-breeding depression. They will be useful for breeding palms for high yield of copra.

INTRODUCTION

High yielding mother palms of Indonesian Tall (IT), (*Cocos nucifera,* var. *typica,* form *typica*) have been selected by P.M.L. Tammes from coconut groves in village gardens near Manado, North Sulawesi, Indonesia. He planted their open-pollinated progenies in 1926 and 1927 at the Coconut Experimental Station, Mapanget, North Sulawesi (Tammes, 1958). This constitutes the first generation of palms.

Subsequently, A.F. Innes used the Mapanget population for a crossing program and planted the progenies between 1957 and 1959 at Kima Atas Experimental Station, near Manado, North Sulawesi - the second generation. A large number of these palms is dead. H. Soedasrip and T. Toar at the Manado Branch of Lembaga Penelitian Tanaman Industri have collected whatever data available regarding Kima Atas population of palms and re-constructed the layout of trials and numbering of palms. Results presented in this paper are based on these records (Liyanage, *et al.* 1986).

Climatic conditions at Kima Atas are satisfactory for coconut cultivation. Soil is fertile, being of volcanic origin. The plantation has been neglected over the years, until management practices with application of NPK fertilizer were introduced in 1975.

MATERIAL AND METHODS

Numbering of palms

The system of numbering of palms adapted by Tammes in the Mapanget population is unique, *e.g.* 32 g 11, 83 f IV, etc.

32 g II : represents seedling No. g derived from mother palm No. 32 and planted in block II.
83 f IV : similarly, seedling f from mother palm 83 planted in block IV.

Material

The Kima Atas population is composed of 11 field trials with 986 palms. Trials are as follows:

A I, A II	: 4 half crossed to another half sib and 3 other palms.
B I	: 3 half sibs crossed to 2 half sibs and 2 other palms.
B II, B III	: reciprocal crosses between half sibs.
C I	: 6 half sibs crossed to 3 half sibs and 3 other palms.
C II	: 5 half sibs crossed to 2 half sibs and 3 other palms.
D I, D II	: 4 half sibs crossed to 1 half sib and 3 other palms.
E I	: 4 palms crossed to other palms.
F I	: 5 palms crossed to other palms.

Half sibs are taken as open-pollinated progenies of a single palm, *e.g.* half sibs of Palm No. 1 - I c II, 1 g III, 1 h III, etc.

Method of recording

Yield records of the 986 palms at Kima Atas were kept from August 1975 to July 1977. Data recorded at each pick were number of bunches, nuts and weight of husked-nuts. Six picks were harvested each year at bimonthly intervals. A sample of 5 husked-nuts taken from each pick was weighed. Total weight of husked-nuts at each pick was calculated on the basis of sample weight: 100 nuts taken at random from each trial were weighed and turned into copra. The relationship between husked-nut weight and weight of copra was 26 per cent. This ratio was used to estimate copra production.

Prior to commencement of yield recording, it was reported that there was considerable theft of nuts from Kima Atas. In order to reduce the error in yield data due to loss of nuts, the following procedure was adopted.

Prior to the first yield recording, bunches on crown of the palm was numbered serially 1, 2, 3.... beginning with oldest bunch and ending with inflorescence just open. Thereafter, number of fruits/female flowers on each bunch was recorded and continued at six-monthly intervals.

If there was a loss of nuts or bunches from any palm, an adjustment in yield data of that palm was made as follows. Say, bunch marked 10 has been removed. Number of female flowers borne on that palm is available. Mean percentage of female flowers developed into fruits in the 9th and 11th was calculated, and number of fruits in the 10th bunch was estimated on that basis. Weight of husked-nuts was also recorded on that basis. Fortunately, as loss of nuts was negligible, it was not necessary to apply this formula.

Statistical analyses

Field trials have been planted in a randomized block lay-out, presumably with an equal number of progenies per treatment. However, due to neglect of the plantation, a number of palms were dead, resulting in fewer than four progenies per treatment. Consequently, statistical analyses was done on a full randomization basis. Statistical analyses was restricted to yield of copra, as it is the most important economic character.

Statistical significance is indicated in the following pages as follows:

*	- significant at P = 0.05	***	- significant at P = 0.001
**	- significant at P = 0.01	ns	- not significant

RESULTS

Summary of data collected for two years 1975/76 and 1976/77 is presented in Table 1. Analyses of variance done for each trial separately with respect to copra production, showed that there were significant differences between treatments only in 5 out of 11 trials. They are:

Trial A I - Cross B > A *
" A II - " A, C > D **
" C I - " E > F *
- A, D > F ***
" D I - " B > C **
" E I - " A, B, C > G *
- D, E, F > G *

Generally, out-crossed progenies are superior to those of sib matings.

When data of 11 field trials at Kima Atas are regrouped, six families could be distinguished, each having selfed and out-crossed progenies (Table 2). Selfed is taken as crosses between half sibs and out-crossed as crosses between unrelated palms.

e.g. selfed : 1 c II x I g III
out-crossed: 1 h IV x 2 e 11

Family No.1 has originated from palm No.1 of IT selected by Tammes from the village groves and similarly for the others.

Out-crossed progenies of families 1, 2 and 99 have given significantly more copra than the selfed, indicating a loss in vigour due to selfing.

There are two field trials covering reciprocal crosses between half sibs (Table 3). Difference between reciprocal crosses with respect to yield of copra is not significant.

DISCUSSION

Yield potential

The Kima Atas population has given 123 nuts/32.3 kg copra per palm/yr, equivalent to 15,130 nuts/.3,970 kg copra per ha/yr, with a low density of 123 palms per hectare. Further, each nut has given 260 g of copra. These figures are generally far above yield data reported for *typica* palms grown on a large scale.

Present tendency is to plant 170 palms per hectare. Estimated yield on that basis, after deducting 15% for casualties, etc. will be about 18,000 nuts per ha/yr. A population of 5,700 progenies of Sri Lankan Tall x Sri Lankan Tall, growing at a seed garden in Sri Lanka, has given an average yield (5-year period) of 18,000 nut ha/yr, with a range of 17,500 to 25,000, under rain-fed conditions. Variations are related to the rainfall pattern. The block has 185 palms per hectare.

The Indonesian and Sri Lankan examples cited above clearly demonstrate the high yield potential of improved varieties of coconut.

There are six palms amongst the Kima Atas population that have given 52 kg of copra per palm/yr (Table 4). They have produced per palm/yr 18 bunches, 168 nuts/58 kg copra with 345 g copra per nut. The best yielder recorded 180 nuts/69 kg copra per year.

General combining ability

It is possible to assess the general combining ability of a coconut palm by crossing it to number of unrelated palms and studying family mean relative to the F_1 population mean.

The Kima Atas population has progenies of half sibs crossed to other palms, which are distributed over a number of field trials. They are grouped into six families (Table 2). Comparison of family means (yield of copra) using the 't' test gave these results:

		Palm No.					
Family No.	32	83	99	2	55	1	
32	:	-	ns	ns	*	**	***
83	:	ns	-	ns	ns	**	***
99	:	ns	ns	-	ns	**	***
2	:	*	ns	ns	-	ns	***
55	:	**	**	**	ns	-	**
1	:		***	***	***	***	**
Copra per palm/yr (out crossed) kg	:	36.26	35.46	34.95	33.65	32.62	30.18
Inbreeding depression (%)	:	nil	nil	14.6	14.6	nil	

Yield of copra per palm/yr is not significant between the three families 32, 83 and 99; 32 has given significantly more copra than 2, 55 and 1; 83 more than 55 and 1. Families 32 and 83 do not show an inbreeding depression. Further, amongst the best six high yielding palms at Kima Atas (Table 4), two of them have been derived by crossing half sibs of 32 and 83. Therefore, the parental palms 32 and 83 could be broadly classified as having general combining ability, broadly half sibs are involved in the study.

Inbreeding depression

If matings between half sibs are considered to be to be selfings, then the in-breeding depression could be calculated from Kima Atas Palms (Table 2) as follows:

Weight of copra of (out crossed - inbred) families divided by out crossed x 100.

Inbreeding coefficient has varied from 0 to 15%. Inbreeding depression was shown in families 1, 2 and 99, but not in families 32,55 and 83. It could be concluded that high yield of the latter group is not due to heterosis effects, probably to cumulative effects of genes.

Selfed and out-crossed progenies of families 32 and 83 have given 10% mare copra than the population mean, but not 55. Considering these factors, families 32 and 83 are valuable genetic material, suitable for breeding.

The potential of progenies of 32 x 83

Fortunately, there are 24 progenies of the cross 32 f II x 83 g III in Kima Atas population. They have given:

16 bunches per palm per year.
134 nuts "
38.95 kg copra "
291 g copra per nut.

Above production amounts to 16,500 nuts equivalent to 4,800 kg copra per ha/yr based on a density of 123 palms per hectare, *i.e.* density of the population.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge contributions made by the following:

A.F. Innes who planted the field trials at Kima Atas.

Staff of the Research Institute for Industrial Crops (LPTI), Indonesia : particularly, Hasman Azis, Ch. P. Corputty, H. Soedasrip, A. Djisbar, T. Toar, S. Sufiani and E. Ermawati.

United Nations Development Program and the Food and Agriculture Organization.

REFERENCES

Liyanage, D.V., Mankey, T., Luntungan, H., Djisbar and Sufiani, S. 1986. Coconut Breeding in Indonesia. *Cocos 4.*

Tammes, P.N.L. 1958. Review of coconut selection in Indonesia. *Euphytica* 4.

Table 1. Mean yield of palms in Kima Atas trial

Trial No.	No. of palms	Per palm per year No. of bunches	No. of nuts	Weight of copra (kg)	Calculated yield ha/yr No. of nuts	Weight of copra (kg)
AI	121	15.4	108	20.15	13,284	3,585
AII	118	15.8	124	33.28	15,252	4,093
BI	78	15.3	125	35.35	15,375	4,340
BII	59	15.6	111	25.16	13,653	3,095
BIII	42	16.5	130	34.14	15,990	4,199
CI	141	16.3	134	33.33	16,482	4,100
CII	73	15.9	125	31.63	15,375	3,890
DI	50	16.1	119	32.35	14,637	3,979
DII	62	14.9	114	36.61	14,022	4,503
EI	149	16.0	127	30.94	18,161	4,424
FI	93	15.9	124	34.49	15,252	4,242
Population mean		15.9	123	32.29	15,129	3,972

Note: E I has 143 palms per ha, all other trials 123 palms per ha.

Table 2. Data of Kima Atas palms on a family basis

Family No.	progenies	No. of bunches	Mean per palm per year No. of Nuts	No. of kg	't' value	Weight of copra CV, %	depression %	inbreeding
1	selfed	34	16	102	26.43		26.5	12.4
	out-crossed	136	16	113	30.18	2.79**	23.3	
2	selfed	25	16	111	28.89		23.2	14.1
	out-crossed	140	16	128	33.65	3.11**	26.0	
32	selfed	11	15	120	36.38		20.7	nil
	out-crossed	57	16	110	36.26	0.02	21.0	
55	selfed	46	16	115	33.34		21.6	nil
	out-crossed	148	15	121	32.62	0.56	21.4	
83	selfed	49	16	131	35.80		9.2	nil
	out-crossed	98	15	117	35.46	0.20	23.3	
99	selfed	70	16	123	29.85		23.2	14.6
	out-crossed	147	16	137	34.95	4.90**	20.7	

Table 3. Yield data of progenies of reciprocal crosses

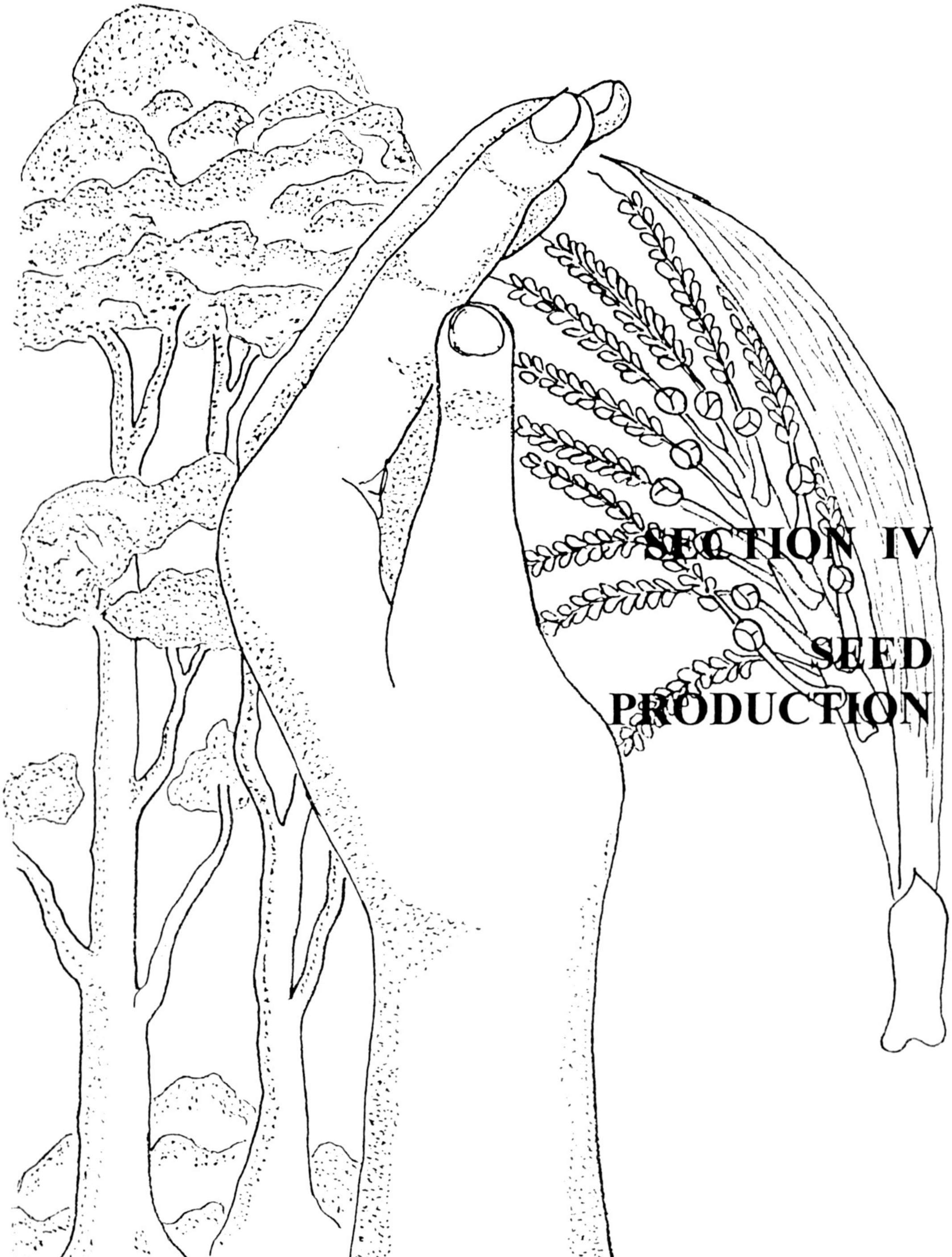
Block No.	Cross	No. of Progenies	No. of bunches	No. of nuts	Weight of copra kg	't' value	CV %
B II	80 b III x 80 c IIa	27	16	103	23.35		22.3
	80 c II a x 80 b III	32	14	116	26.70	1.25	27.4
B III	80 f II a x 82 h IIa	25	17	129	34.01		22.0
	82 h IIa x 82 f IIa	17	18	136	35.36	0.43	11.0

Table 4. Exceptionally high yielding palms in Kima Atas population

Block No.	Palm No.	Cross	Per palm per year Bunches	Nuts	Copra (kg)	Copra per nut (g)
A II	276	55 c IIa x 55 g IIa	15	150	55.69	370
B I	437	83 c IIa x 83 f III	18	173	54.04	310
D I	1,455	31 f IV x 55 g IIa	18	180	68.87	380
D II	1,668	32 g II x 83 g III	19	148	52.16	350
D II	1,686	32 g II x 83 g III	18	187	52.90	280
F I	2,379	1205/33 x 1230/33	17	170	64.97	380
		Mean	18	168	58.11	345

SECTION IV

SEED PRODUCTION



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Ceylon Coconut Quarterly
Vol. 12, 1960

USE OF ISOLATED SEED GARDENS FOR COCONUT SEED PRODUCTION

ABSTRACT

The present situation regarding genetic parameters pertaining to selection of coconut palms is reviewed. They have been considered to develop methods for mass production of seed. Although controlled pollination is feasible, only a limited quantity of seed could be produced in that manner, and that would not be sufficient to meet any extensive national programme for planting. This difficulty may be overcome by the use of isolated seed gardens.

Spatially isolated seed gardens are planted with palms of known parentage. Within the garden palms of high breeding value are used as female parents and the pollen source is limited to known male transmitters, thereby ensuring that seed to be collected is the result of crossing between desirable palms.

INTRODUCTION

The *typica* variety of coconut palms (*Cocos nucifera)* which is grown on a plantation scale in different countries is pre-dominantly out-breeding and therefore highly heterozygous. Consequently variation between palms with respect to shape, size and colour of fruit; quantity of copra per nut, number of nuts per palm and vegetative characters are considerable. Hitherto, mass selection has been practised extensively - collection of open pollinated seed from phenotypically superior palms.

In order to meet the national planting and re-planting programs in Ceylon, about 3,000,000 seed nuts are required yearly. This quantity of seed is collected from selected palms in selected high yielding blocks. Initially, high yielding blocks giving at least 15 cwt. copra per acre/year are selected and from them high yielding palms with desirable agronomic characters are marked. Seed collection is restricted to these palms only.

Response to selection for any character will depend on variations present in the population and on its heritability. Genic diversity between palms is considerable; heritability has been estimated for only a few characters. Measurement of the efficiency of any selection programme has to await evaluation of heritability estimates. Progress due to selection would be necessarily slow, as the life cycle of coconut palms is long.

ISOLATED SEED GARDENS

There are many difficulties in large scale production of quality seed coconuts, even if male transmitters are identified. Seed production has to be by hand pollination, which is a difficult and laborious process. It is physically impossible to raise large quantities of coconut seed by using that method. Seed gardens may be adopted to overcome these difficulties.

In forestry management in Sweden, use of isolated seed gardens is a standard practice in seed collection: "This is our trump card in forest tree breeding. It is the means of growing seed through controlled pollination in any desired quantity" (Larsen, 1956). They have the advantage of clone multiplication.

The Coconut Research Institute, Ceylon has already established an isolated coconut seed garden in the centre of a crown forest reserve (Liyanage, 1955) - see note below. First step is the opening up of a spatially isolated coconut plantation with seedlings of known parentage. Isolation is necessary to protect palms within the seed garden from contamination with pollen from other coconut palms. Agents of pollination of coconuts are largely insects (mainly *Apis indica*) and wind. The foraging area of the Ceylon honey bee has been shown to be not more than 750 yards from the bee hive in open country (Lindaur, 1955, unpublished). Forest vegetation to a depth of 350 yards has been found to give sufficient protection from coconut pollen carried by wind. Thus, an isolation belt of forest vegetation more than 750 yards wide is sufficient to protect the seed garden from unwanted pollen grains.

Next step is the identification of a sufficient number of male transmitters from palms within the seed garden. All remaining palms, except those identified as male transmitters should be emasculated regularly. Thus seed collected will be the result of natural pollination between female parents of high breeding value and the male transmitters. A large quantity of quality seed could be collected in this manner.

REFERENCES

Larsen, C.S. 1956. *Genetics of Silviculture.* Oliver and Boyd, London.

Liyanage, D.V. 1955. *Annual Report of the Coconut Research Institute,* Ceylon for 1955.
(an extract is given below)

An extract from the Annual Report of the Coconut Research Institute, Ceylon for 1955 (page 45)

<u>The seed garden.</u> The first programme on controlled pollination covers the establishment of an isolated seed garden for coconuts. The seed garden situated within Ambakalle forest reserve in Chilaw district was formally inaugurated on 23rd April, 1955 by the Minister of Agriculture and Food by planting a seedling. Since then, considerable development work involved in opening of jungle land has been in progress. 245 seedlings derived from crossing high yielding palms were planted in December 1955. Further 3,503 hand pollinated nuts were harvested and pollinations were done on nearly 16,500 female flowers, out of which about 30% are expected to develop. It is proposed to plant at least 25 acres a year from 1956 onwards.

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Cocos
Vol. 1, 1983
Jointly with Hasman Azis

A NEW TECHNIQUE FOR ESTABLISHING COCONUT SEED GARDENS

ABSTRACT

Four coconut seed gardens, covering an area of 510 ha. have been developed at four locations in Indonesia. Two of them are situated amidst coconut plantations. A barrier, 12 coconut rows deep, planted with the Tall strains used within the garden, reduced contamination. Dwarf x Tall seed nuts were produced with a high degree of legitimacy and the rate of contamination was 2.6%.

The high degree of legitimacy achieved is attributed to the mechanism of pollination of coconut flowers by honey bees and their behaviour - main agent for pollination. Ritual movements and body jerks of bees when they visit female flowers ensure that pollen grains and mites loaded with pollen, sticking to the bees, are not carried far from sources of their origin. Wind pollination is negligible.

Female and male parents of coconut are planted within the seed garden and seed is produced by natural pollination, thereby eliminating assisted pollination. Two types of seed are produced: Dwarf x Tall and Tall x Tall.

Indonesian model of seed gardens reduces the cost of seed production due to a number of factors: location of seed garden within seed distribution area, rather than in isolation, reduces expenditure on transport of seed nuts outwards and on supplies required for maintenance of palms inwards; elimination of expensive and tedious pollen processing and labour involved in assisted pollination; easier supervision and administration of the seed garden.

INTRODUCTION

Coconut seed gardens have been established in a number of countries for mass production of Dwarf x Tall seed. Their design and development vary. In one type, Dwarf palms to be used as female parents and Tall as male are planted in two separate, spatially isolated blocks. Seed nuts are produced by assisted pollination of emasculated Dwarf palms, with pollen processed from the Tall palm block. In another system, both female and male parents, in certain proportions are planted within the same block, situated in isolation from other coconut palms. Dwarf palms are emasculated and natural pollination with Tall palms is allowed to occur.

Previously, the minimum distance separating a seed garden from other coconut groves was decided on the flight range of honey bees and distance that wind can carry pollen. A 80 ha seed garden established in Sri Lanka in 1955, had a spatial isolation barrier of 1.3 km of forest. This distance was based on the flight range of *Apis indica*, the principal agent of pollination, which was considered then to be about 1.0 km (Liyanage, 1955). Subsequently, it has been shown that an isolation barrier of 300 m is sufficient to assure satisfactory legitimacy of seed (Nuce de Lamothe *et al.,* 1975). Coconut pollen is not carried through a thick jungle belt of about 320 m, even when winds are favourable (Manthiriratne, 1965). Still tendency is to establish seed gardens in isolated places far away from existing coconut plantations. This paper describes some improved techniques used for developing seed gardens in Indonesia.

INDONESIAN MODEL OF SEED GARDENS

Four seed gardens comprising a total area of 510 ha, situated in Aceh, West Java, South Sulawesi and North Sulawesi provinces were planted between 1976 and 1978. Yellow form of the Dwarf variety from Nias island was used as the female parent and three selected local Tall variety strains, *viz.* Tenga, Bali and Palu as male parents.

Tall strains used as male were derived from uniformly high yielding blocks under smallholder management. The population characteristics were (Liyanage and Corputty, 1975):

Variety	Ratios between fruit components (%)			Copra/nut	Copra ha/yr.
	Husk/fruit	Nut/fruit	Endos/nut	(g)	(kg)-estimate
Tenga Tall	34.4	65.6	44.5	296	3,500
Bali Tall	25.6	74.4	44.7	340	3,500
Palu Tall	21.9	78.2	41.1	354	3,600
Yellow Dwarf	40.3	59.6	43.0	188	-

The following design is used for each seed garden. Four rows of dwarf palms are followed by a single row containing the three Tall strains. In the Tall rows, single palms of Tenga, Bali and Palu are repeated serially maintaining that order. Thus every fifth row consists of Tall palms in the order Tenga, Bali, Palu, Tenga, Bali, Palu, etc. Surrounding the seed garden, there are 8 to 12 rows planted with the selected Tall strains. These rows form a barrier between the effective seed garden and coconut groves adjacent to it. This technique minimizes unwanted pollination of Dwarfs in the seed garden with palms and Tall palms outside the barrier. In two seed gardens, 8 rows of Tall palms form the barrier as coconut holdings are not within the immediate vicinity, but in the other two, 12 rows are used as village coconut groves are adjacent to them.

Rows of palms are 7 m apart in each seed garden. Along rows dwarfs are spaced 7 m and Tall 9.25 m. Square planting 7x7 m is too wide a spacing for Dwarfs, yet this system has been adapted to reduce their height to facilitate emasculation work. There are 9,068 Dwarf palms and 6,901 Tall palms, including those in the 12-row barrier, in the 100 ha seed garden in North Sulawesi.

Efficiency of the 12-row barrier of palms

Paniki seed garden (PSG) in North Sulawesi has coconut groves just outside the barrier. It has 12 rows of selected Tall strains in the barrier. Dwarf palms flowered earlier than Tall palms. Then Block I exposed to village groves on two sides was selected for a trial to test efficiency of the 12-row barrier. Dwarf palms in flower in this block were emasculated at intervals as necessary. This was done by splitting spathes open one or two days prior to their natural opening. Spadices in all the other five blocks were cut. Emasculation was carried out for five consecutive months. During that period, there was no pollen emanating from palms within the seed garden, subject to efficiency of emasculation, but pollen was available from palms in village groves, adjacent to the 12-row barrier of palms.

The control was a block of Nias Yellow Dwarf palms of same age as those in trial area and situated outside Paniki seed garden (PSG) amidst a coconut plantation. Natural setting of female flowers was allowed to occur without emasculation. Twenty five palms were recorded. Number of female flowers and fruits developing in each inflorescence after eight weeks from date of emasculation were recorded. Results were:

		Trial area (PSG)	Control
Total number of inflorescences	:	1,244	166
Total number of female flowers	:	9,738	1,845
Total number of fruits developing	:	404	460
Setting in all inflorescences (%)	:	4.1	24.9
Setting leaving out first 5 inflorescences (%)	:	4.7	31.4

In trial area in PSG, 4.1% of female flowers developed into fruits, against 24.9 in the control. Generally, first few inflorescence produced in young coconut palms carry only a small number of female flowers and if there is setting, the percentage will not be within normal range. Therefore, setting was calculated leaving out the first five inflorescences borne on each palm, in order to get over this bias. They produced an average of 17 to 21 female flowers, with a setting of 4.7% and 31.4% in the trial and control respectively. The low setting of female flowers in the trial can be attributed to lack of fertilization in the absence of pollen. This indicates that the 12-row barrier of palms is quite sufficient for protection of PSG palms from un-wanted pollen from palms in the neighbourhood.

Setting of some fruits in the trial after emasculation can be attributed to three possible causes: (a) faulty emasculation resulting in leaving out a few male flowers, (b) pollination with Tall variety palms outside seed garden, and (c) perhaps due to parthenocarpy.

In order to test this parthenocarpy theory, 12 palms that produced some fruits were selected. Two inflorescence in each of these palms were emasculated and covered with a bag. Since there cannot be any pollination from an outside source, any fruit development should be attributed to parthenocarpy. None of the 431 female flowers developed into fruits. Thus, parthenocarpy could be ruled out.

Whether 4.7% fruits produced in the trial are due to faulty emasculation or the result of cross pollination with palms outside the barrier, can be determined by germinating them. Colour of leaf stalks of germinating seed will give an indication: yellow due to faulty emasculation (true to mother type) and any other colour due to pollination with palms outside the barrier.

Out of the 93 fruits that were developing in the 6th to 9th inflorescence, 65 nuts were harvested, balance having dropped immaturely. These nuts were planted in a nursery; four seedlings were identified as Dwarf, 22 as hybrids and remaining 39 nuts did not germinate. In order to make a correction for fruits that did not germinate, assume that 95% of 65 fruits will germinate and that the ratio hybrids : dwarf will be 24 : 4. Then 52 seedlings out of the 65 fruits/1973 female flowers will turn out to be hybrids, equivalent to a contamination rate of 2.6%. Thus production of illegitimate seed is negligible.

DISCUSSION

Insect pollination

Interesting work on pollination of the Dwarf variety palms of coconut has been done in Indonesia (Jesmandt *et al.*, 1975; Moeso, 1979). According to these authors:

Many insects visit coconut flowers, but not all of them are pollinators, some being predators. Honey bee (*Apis indica*) and mites are important agents for pollination.

Mites (*Neocypholaelaps ampulula*) appear in newly opened spadices and disappear from them subsequently. Honey bee transport mites from palm to palm. When a bee visits a coconut inflorescence at the end of its male phase, hundreds of mites crawl up its legs and rest on the dorsal part of the thorax. The bee then visits another inflorescence, makes specific vibrating movements and during that process mites crawl down to the flowers.

Mites are loaded with pollen grains. Bees also carry pollen sticking to the legs outside the pollen sacs. When it next visits a female flower, mites and extra pollen sticking to its legs are shed on the flower during the ritual of rotations around stigmas. Thus, a honey bee cannot carry pollen grains of one tree, beyond two or three subsequent trees which it visits.

It is clear from these observations that honey bees and mites (indirectly) play an important role in pollination of the Dwarf variety of palms in Indonesia. Flight range of a local honey bee is large, up to 1.6 km, but when in search of pollen or nectar, it makes short flight landings on palms one after another in close proximity. Ritual movements that a bee performs after landing on a female flower, ensures that pollen grains and mites sticking to its legs are not carried far from their source of origin (Moeso, 1979). Thus, spatial isolation of a seed garden need not be related to the flight range of honey bees. The low setting of female flowers after emasculation, referred to earlier, substantiates this point.

Wind pollination

Wind is referred to as another agent for pollination of coconut palms. Just outside 120 m from the situation of Dwarf palms in Paniki seed garden, there are hundreds of coconut palms releasing pollen daily. But, only 2.6% seed has been produced in emasculated Dwarf palms with pollen derived from palms outside barrier. These data indicate that wind pollination of coconut palms is negligible - at least in Indonesia.

Natural vs. assisted pollination

The advantages of natural pollination in seed gardens are: hand pollination of female flowers is not necessary during any time of the year, thereby making it unnecessary to process pollen. Elimination of both these procedures reduces cost of seed production. Two types of seeds are available: Dwarf x Tall and Tall x Tall. Currently, production of satisfactorily high yielding coconut planting material requiring low inputs and suitable for growing under small holder conditions is gaining ground. Tall x Tall seed is likely to meet this requirement.

On the other hand, advantage of assisted pollination is attributed to flexibility, *i.e.* different male parents can be used to pollinate Dwarf palms in the seed garden periodically. This depends on progress of research, directed to identify male parents that combine well with Dwarf (as female) to give higher yielding progenies than at present. After all, research during the last 30 years has produced only about 3 to 4 high yielding Dwarf x Tall hybrid varieties. Differences between them cannot be evaluated in the absence of comparative trials. Since breeding new strains is a slow process in a perennial crop like coconuts, this type of flexibility is not so advantageous.

Location of seed gardens

A distinct advantage of the Indonesian model of seed garden is that it can be situated in coconut areas. One seed garden could be established in each province. Size would depend on demand for seed, but preferably, not less than 100 ha. This system reduces expenditure involved in transport of seed nuts to growers and also for transporting supplies required for maintenance of the garden from main city, compared to seed gardens located in isolated places. Further, supervision and administration are much easier. These factors contribute to a considerable reduction in cost of seed production.

Choice of male parents

The Indonesian coconut breeding program is unique in that variety trials are carried on simultaneously with the establishment of seed gardens. This is largely to save time. By the time performance of Dwarf x Tall progenies is evaluated from progeny trials, a large quantity of seed will be available from seed gardens for distribution. Tall strains have to be selected judiciously. Indications from trials are that the three types of hybrids - Dwarf x Tenga Tall, Dwarf x Bali Tall and Dwarf x Palu Tall - show precocity for early bearing and have a good potential for yield. Their total production of copra per ha will be practically the same, but there will be differences in copra per nut. However, if any particular Tall strain produces hybrids with a lower yield, it could be removed from the seed garden without any detrimental effects.

If a genetically uniform variety is grown in large areas, risks due to pest and disease damage are likely to be more than when hybrids of greater genetic diversity are planted. Seed gardens with more than one male parental type, will produce progenies of different genotypes, that will be adaptable to a wider range of environmental conditions, as is the case with the Indonesian model.

ACKNOWLEDGEMENT

Our thanks are due to Prof. Moeso Suryowinito for advice; Prof. T.A. Davis and Mr. Sudasrip for initiating the emasculation trial at Paniki seed garden; Messrs H. Tampake and J. Dmmalik for supervision of field work.

REFERENCES

Jesmandt, S., Santianawaty and Moeso, S. 1975. The pollination of the Dwarf type of coconut. Paper presented at *The Fourth Session of the FAO Working Party on Coconut Production, Protection and Processing.* Kingston, Jamaica.

Liyanage, D.V. and Corputty, Ch. P. 1975. Coconut germplasm in Indonesia. *Ibid.*

Nuce de Lamothe, M. and Rognon, F. 1975. Assisted pollination and contamination by undesirable pollen. *Ibid.*

Liyanage, D.V. 1975. Annual report of the Coconut Research Institute, Ceylon.

Manthriratne, M.A.P.P. 1965. Coconut pollen. *Ceylon Coconut Q., 16.*

Moeso Suryowinoto. 1979. Personal communication.

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Cord
Vol. 4, 1988

COCONUT SEED GARDENS : A REVIEW

ABSTRACT

Coconut seed gardens are necessary for the mass production of improved coconut cultivars. They will play a dominant role in development programmes until tissue culture techniques create new plants. Models of seed gardens developed in Sri Lanka, Indonesia and Ivory Coast are outlined. Differences between them with regard to structure and management are enumerated.

The necessity for seed gardens

The coconut palm (*Cocos nucifera* L.) has a single growing point, which contributes to the elongation of stem and formation of leaves. Axillary buds generally develop into inflorescences without branching. Hence , asexual propagation is not possible under normal conditions.

A selected palm produces about 50 nuts per year with artificial pollination. If a million seed coconuts are required, 20,000 palms have to be pollinated - an expensive and nearly impossible task.

Therefore, the concept of seed gardens was developed for mass production of seed. It is a special coconut plantation, carrying palms of known identity for production of particular types of seed. It should have an isolation barrier, sufficiently wide to prevent cross pollination of palms within the seed garden with those in the neighbourhood. A large quantity of seed could be collected from them under natural pollination (Liyanage, 1953,1960).

SRI LANKAN MODEL (SLM)

The objective of the first coconut seed garden developed in Sri Lanka beginning 1955 was mass production of seed of an improved cultivar of Sri Lankan Tall (SLT) palm. It is largely cross-pollinated. The principal agent of pollination was considered to be the honey bee (*Apis indica*) then. Wind pollination was negligible.

Based on these factors, the concept was to grow an improved cultivar of SLT in an isolated block. The cultivar was the offspring of SLT x SLT crosses. It was considered that a forest barrier 800 m wide all round the block would prevent cross pollination of palms within the block with those outside. This forms an isolated seed garden.

Initially, a 40 ha block of land from a forest reserve with the required isolation barrier was acquired to establish the seed garden. It was planted with offspring of SLT x SLT. The parents were selected on a basis of high yield of copra and desirable morphological characters. Later it was enlarged to 125 ha.

When palms in the seed garden flower, natural cross-pollination takes place between them. Emasculation of inflorescences is not necessary. Resulting seed nuts are SLT x SLT of a high quality and a high degree of legitimacy.

Although the seed garden is situated in a marginal area for coconut cultivation with about two months of drought occurring twice a year, production under rain-fed conditions has been high. Data given below show how the crop has fluctuated between 11,000 and 25,100 nuts ha/yr depending on rainfall.

Year	1982	1983	1984	1985	1986	Mean
Nuts per ha.	18,200	17,500	11,100	25,100	17,800	17,900
Total rainfall (mm)	1,236	1,209	2,389	1,305	1,014	1,431
No. of wet days	110	105	134	110	90	110

In the year 1985, production exceeded 25,000 nuts per ha as rainfall and distribution in the previous year were satisfactory. In 1984, yield dropped to 11,000 nuts per ha due to adverse climatic conditions prevalent in 1983. Thus, it could be expected that plantations raised with seed of the isolated seed garden, would give about 18,000 nuts ha/yr under rain-fed conditions and over 25,000 nuts ha/yr with irrigation.

Under satisfactory environmental conditions, one hectare of seed garden will provide seed to plant 50 ha of land, assuming 20% seed rejection, 30% rejection in nursery and plant 185 seedlings per ha. The ratio with irrigation is 1 : 75.

The Coconut Research Institute, Sri Lanka has established two more seed gardens at Makandura (58 ha) in 1985 and Maduruoya (85 ha) in 1986 to produce an improved cultivar of SLT. Both of them are based on the Indonesian Model, referred to later in this article.

The SLM of seed gardens was designed initially for mass production of an improved cultivar of SLT palms. It was subsequently modified to produce, in addition, Green Dwarf (GD) x SLT hybrid seed. In November 1959, a block (3 ha) within the seed garden was planted with GD. The inflorescences of GD were split open prior to their natural opening and emasculated, so that pollen of this form does not contaminate the seed garden. Seed collected from GD is a result of natural crossing with SLT.

If the purpose of seed garden is for production of hybrid seed only, number of SLT male parents should be minimal. A ratio of 81 seed parents to 9 pollen parents is a satisfactory combination for production of hybrid seed (Manthriratne, 1983).

It is possible to improve further quality of seed nuts derived from SLM seed gardens by restricting the pollen parents to selected superior palms only.

INDONESIAN MODEL (IM)

The objectives of seed gardens developed in Indonesia by the author under UNDP/FAO Coconut Development Project were two-fold: mass production of hybrid seed and also seed of improved cultivars of Indonesian Tall (IT) palms.

Four varieties/cultivars of coconut were identified after carrying out a germplasm survey in Indonesia. They were found in uniformly high yielding blocks with the following population characteristics (Liyanage and Corputty, 1975).

	Copra per nut (g)	Copra ha/yr (kg)
var. *typica*		
Tenga cultivar (TT)	296	3,500
Bali cultivar (BT)	340	3,500
Palu cultivar (PT)	354	3,600
var. *nana*		
Nias Yellow Dwarf (NYD)	188	-

Having selected the four varieties/cultivars, they were planted in a block within an existing coconut plantation, taking particular care to minimize cross-pollination between palms within and outside the block by a special process of isolation (Liyanage and Azis, 1983).

Four rows of NYD followed by a row containing TT, BT and PT were planted. Every fifth row is planted with the latter in the same order. Surrounding seed garden are 12 rows planted with above three cultivars to form a barrier, preventing palms inside seed garden being pollinated with those outside the barrier.

NYD palms are emasculated regularly, but not the IT cultivars. NYD will be pollinated with pollen from the latter palms and IT will cross between themselves, all under natural conditions without artificial pollination. Types of hybrid nuts gathered from Dwarf palms are NYD x TT, NYD x BT and NYD x PT; also improved cultivars of IT - combinations of crosses between TT, BT and PT.

The three IT cultivars were planted in the seed garden as a safety precaution, as performance of hybrid combinations were not known at the time of planting. In the accelerated breeding program carried out in Indonesia, variety trials and seed gardens were planted simultaneously. Should any one of hybrid combinations prove subsequently to be uneconomical, the respective tall cultivar will be removed from the seed garden (Liyanage *et al.*, 1986).

A 100 ha seed garden in which dwarf palms were planted 7 x 7 m apart and IT 7 x 9,25 m contains 9,000 dwarf palms and 6,900 IT palms, including those in the barrier. The Research Institute for Industrial Crops, Indonesia planted 510 ha of seed gardens at four locations based on Indonesian Model between 1975 and 1978.

IVORY COAST MODEL (ICM)

Seed gardens were planted in Ivory Coast initially on the SLM basis having female and male parents in the same block with adequate isolation. The arrangement was to have two rows of yellow dwarf (YD) followed by a row containing YD and West African Tall (WAT). Female and male parents were in the ratio of 5:1. Isolation barrier was 200 m of forest cover. Dwarf palms were emasculated regularly for production of hybrid seed (Nuce de Lamothe and Rognon, 1972).

Subsequently, above design was changed to carry only female parents in the seed garden (ICM). They were emasculated and pollinated with pollen collected from palms growing outside the garden - assisted pollination.

They claim that with assisted pollination, several selected coconut cultivars could be used as male parents at different times to pollinate YD, to produce different types hybrid seed. Assisted pollination requires collection, processing and storage of pollen.

Coconut seed gardens have been developed in Ivory Coast, the Philippines and in Jamaica based on ICM, for exclusive production of dwarf x tall seed.

DISCUSSION

Efficiency of parental selections in the IM:

The Government of Indonesia required from 1972 large quantities of improved seed for development of the coconut industry. None was available then. UNDP and FAO were requested to assist them.

In the absence of coconut variety trials in Indonesia, the author carried out a bold, imaginative and accelerated breeding program. Variety trials and seed gardens were established simultaneously, knowing that hybrids between selected palms of dwarf of Malaysian origin and selected tall cultivars produced early bearing and high yielding offspring. The variety trials proved this assumption 10 years later (1982). Large quantities of hybrid seed were available to the industry then (Liyanage *et al.*, 1986).

Efficiency of the barrier of IM

Isolation of the seed gardens with coconut palms, rather than with forest trees, was based on some important observations made by Indonesian scientists (Jesmaudt, 1975). They pointed out that mites living on coconut inflorescences are the real agents of pollination in coconut. They are transported from palm to palm by the honey bee and pollen sticking to their bodies is shed on the second or third inflorescence that bee visits (Jesmaudt *et al.*, 1975).

Thus, when bees visit palms in the seed garden, they carry mites with pollen collected from inner rows of the barrier, *i.e.* from known IT cultivars. Barrier composed of 12 rows of IT cultivars reduces considerably inflow of pollen from palms outside the barrier to seed garden proper. Contamination was only 2.6%. IM seed gardens produce NYD x IT and IT x IT seed with a high degree of legitimacy (Liyanage and Azis, 1983).

Comparison between the three models

The three models of seed gardens differ in structure: SLM and IM have both female and male parents growing within the seed garden, whereas ICM carries only the female parent. Natural cross pollination occurs between palms in SLM and IM; artificial pollination has to be carried out in ICM. This involves pollen processing, labour for pollination and supervision which increase cost of production of nuts.

Two types of seed are available from SLM and IM: hybrid and Tall cultivars, whereas ICM gives only hybrid seed. The advantages of IM being located in coconut growing areas are numerous:

- Inward and outward transport of inputs for the seed garden and seed respectively are cheaper,

- supervision and administration are cheaper and easier,

- staff attached to the seed garden live near towns where marketing and educational facilities are available, and

- these factors considerably reduce cost of production of seed nuts.

An advantage of ICM over the other two models is that it could produce different types of hybrid seed, provided female parent remains the yellow dwarf in new combinations.

Seed gardens will remain a dominant force for production of coconut seed until tissue culture succeeds in creating new plants.

ACKNOWLEDGEMENT

Thanks to Christie Perera, Librarian, Coconut Research Institute, Sri Lanka for a quick bibliography search.

REFERENCES

Nuce De Lamothe, M. and Rognon, F. (1972). The production of hybrid coconut seed by controlled pollination. *Oleagineaux* 01.

Jesmaudt, S., Santinawaty and Moeso, S. (1975). The pollination of Dwarf type of coconut. Paper presented at the *FAO Working Party on Coconut Production, Protection and Processing.* Kingston, Jamaica.

Liyanage, D.V. (1953). An isolated seed garden for coconut. *Ceylon Coconut Quarterly.* 12 (3/4).

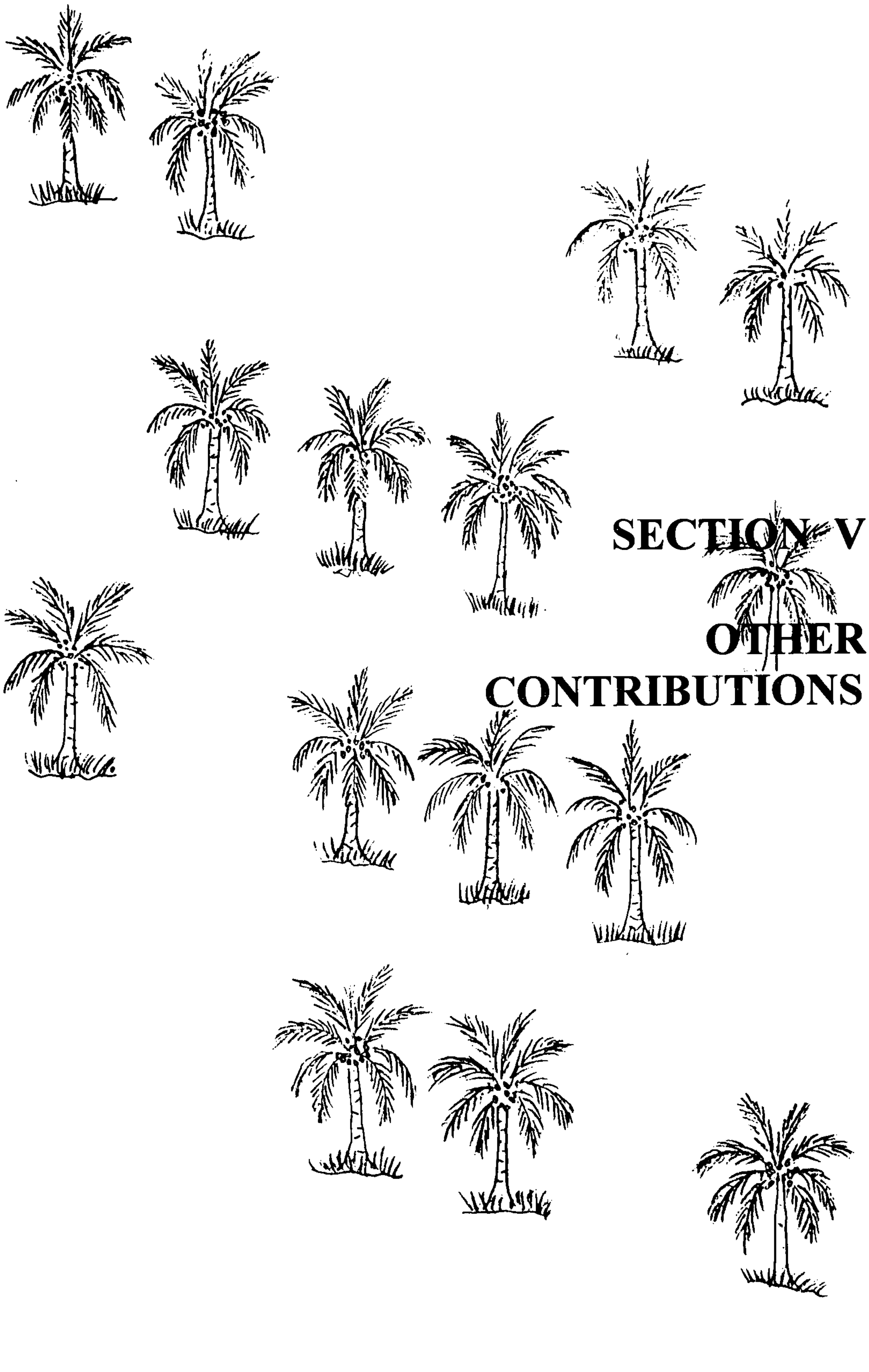
__________ (1960). The use of isolated seed garden for coconut seed production. *Ibid.* 12 (3/4).

__________ and Hasman Azis (1983). A new technique for establishing coconut seed gardens. *Cocos* 1.

__________ Mankey T., Luntungan H., Djisbar A. and Sufiane (1986). Coconut Breeding in Indonesia - 1. *Cocos* 4.

__________ and Corputty Ch. P. (1975). Coconut germplasm in Indonesia. Paper presented at the *Fourth Session of the FAO Working Party on Coconut Production, Protection and Processing.* Kingston, Jamaica.

Manthriratne M. A. P. P. (1983). The mechanics of hybrid seed production through seed gardens. *Coconut Research and Development.* Edited by N.M. Nayar. Wiley Eastern Ltd. New Delhi.



SECTION V

OTHER CONTRIBUTIONS

18

Ceylon Coconut Quarterly
Vol. 6, 1955

HEDGE PLANTING FOR COCONUTS

SUMMARY

As available planting material in coconuts is variable, a system of hedge planting is suggested whereby more seedlings than necessary are transplanted and selectively thinned to a required density, so that the ultimate stand is composed of high yielding palms. Theoretical considerations are adduced in favour of this system of planting, but no definite recommendation is made due to lack of supporting experimental evidence. The Institute is initiating a field trial to compare hedge planting with the conventional method of planting.

INTRODUCTION

Since coconut palms were planted on a plantation scale in Ceylon, the common practice has been to transplant seedlings at the corners of a geometrical figure: a square, rectangle or triangle so that plants within rows or columns are in straight lines. It is difficult to conceive how this practice originated; presumably the European settlers who were conversant with systems of planting orchard crops introduced it to the island. Let us examine the genetic make up of available planting material and consider whether maximum yield could be obtained from an unit area with the orthodox system of planting.

VARIATION BETWEEN PALMS

The variety of coconut palms grown on a commercial scale in Ceylon is heterozygous due to cross pollination, and in the absence of any known methods of vegetative multiplication, there is considerable variation between plants raised from seed nuts. Each plant has its own gene dose different from the others. Multiple genes determine the yield of copra and their expression depends on the environment. Consequently, it is unlikely that a uniform stand of good palms could be obtained however much coconut seedlings derived from *open-pollinated* seed nuts are selected, at least during the first few generations of a selection program, unless the stand is thinned.

A cursory glance at any coconut plantation would reveal the extent of variability between palms. These variations are illustrated in Fig. 1 and Tables 1, 2 and 3. Fig. 1 represents summarized data collected for a period of 20 years from a block of 300 palms about 60 years old. Tables 1, 2 and 3 represent data collected from the 11th to 14th year of a younger plantation, planted in 1939 with stringently selected seedlings.

In Fig. 1, vertical hatching covers segments of the curves where a smaller percentage of palms has given a larger percentage of the crop and horizontal hatching where more palms have given a smaller crop. *Note that 30.0% of the palms giving less than 59 nuts a year has contributed only 19.7% of the total crop, whereas 33.8% of palms giving more than 80 nuts a year has contributed 44.0%.*

These statistics are for a high yielding block with an average of 70 nuts per palm/year and if a low yielding block is considered, a higher frequency of palms giving poor returns is likely. It is these palms that offset good average yields possible from a plantation.

Above tables indicate variation between palms in spite of stringent selection of seedlings derived from open-pollinated seed nuts. Nearly 30% palms are late flowering - more than 7 years - and low yielding , less than 40 nuts/20 lb. copra per palm/year.

Besides variations in yield and flowering age, other differences occur, *e.g.* orientation of crown, length of bunch and leaf stalks, size of nut, tolerance to drought and water logging, differential responses to manure, etc.

HEDGE PLANTING

One possible approach to the problem is to change present conventional system of planting to hedge planting, where more plants than necessary are transplanted and systematically thinned to a required density. It is possible to space rows as usual and plant about 30% more seedlings within each row. During the first three years after transplantation, palms that show poor growth should be removed. In a field trial at Bandirippuwa placed in a low lying area, about 20% of the stand could have been removed due to poor growth within first three years. Remaining extra palms could be removed in 6th and 7th years, out of those showing undesirable characters and late flowering types. Remaining palms conform to required density with desirable characters.

For instance, for a final density of 74 palms per acre, planting could be done in the following manner. Rows are lined 28 feet apart and within them planting holes are marked 16 feet apart, so that each hole alternates with that in the adjacent row. Thus, 97 holes are marked per acre and a seedling planted at each site, *i.e.* 30% more. Thereafter, each plant should be examined periodically and those that fall below the required standard uprooted, leaving 74 palms per acre eventually.

With the orthodox method of planting, a spacing of 24x24 feet on the square system or 26x26 feet equilateral triangular system gives 74 palms per acre. Palms are uniformly spread in rows and columns, whereas in hedge planting only rows are evenly spaced.

The intrinsic advantage of hedge planting is that by the 10th year of planting, a uniform stand of good yielding palms could be obtained without affecting density or age uniformity. It may be said that thinning could be done even with the orthodox method of planting. Yes, with a difference! Each plant removed has to be replaced: If a three old young palm is thinned out, three years are lost, as supply would take the same period or more to attain growth of replaced palm.

Spacing of palms within rows in hedge planting may be irregular as three to four adjacent palms may give good yields and consequently not removed or *vice versa.* It is unlikely that such juxtaposition of palms would adversely affect their growth and yield. In support of this hypothesis there is an observation of Preuss (1921) that 'A common observation that appears to me to be worthy of note here is the presence of small groups of 3 to 6 palms, not more than 10 to 16 feet apart from one another, which are very heavy yielding and, in this respect scarcely inferior to single palms normally spaced.' Even in village gardens, groups of five to six productive palms spaced not more than 12 feet apart are common.

With hedge planting land between rows could be planted conveniently with inter-crops. Hedge rows could be on contours. Expenditure is about 30% more during the first two years on holing, filling, cost of plants and upkeep. After the 8th year, when required stand is established, expenditure is same as with conventional planting. Increased expenditure during the early stages is likely to be more than compensated with increased yields from the plantation.

Hedge planting has been successfully adopted in other perennial crops, *e.g.* rubber, forest and fruit trees. At one time mixed planting of rubber and coffee was done in Indonesia; rubber grown in hedge rows 27 feet apart and coffee in spaces between them. According to Dijkman (1951), 'Both commercial and experimental data from such plantings have shown that rubber trees in these avenues, selectively thinned on a basis of yield up to 30% of the original stand, produced 30 to 50% more than conventional rubber plantings of the same clones or seedlings initially planted on 6x6, 6x7 or 7x7 metre spacing and selectively thinned from 20 to 30%'.

Considering that in these crops more homogeneous planting material is available and yet more plants than necessary are planted and selectively thinned to the required density, the case for hedge planting manifests itself more in the case of coconut palms, as available planting material is heterogeneous.

REFERENCES

Preuss, 1921. *Die Kokos palmae and ihre kulture.* Extract from a translation by W.V.D. Peiris.

Dijkman, M.J. 1951. *Hevea- nearly 30 years of research in Far East.* University of Miami Press.

Table 1. Frequency distribution of flowering period of palms

Flowering age (months)	Frequency of palms	Percentage of total
54 - 59	3	3.8
60 - 71	29	36.7
72 - 83	25	31.6
84 and over	22	27.8

Average flowering period = 78.3 months

Table 2. Frequency distribution of yield of nuts per palm/year

Yield of nuts	Frequency of palms	Percentage of total
0 - 19	15	9.4
20 - 39	25	15.6
40 - 59	56	35.0
60 - 79	36	22.5
80 - 99	23	14.4
100 - 119	5	3.1

Table 3. Frequency distribution of yield of copra per palm/year

Yield copra (lb)	Frequency of palms	Percentage of total
0 - 9	18	11.3
10 - 19	26	16.3
20 - 29	42	26.3
30 - 39	40	25.0
40 - 49	27	16.9
50 - 59	7	4.4

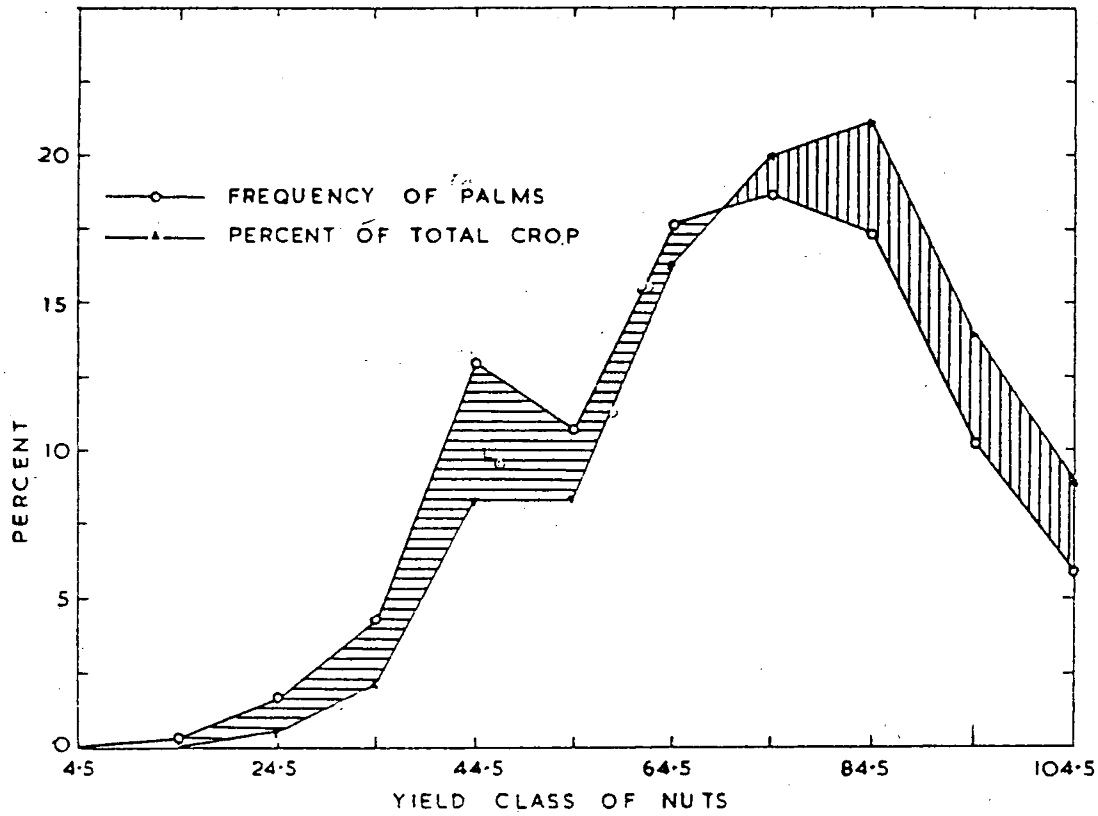


Fig. 1 The frequency of palms and the percentage of the crop contributed by each yield-class of a high-yielding block.

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Ceylon Coconut Quarterly
Vol. 14, 1963

METHODS OF UNDER-PLANTING IN SENILE COCONUT PLANTATIONS

SUMMARY

Results of three methods of under-planting coconut plantations are presented. The late thinning system is not suitable, as bearing age of young palms are unduly delayed due to the presence of old stand of palms. New clearing system is not desirable from an economic point of view, due to total loss of crop from old stand of palms. Gradual thinning system seems to be a feasible method of under-planting

INTRODUCTION

A number of coconut plantations in Ceylon have reached a condition of total senility showing a progressive decline in production. The age at which a coconut palm reaches this condition cannot be defined precisely, as a number of environmental factors are involved. A reliable index is the yield: if production decreases gradually in spite of regular cultivation, balanced manuring, good management and without adverse effects of pests and diseases, then it could be presumed that decline is due to age of palms. A field trial to study the relative merits of three systems of under-planting was planted in May 1950. Data collected are presented in this paper.

No attempt is made to discuss regeneration of palms in general. Some of these aspects have been referred to in CRI Bulletin No. 5 by W.V.D. Pieris. However, it is pertinent to refer to a system adopted by some progressive estates of a process of selective thinning of palms from the time seedlings are planted. Young palms that are not vigorous and adult palms that are not yielding enough are uprooted periodically and selected seedlings are planted at the same sites. Then palms will vary in age, question of senility of a plantation would not arise.

DESCRIPTION OF THE EXPERIMENT

The experiment was carried out at Bandirippuwa Estate on a block of palms with senile palms. Planting distances were not regular, with a density of 64 palms (approx.) per acre. Soil was largely a sandy loam, liable to water logging. Three methods of under-planting were tried out:

<u>Late thinning</u> : Under-planting with the old palms remaining and removing them 8 years later.

<u>Gradual thinning</u> : Under-planting and removing old stand of palms gradually during the first 8 years. In this case, 12% of the old palms close to new planting sites were

removed before transplanting seedlings. Thereafter, old palms were removed yearly. At the end of each year, percentage of old palms remaining was as follows:

1st year - 82	2nd year - 72	3rd year - 60	4th year - 42
5th year - 32	6th year - 20	7th year - 8	8th year-none

During the first two years, all old palms within 8 feet from the new planting sites were removed, thereafter removal was based on yield of nuts per palm.

New clearing : Planting after complete removal of old palms.

Design of the experiment was randomised lay out, with 7 replications and 25 palms per plot, each plot being separated by a guard row of palms. Selected seedlings were planted 26 x26 feet on the square system. Manuring and cultivation were done regularly.

Data collected from each palm - leaf production during the first 5 years , flowering period, yield of nuts and weight of husked-nuts. Analysis of variance was done after appropriate transformation of raw data.

RESULTS

Leaf production

Leaves produced per plant, excluding those not dissected were recorded at the end of each year. Data from the 1st to 6th year are given in Table 1. The six years data have been treated to a combined analysis of variance and the following factors were significant: blocks ($P = 0.05$), treatments ($P = 0.01$), years ($P = 0.001$), years x treatments ($P = 0.001$). As both treatments and interaction years x treatments are significant, it is sufficient to study interaction.

The pattern of yearly leaf production during the first six years of growth of young palms was related to treatment type. Leaf production was practically the same for all treatments in the first year. Plants in new clearing treatment have produced significantly more leaves than those in the other two treatments from second to sixth year. Leaf production between gradual thinning and late thinning treatments has been in favour of the former from fourth year onwards. The three systems of under-planting could be placed in the following order of merit: (i) new clearing, (ii) gradual thinning and (iii) late thinning.

Flowering period

Flowering period of a palm is the period from transplanting a seedling to emergence of the first spathe. Palms in flower, cumulative for each year are given in Table 2.

Variance ratio for each year was significant, indicating that type of treatment had an effect on flowering. From 7th to 10th years, significant differences existed only between new clearing and late thinning treatments, differences between other combinations of treatments being not significant. Presence of the old stand of palms in late thinning treatment has retarded growth of the second plantation considerably, that only 55 percent of young palms were in flower in the 9th year, whereas over 74 percent flowered in the other two treatments.

Bearing age

Bearing status of palms was related to the treatments (Table 3). A full bearing palm was taken as one that gave a crop in the first harvest gathered at beginning of a year or prior to that.

Differences between treatments with respect to the number of full bearing palms during the three years were significant (6th year at $P = 0.01$, 7th and 8th years at $P = 0.05$), those with respect to partial bearing palms were not significant. In the 8th year, new clearing treatment gave significantly more palms in full bearing than the other two treatments, difference between latter being not significant. In the 9th year, new clearing was superior to late thinning but not to gradual thinning. In the 10th year, new clearing and gradual thinning were superior to late thinning.

Yield of nuts and copra

Palms started bearing in the 7th year, thereafter yield per acre increased progressively until the 12th year (Table 4). There was a heavy incidence of yellowing of leaves due to magnesium deficiency in the 9th and 10th years in three blocks, which arrested the progressive increase of crop in the 10th year.

An analysis of variance after appropriate transformations showed differences between treatments were significant at $P = 0.05$ as follows:

8th year yield of nuts only,

9th and 10th years yield of nuts and copra,

11th and 12th years differences not significant.

When critical differences were evaluated, only significant factor was that palms in new clearing treatment have given higher yield of nuts and copra than those in late thinning during 8th, 9th and 10th years, except yield of copra in the 8th year. Differences between new clearing and gradual thinning, latter and late thinning have not reached the required significant level.

DISCUSSION

When evaluating a suitable system of under-planting senile coconut plantations, economic aspects wherein a reasonable income could be derived from the old palms without unduly retarding growth of young palms have to be considered. From the results presented, treatments could be placed in the following order of merit with respect to growth, bearing age and yield of the young palms: (a) new clearing, (b) gradual thinning and (c) late thinning.

Presence of the old stand of palms in late thinning treatment has retarded growth of the under-plantation by over 50 percent at the end of the 8th year, so much so, that only 44 percent were in flower and 83 percent non-bearing. In new clearing treatment, comparative figures were 83 and 50 percent respectively. Even at the end of 10th year, late thinning had 58 percent palms non-bearing. Therefore, late thinning system is not a satisfactory method of under-planting.

If new clearing method is accepted, there is a total loss of crop from old palms during the first seven years - 14,000 nuts (approx.) per acre. Yield of young palms during the first few years of bearing has not been extraordinarily high to compensate for loss of crop from old palms (Table 5). Thus, new clearing system is not suitable from an economic point of view.

Growth of palms in gradual thinning treatment has been depressed relative to those in new clearing (Tables 1 and 2), but magnitude of the differences in yield of nuts (Table 4) is not so high during 8th to 10th year, and thereafter differences even out. Further, if yield of young and remaining old palms is estimated, gradual thinning is at an advantage over new clearing (Table 5), having given nearly 6,000 nuts per acre more during the first 12 years.

Results of this experiment indicate that a system of gradual thinning of old coconut palms is a feasible method for under-planting senile plantations. In this instance, 18 percent of old palms were removed during the 1st year before planting seedlings, 10 percent each year thereafter and final lot in the 8th year. Yearly removal of palms in this manner may not be necessary, provided old palms within 6 feet from planting sites are removed prior to under-planting, which will reduce competition between young and old palms for nutrients and sun light. Remaining palms could be removed at two to three year intervals.

ACKNOWLEDGEMENTS

My thanks are due to Mr. V. Abeywardene, Biometrician for statistical analysis of data.

Table 1. Mean number of leaves produced per 100 plants each year

Treatment		Year after transplantation					
		1st	2nd	3rd	4th	5th	6th
New clearing	-	432	659	722	878	1,121	1,119
Gradual thinning	-	412	607	652	755	944	964

Critical difference between treatments each year = 31

Table 2. Percentage of palms in flower

Treatment		year after planting					
		5th	6th	7th	8th	9th	10th
New clearing	-	11.4	39.4	60.6	83.4	89.7	94.3
Gradual thinning	-	2.9	21.1	43.4	65.1	74.3	78.3
Late thinning	-	1.1	11.4	24.0	44.0	54.9	67.4

Table 3. Bearing status of palms

	Percentage of palms in		
	Full bearing	Partial bearing	Non bearing
8th year after planting			
New clearing	32.4	17.3	50.3
Gradual thinning	13.8	17.8	68.4
Late thinning	8.0	8.6	83.3
9th year after planting			
New clearing	54.3	17.9	27.7
Gradual thinning	38.5	16.1	45.4
Late thinning	18.4	14.9	66.7
10th year after planting			
New clearing	75.1	9.8	15.0
Gradual thinning	56.3	12.1	31.6
Late thinning	35.6	6.9	57.5

Table 4. Yield per palm in full bearing and yield per acre

		Per palm		Per acre	
		Nuts	Copra (lb)	Nuts	copra (lb)
7th year					
	New clearing ..	-	-	337	1.91
	Gradual thinning ..	-	-	146	0.64
	Late thinning ..	-	-	42	0.24
8th year					
	New clearing ..	44	26.2	1,064	5.69
	Gradual thinning ..	49	27.6	537	2.71
	Late thinning ..	32	19.2	225	1.21
9th year					
	New clearing ..	46	25.6	1,720	8.42
	Gradual thinning ..	47	24.3	1,244	5.76
	Late thinning ..	43	23.9	790	2.96
10th year					
	New clearing ..	36	20.0	1,766	8.71
	Gradual thinning ..	34	18.2	1,263	6.03
	Late thinning ..	34	16.4	790	4.04
11th year					
	New clearing ..	45	27.3	2,389	12.94
	Gradual thinning ..	45	26.9	2,014	10.57
	Late thinning ..	48	30.3	1,584	8.65
12th year					
	New clearing ..	-	-	2,906	15.31
	Gradual thinning ..	-	-	2,715	15.75
	Late thinning ..	-	-	2,097	11.21

Table 5. Total yield of nuts per acre that may be gathered during the first 12 years under the three systems of under- planting

	From under-plantation	From old plantation (estimated)	Total (approx.)
New clearing	10,182	nil	10,000
Gradual thinning	7,919	8,000	16,000
No thinning	5,332	14,000	19,000

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Extract from
Coconut Research Institute Annual
Report for 1956 (Sri Lanka)

INSECTS ON COCONUT INFLORESCENCES

Coconut flowers are said to be insect and wind pollinated. A trial to study the relative efficiency of each agent is in progress. In the course of this study, a census of winged and wingless insects commonly visiting coconut inflorescences was taken. Altogether 13 species of insects were collected. The Commonwealth Institute of Entomology, London identified them as follows.

Coleoptera	Curculionidae	1. *Derelomus sp.*
Hymenoptera	Apidae	2. *Apis indica* Fab. 3. *Halictus* sp. 4. *Nomioides* sp.
	Vespidae	5. *Ropalidia marginata* Lep.
	Formicidae	6. *Camponotus* sp. 7. *Camponotus (Orthontomyremex) sericeus* Fab. ssp. *Opaciventris* M. 8. *Pheidole* sp.
	Braconidae	9. *Triaspis* sp.
Diptera	Culicidae	10. *Armigeres obturbans* Walk.
	Calliphoridae	11. *Lucilia (Hemipyrellia) ligurriens* Wied.
	Muscidae	12. *Musca (Eumusca)* sp.
Dermaptera	Forficuliadae	13. *Chelisoches morio* (F).

Our observations indicated that the honey bee *(Apis indica)* was the commonest and most frequent winged visitor to the male and female flowers, and by far, perhaps the only insect of any economic importance in pollination of coconut palms. Bees appeared on the inflorescence about 6:00 a.m., thereafter frequency of visits increased and by 4:00 p.m. they were less frequent. The minimum number of bees on an inflorescence was recorded about 6:00 p.m.

Small black ants (*Pheidole* sp.) were frequently found on the inflorescence. They were not found on the stigmatic surface and their field of movement was limited. It is likely that they are only foraging insects and serve no useful purpose in pollination. *Derelomous* sp. was found though not frequently, largely common on male flowers. According to information received from the Commonwealth Institute for Entomology, this species frequent male flowers of various palms and are doubtfully injurious, but may help fertilisation. Another common insect not mentioned in the above list is the mite. These have been referred to in the Annual Report of the Coconut Research for 1953.

The female flower at receptivity shows a trifurcated stigma with a glistening viscous fluid in the centre. About the same time nectar is found to exude from the three longitudinal slits, the large black ant (*Camponotus sericeus* ssp. *Opaciventris*) was found to feed on the nectar and drive away honey bees by running towards them, should the latter settle near or on the stigmatic surface. This species may be considered as a possible limiting factor for bee pollination in coconut palms.

ACKNOWLEDGEMENTS

We thank the Commonwealth Institute for Entomology, London for identifying the insects.

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IMPROVEMENT OF SMALL HOLDINGS THROUGH SUSTAINABLE AGRICULTURE AND LOW COST TECHNOLOGY

SUMMARY

Management practices recommended to increase coconut production in small holdings are largely based on seed-fertilizer-agrocide technology. The goal is to maximise production. High yielding varieties that need high inputs and management practices have been introduced. Application of chemical fertilisers, pesticides and weedicides are advocated. The small holders with limited funds at their disposal and faced with other constraints are unable to purchase the inputs. Thus an inappropriate technology is being passed on to them.

The small holders need improved cultivars that give a satisfactory yield with low inputs, not necessarily very high yields. Cost of chemical fertilisers and its application, and cultural practices constitute 50% and 14% respectively of the total expenditure on maintenance of coconut holdings. Any technology developed to reduce that expenditure would be of considerable benefit to the small holders. A feasible approach to achieve this goal is bio-farming.

Bio-farming is building up fertility of the soil by incorporating organic material. Integrating animal husbandry with coconut cultivation and integrated pest control measures are important aspects of this system. Fertility of the soil is maintained for successive generations to grow crops successfully. Cost of inputs is reduced considerably, as micro-organisms and earth worms flourish under these conditions and convert waste into nutrients. The eco-system remains stable. Bio-farming is a low cost technology suitable for the coconut small holders to increase production and productivity.

INTRODUCTION

Coconut cultivation is generally a small holder enterprise. Production of nuts is low due to various constraints faced by the farmers. Assuming that 20% of the area under cultivation in all the countries consist of non-bearing palms and vacancies, average production for the period 1984-1988 was 4,900 nuts per ha of bearing palms per year. If improved management practices are carried out on the existing holdings, yield could be increased by at least 50 percent. But they are beyond the capacity of farmers to implement.

A recent study on the constraints faced by small coconut farmers has indicated that lack of or non-availability of capital for investment and high cost of inputs, amongst a number of other factors, restrict their efforts to increase production (1). Methods to increase production in small holdings about one ha in extent by application of low cost technology that farmers could adopt are discussed in this paper.

"Small holders are generally rational and efficient operators, who work under difficult personal circumstances, different priorities and values compared to the large estate owners. Some of the factors that determine their decisions are: limited availability of funds, risks that arise from time to

* This paper is a condensed version of two published papers - Low cost technology for the development of small coconut holdings (*Cord* Vol. II, 1986) and Sustainable agriculture for small coconut farmers (*Cord* Vol. VI, 1990).

time due to crop failures, fluctuating prices and inability to provide the necessary inputs to increase production" (Fowler and Tesky, 1985). Any advice given by the extension officers to improve crop production should include factors to ameliorate these conditions

CURRENT MANAGEMENT PRACTICES

Current practices recommended for the small coconut holders to improve production encompass to a large extent a seed-fertiliser-agrocide technology. Planting material consists of hybrids derived by crossing Dwarf x Tall coconut varieties. They are early bearing and could produce 3 to 4 tons copra ha/yr, provided agro-climatic conditions are suitable for coconut cultivation and management levels are satisfactory. They are not so hardy as the Tall variety that is commonly grown and cannot withstand droughts longer than six continuous weeks, subject to soil conditions. Application of high doses of chemical NPK fertiliser is recommended. Weedicides and pesticides are applied to control weeds and pests.

The farmer has to purchase these inputs from outside sources, which is difficult as his funds are limited. Risks due to crop losses and fluctuating prices - sometimes below the cost of production - discourage him to apply the inputs. NPK fertiliser has to be applied year after year, otherwise there is a sudden drop in production. Pesticides are not selective, both beneficial and harmful insects are destroyed with the spray, disrupting the eco-system.

Considering the constraints faced by the farmers, a technology of this type is inappropriate for them. "They need improved cultivars that produce more nuts that are marketable - not necessarily high yields - and low cost management practices." Unfortunately, main thrust of the researches has been to maximise production from coconut holdings through a system of chemical farming which may be satisfactory for estates, but not for small holdings.

According to Jalli (1985), coconut hybrids were issued to small holders in Malaysia in early seventies hoping to give a boost to their income from the high yields expected from the hybrids. Unfortunately, "farmers were finding .... The fruits not readily marketable: retail markets found it not popular among housewives, fruits too small for home or shop keepers' scrapers, too oily and lacking in the right flavour .... It seems reasonable to accept the opinion that we have made a mistake in technology transfer".

The broad parameters that contribute to cost of production in coconut small holdings in Sri Lanka and India are given below. Expenditure on fertiliser and cultural practices amount to 60 and 14 percent respectively of the total expenditure. Therefore, any technology developed to reduce expenditure on these two items will facilitate small farmers to increase coconut production and their income. A feasible approach to achieve this goal is to introduce bio-farming.

Item	Percentage of total expenditure In Sri Lanka	In India
Fertiliser and application	50	44
Cultural practices	14	21
Plant protection	06	05
Harvesting	06	17
Miscellaneous	24	13

Source: For India - Nair 1979. For Sri Lanka - CDA unpublished.

Major high cost inputs are fertiliser and cultural practices amounting to about 65% of the total expenditure on maintenance of land. Cost of chemical fertiliser and cultural practices is increasing yearly. Expenditure on them is already is beyond the resources available to small coconut farmers. If coconut production is to be increased, a low cost farm technology that is within the capacity of the farmers to implement has to be introduced. Researchers have developed a number of systems in this connection, but they have not filtered across sufficiently to the growers.

BIO-FARMING

Bio-farming is essentially building up fertility of the soil by using organic material which promotes active growth of earth worms and micro-organisms. Frissel (1978) has pointed out that fertilisers, particularly those containing nitrogen, require fossil energy in their manufacture, which is becoming increasingly expensive and further it is a diminishing resource. The economically workable deposits of raw materials used to produce phosphorus and potassium fertilisers do not have an infinite life. These considerations amongst others, emphasise the necessity for the development of systems for movement of nutrients for the growth of plants and animals from soil → plant → animal → soil again. He describes this system as nutrient cycles - bio-farming in other words.

An efficient way to maintain organic matter and increase soil fertility is by planting leguminous creeping covers and tree crops and incorporating bio-mass into the soil. But, that is not possible in small holdings where priority may be for food production. Cover crops recommended now, complete their life cycle in about six months - too long a period for the land to be left under non-edible crops. Nevertheless, burying coconut husks, portions of root and tuber crops and other refuse including kitchen ash available on the farm could add organic matter to the soil. Quick growing leguminous trees like *gliricidia* and *leucaena* species should be grown along the fence and inside the block wherever possible. They have to be regularly lopped and leaves and branches buried in the soil.

Researchers should develop quick growing leguminous cover crops that grow under shade of coconut palms, producing large quantities of nitrogen in root nodules and in vegetative material within about three months, preferably with edible pods and leaves. Most of the cover crops available today, eg *Mucuna utilis, Calapagonium* spp. take about six months to complete the life cycle and could produce about 10 tons of vegetative material per ha/yr, giving 200kg nitrogen. It may be possible to breed strains of some of these varieties that complete the life cycle in a shorter period without reducing the quantity of vegetative material. Farmers could afford to leave land under cover crops for about three months every two years in order to enrich the soil.

Integrating animal husbandry with coconut cultivation is appropriate for the small holder: raising cattle, goats and chicken without over stocking. Improved pasture and fodder have to be produced in the allotment. Animal dung when applied to palms provide a major portion of nutrients, but not a complete mixture. Nair (1979) has assessed productivity from one hectare of coconut land with four milk cows fed with improved pasture and legumes grown on the same block. Income derived by the farmer (in 1976) was sufficient to support a medium sized family on average living conditions. Cow dung and barn waste were used to manure palms. They have described a number of systems that could be practised based on mixed farming.

With this system of farming, farmers could provide most of the inputs necessary to increase coconut production from the farm itself, at a low cost and also get an additional income by selling the produce from animals.

With bio-farming, application of nitrogen and phosphate could be eliminated altogether under conditions as in Sri Lanka, thereby saving about 45 per cent from the inorganic component. Further, with zero tillage, expenditure on cultural practices could be saved by about 50 per cent. In this way, the total cost of production of nuts is reduced by about 34 per cent.

However, there are problems. The present rate of stocking cattle with improved pasture is about five heads/hectare. They could provide dung to manure about 68 palms per year, whereas the normal stand of coconut palms is 155 per hectare. Considering the fact that growing leguminous plants and burying the bio-mass in soil provide additional nitrogen, phosphate and potassium, total quantity of animal dung required per palm could be reduced. Knowledge on these aspects of manuring is meagre and further research on them is necessary.

Advantages of bio-farming

- Soil made rich with micro-organisms and earth worms.
- Nutrients are gradually released so that yield of nuts do not fall suddenly.
- Soil maintained in good physical condition improving aeration, structure and moisture holding capacity.
- NPK minerals are added that increase vigour of crops and their resistance to pests and diseases.

Bio-farming creates a congenial environment for earth worms to live in the soil. They play a vital role in improving the soil as indicated below:

- Organic waste is turned into soil nutrients by their constant burrowing, mixing and digesting.
- Keeps soil loose and rich giving it a better capacity to retain air and water.
- Neutralise the excessive acidic or alkaline soils.
- Transport mineral and sub soil compounds to the surface.
- Earth worm excreta contains twice the amount of phosphate and eleven times potassium than present in the surrounding soil.
- Promote bacterial growth, especially *actinomycetes*.

Earthworms that convert organic waste to compost are produced by certain UK companies on contract. About 50,000 tiger earthworms (*Eisenia foetida*) could deodorise one cubic meter of waste in 24 hours. After that they accelerate the composting process causing chemical changes and producing odour-free compost that is rich in humus. Once the composting is over, earthworms are extracted from the compost and recycled or used to provide high protein animal feed.

Thus, if the small coconut growers could be encouraged to develop a system of bio-farming, cost on application of artificial fertiliser is reduced, production increased, soil fertility maintained and cost of production of nuts reduced.

DISCUSSION

There are four salient factors involved in the improvement of small coconut holdings, viz. (a) use of appropriate planting material, (b) low cost inputs and management practices, (c) increasing productivity and (d) a satisfactory farm gate price for the produce. Only the first two factors are discussed in this paper.

Planting material

In a perennial crop like coconut with a productive life span of about 50 years, choice of appropriate coconut cultivars is the foundation of the industry. They should suit agro-climatic conditions, management capability of the growers and easy marketing of produce. <u>Small coconut farmers require improved cultivars that produce more nuts, not necessarily very high yields, with low cost management practices</u>.

In some countries in South East Asia, cultivation of DTC in small holdings has been promoted vigorously and large quantities of that seed distributed. Most of them have not performed up to the expectations in production and quality of fruits. Serious technical problems such as small size of nuts, alternate bearing tendencies, damage due to drought and diseases have created considerable losses to the farmers , after they have waited for five years to get an increased income (APCC, 1986).

Malaysian experience in introduction of DTC has been described as follows (Jalli, 1986):

> "Introduction of a ....(DTC) variety in Malaysia in the early seventies, was thought to be a great innovation. It has been expected to give a boost to farmers' income because of the high yields that could be expected. While high yields proved to be true, income did not however necessarily increase significantly in all cases. There was one cultural problem which had not been anticipated. Farmers were finding ...... fruit not readily marketable. Retail markets found it not popular among house wives. The fruit is too small for the home or shop keepers' scrapers. More serious, it is said to be more oily and lacking in the right flavour ...... In this context it is reasonable to accept the opinion that we made a mistake in technology transfer".

Out of the improved coconut cultivars available, TTC is suitable to be grown in small holdings. It tolerates a wide range of environmental conditions, low levels of management and yet give a satisfactory yield.

Chemical fertiliser

One of the recommendations to increase coconut production is application of chemical fertilizer. Cost of ingredients used in the mixture has increased substantially in the recent past and is likely to increase further. In the Philippines during the period 1976 to 1974, ex-warehouse price of a 50 kg bag of urea has increased from 75 to 274 Pesos, super-phosphate from 43 to 108 and muriate of potash from 52 to 190 (Cosico,1985).

There is no doubt that application of chemical fertilizer is a quick method to increase yield of coconuts, provided rainfall is adequate and well distributed. Its continued use does not improve soil structure and fertility of the soil.

A system of sustainable agriculture with low cost technology has to replace chemical farming practised by the small coconut farmers to increase production.

Sustainable Agriculture

Sustainable agriculture is described in a number of ways: biological farming, bio-farming, conservation farming, etc. The general principle in all of them is to eliminate or reduce use of chemical fertilizers, herbicides and pesticides in crop production and replace them with organic material. Some of the nutrients required for plant growth could be derived from vegetable material and animal litter. Pests could be controlled with other insects.

Sustainable agriculture is said to be one of the fastest growing areas of agriculture in the western world. "Farmers are kicking the chemical habit and finding that farming without chemicals is better for the soil and does no harm to the pockets" (International Agricultural Development Journal, 1985).

Researchers have described a number of leguminous and other plants that provide nitrogen, phosphorus, potassium, calcium and magnesium - essential elements for the growth of coconut palms. Amongst them are species of *Leucaena, Gliricidia, Crotolaria, Centrocema, Calapogonium, Pueraria, etc.*

Leucaena and *Gliricidia* are known for their huge foliage production. In a pure stand of the former about 120 mt of green foliage could be harvested per ha/yr. It contains 1,000 kg nitrogen, 200 kg phosphate and 800 kg potash (Liyanage, 1988).

The Coconut-*Gliricidia* model

Gliricidia stands pruning - two to four loppings are possible in a year. One hundred plants two to three years old, could provide about 200 kg of green foliage with two loppings per year. This amount increases as plants mature. Nutrients supplied by the above quantity of loppings is equivalent to 13 kg urea, 4 kg saphos phosphate, 6 kg of muriate of potash and 5 kg of dolomite. Application of 30 kg of *Gliricidia* loppings per palm/year, provide all the nitrogen and 15 to 20 per cent of phosphate and potassium requirements of a palm, plus small quantities of magnesium and calcium (Liyanage, 1988).

Generally, *Gliricidia* is established by cuttings, which may be a limiting factor in popularising the plant. Propagation by seed is more convenient and economical. These plants flower between January and March. Un-pruned trees produce a large number of flowers, only a few pods reach maturity. Harvesting period is about 20 days in April. A kilogram of seed contains about 5,000 to 10,000 seed (Liyanage, 1988).

A simple technology to bring fertility to denuded land has been developed in the Philippines. Giant *Leucaena* is planted in double hedges on contours four metres apart. Trees are cut back ten times a year and loppings utilised to fertilise crops between the hedges. Corn, bean, pineapple, peanut, banana. sweet potato and fruit trees have been grown successfully (Watson, 1985).

The same system could be followed in Coconut-*Gliricidia* model. In addition to planting two rows along boundaries, three hedge rows could be planted in every third or fourth row of coconut palms. Then there would be sufficient green manure for coconut palms and food crops.

REFERENCES

APCC. 1986. Guidelines for extension workers.

APCC. 1988. Report on the workshop of farmers' receptivity to new coconut technology.

Cosico, W.C. 1985. Organic fertilisers. Farming Systems and Soil Resources Institute, Philippines.

Curran, H. 1977. Giant Ipil Ipil. The super marvellous miracle tree. *PCCAARD and U.S. Nat. Acad.*

Fowler, M.H. and Tesky G. 1985. The role of small holder farming. APCC Quart. Supplement.

Frissel, M.J. 1978. Cycling of mineral nutrients in agricultural ecosystems. *Elsevier Scientific Publishing Co.* Amsterdam.

International Agricultural Development Journal, Sept/Oct 1985.

Jali, N.H. 1986. Guidelines for extension workers. Paper presented at work shop on Organisation, Programs, and Training of officials and small coconut farmer's leaders in coconut extension. APCC.

Liyanage, L.V.K. 1988. *Gliricidia* as a multipurpose tree for coconut plantations. *Coconut Bulletin* (Sri Lanka).

Nair, P.K.K. 1979. Intensive multicropping with coconuts in India. Verlog Paul Parey, Berlin.

Watson, H.L. 1985. Innovative technique restores fertility to bold mountain sides. As reported by D.C. Abadilla in *Bulletin Today.*

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Presidential Address, Section B - Agriculture
Twenty First Annual Session, December 1965
Ceylon Association for the Advancement of Science

PLANTATION TREE CROPS IN THE TROPICS

INTRODUCTION

In the development of tropical agriculture, perennial crops have played a considerable part, so much so, that in most tropical countries, a large percentage of national wealth was derived from export of crop produce. Foundations of plantation enterprises were laid down towards the latter part of the 18th century, and development since then has been gradual and consistent. Initial step taken to assist agriculture in the tropics was to establish Botanic Gardens, where new varieties of crop plants introduced from other countries were grown, to ascertain their suitability under local conditions (Tempany and Grist, 1958).

Botanic Gardens were established at Mauritius in 1743, West Indies in 1780, and in a number of countries thereafter. Introduction of Para rubber to the East through Kew Garden (England), Heneratgoda Garden (Ceylon), Botanic Garden (Singapore) are well known. The rubber trees of Ceylon and Far East have been derived largely from 2,379 rubber seedlings raised at Kew Gardens from seed that Wickham collected from Brazil in 1876. Malayan rubber industry is said to be founded only on 27 of these seedlings. Similarly, oil palm industry in Indonesia is based on four palms introduced to that country.

Towards the end of the 19th century, development of plantation agriculture was so extensive in each country, that the small staff attached to Botanic Gardens was inadequate to handle various problems associated with the introduced crops. Governments then created Departments of Agriculture with a larger technical staff to study them.

Subsequently, as large scale crop cultivation became lucrative enterprises, a number of private organisations established and financed their own research stations, sometimes with assistance of Governments concerned, to work on particular crops. This concept of commodity research stations was accepted first in Indonesia; an experimental station for the sugar cane industry was established in 1880, followed by stations for rubber, tea, coffee, oil palm and other crops. These commodity research stations were established much later in the other tropical countries. Research Institutes/Stations for rubber, tea and coconuts were established in Ceylon between 1920 and 1930. The great advantage of these single crop organisations has been that they have given undivided attention and effort, when adequately staffed and equipped, their contribution to the knowledge of crops under their care have been remarkable (Tempany and Grist, 1958).

Development of tropical agriculture has been so vast over the years, that some countries in Africa and East, supply most of the requirements of the World's requirements of certain products as indicated below.

Sections on rubber, oil palm, cocoa, cinchona and some paragraphs that were presented in the original article are not included in this paper.

Regional production rates 1962 - 1963 on a percentage basis
(FAO, 1963)

Product	*Africa*	*Far East*	*Latin America*	*Others*	*World Total**
Palm kernel & oil	75.4	14.7	9.0	0.9	2,110
Cocoa	71.4	0.6	26.1	1.8	1,190
Copra	3.3	78.8	7.8	10.0	3,200
Rubber	6.8	91.2	1.2	0.8	2,145

* in 1,000 metric tons

It is my intention to survey work that has been in progress at the commodity research stations devoted to tree crops in the tropics, in relation to breeding and assess their impact on present agricultural trends. Tree crops that have been studied are Rubber (*Hevea brasiliensis* Muell. Arg.), Cocoa (*Theobroma cocao* L.), Oil palm (*Elaies guineensis* Jacq.), Coconuts (*Cocos nucifera* L.) and Cinchona (*Cinchona* spp.). Most number of research stations and the largest number of research workers devoted to a single crop is Rubber.

Coconut

Although, area under coconuts in the world is about 8.51 million acres, relatively less research has been done on this crop compared to other tropical crops. There were only two research stations, one in India and the other in Ceylon, devoted to this crop up to about 1950.

In coconuts as in oil palms, vegetative propagation is not possible. Further, quantity of seed that could be collected from a coconut palm is limited - not more than 100 to 125 nuts per year, whereas oil palms could produce over thousand seeds each year. These limitations considerably restrict breeding procedures in coconut.

In all coconut growing countries mass selection is being practised: open pollinated seed collected from superior palms are distributed. Although, this method has been practised during the last 60 years or so, it was only recently that the feasibility of such selection has been demonstrated in Ceylon.

Efficiency of this method of selection, depends largely on heritability estimates of the characters for which selection is applied. Heritability values of some economic characters of the palm have been evaluated: yield of copra 0.67, weight per husked-nut 0.95 and ratio of nuts to female flowers per bunch 0.81. Since these estimates are high, genetic progress could be expected if individual palms are selected based on these characters (Liyanage and Sakai, 1960).

Further, if the best 5 per cent of palms in a block are selected on a basis of weight of husked-nuts, progeny yield is 16 per cent more than population mean. Selection on a downward basis, *i.e.* taking the worst 5 percent with respect to the same character, gives a progeny mean yield 12 per cent less than population mean (Liyanage, 1964).

Much of the variation in yield between palms is due to variations in number of nuts per bunch. A selection index has been computed using this character, bunches per year and weight per husked-nut - all components of yield of copra - and correlation of this index with weight of nuts of progeny was low ($r = 0.2344$). Therefore, this selection index was of little value for selection purposes.

The idea of 'prepotency' relative to coconut palms has been put forward in Ceylon, and already few such palms have been identified by progeny testing. A 'Pollen Bank' has been developed with pollen collected from these palms. Only a few progenies could be raised from seed of prepotent palms, but a large number could be produced by crossing selected females with pollen of prepotent palms, and they are expected to give high yields (Harland, 1957; Liyanage, 1964).

Coconut palms normally take 6 years to flower initially, a strain has been developed that flowers in 3 years. This strain exhibits hybrid vigour. Experimental material has given a mean yield of 150 nuts per palm/year, *i.e.* about 21/2 times the yield of an average coconut palm cultivated in Ceylon today. The hybrids are being studied on a larger scale to evaluate their performance under plantation conditions.

In a crop like coconuts, with a long life cycle and without methods of vegetative multiplication, any juvenile characters related to production are of considerable value. Total leaf production during the first 40 months of growth of progeny of the best 10 percent palms in a block, is highly correlated with subsequent yield ($r = 0.7295$). This is an important finding, in that palms of high breeding value could be tentatively identified within 40 months against the usual period of 10 to 12 years (Liyanage, 1964).

DISCUSSION

As the crops that we have dealt with are pre-dominantly out-breeding, a reservoir of genetic variation existed in seedling populations. Naturally, initial step in crop improvement was selection. The commercial product of plantation crops, latex, beans or oil is quantitative in inheritance, and response to selection will depend on the nature of genetic parameters. The present technique of bio-metrical analysis for quantitative inheritance was not known to earlier workers. Further, there was no urgency to determine these parameters, as most of the crops studied could be multiplied vegetatively. Thus, little work has been done on this aspect of the problem.

Response to selection will depend on heritability estimates of the character for which selection is made and they are available only for coconuts. The high heritability estimate for yield of copra, justifies mass selection that has been practised on coconuts for the last half century or so. In development of Malayan rubber clones, less than 2 per cent of the total number of clones tested are finally selected for large scale trials (Baptiste, 1962). This shows that the character yield of latex of rubber trees, presumably has a low heritability, or in other words, high yield of selected parents has been due to non-additive genetic effects.

In rubber and cocoa breeding programs, bi-parental crosses have been the foundation for evolving improved strains - pairs of crosses that exhibit specific combining ability have been isolated. High yielding clones that have been developed in rubber demonstrate utilisation of 'spurious dominance', and that phenomenon could be used on a commercial scale due to the advantage of vegetative propagation.

In oil palm, both specific combining ability and hybrid vigour have been used in production of commercial seed. Even in the absence of vegetative multiplication methods, the large quantity of seed produced each year is an advantage to use these techniques.

In the absence of both these factors in coconuts, emphasis has been to isolate palms with general combining ability and use their pollen in crossing programs. By using these techniques, new strains have been developed in each crop, that give two to four times the yield of un-selected populations.

Effect of polyploidy and heterosis has not been studied in any of these crops yet. Polyploidy in rubber need not be only an academic exercise, perhaps productive strains could be developed. Utilisation of heterosis by in-breeding and crossing may be particularly applicable to seed crops, but owing to the long life cycle involved, this method has not been used .

This is a weakness of the commodity research stations. As they are largely financed by commercial organisations, emphasis was on research programmes that pay dividends during a relatively short period, other programmes that take a long period to consummate have been neglected.

Heterogeneity and incidence of pests and diseases

Out of the five crops that we have discussed, recent commercial plantings of rubber and cocoa are exclusively from a few selected clones. Due to their continued use, much of the variability that existed in seedling populations have been reduced, but in oil palm and coconut, due to use of seed as planting material, variability is still conserved.

Incidence of pests and diseases of these crops may be related to heterogeneity of the populations. Most of the cocoa plantations in the world have at least one disease or pest problem; a well known example being virus diseases and mirid pests in West Africa. Similarly, for successful cultivation of rubber, pests and diseases have to be controlled, *e.g. Oidium* in Ceylon. On the other hand, the two crops propagated by seed have a relatively lower incidence of pests and diseases, except in a few isolated regions.

Simmonds (1962) has pointed out that measures contributing to maintenance of as much variability as agricultural circumstances allow should be adopted, *i.e.* variability should be deliberately maintained in crops. Mixtures in comparison to pure lines are more stable in performance and they show general population adaptation.

A good example of this phenomenon is the cotton crop of a part of Central India, where a complex mixture well adapted to local needs are grown. The mixture contains several strains of the indigenous diploid Desi cotton, together with a proportion of the introduced American tetraploid, Upland.

Upland cotton on pure stands does not do well and suffers from disease, especially red leaf and leaf-roll, but the mixture does much better with a lower incidence of disease. It is immune to cotton wilt to which Desi is susceptible, and checks the spread of this disease in the Desi component in early stages of growth. Further, Desi component gains on yield and ginning out-turn, the Upland on germination and lint fineness. The result is a series of populations at equilibrium that are adapted to the local environment (Simmonds, 1962; Ramiah and Panse, 1941).

Disadvantages of not having a heterogeneous crop population is well illustrated by the use of RRIM 501 rubber clone on a large scale in Malaya. It is high yielding giving about 1,000 lb per acre in the second year of tapping, and has been planted in about 55,000 acres in Malaya (Planters' Bulletin, 1965). This clone has been recommended for many years and tapped since 1935, but withdrawn in 1960 due to wide spread trunk-snap (Wrigley, 1961).

Therefore, considerable caution should be exercised in recommending a single clone for planting over large areas. Research should be undertaken to study various interactions between a mixture of clones or seed, in comparison with pure stands and ascertain the economics of co-existence of a number of clones, or a series of populations, relative to plantation crops.

Pests and diseases

Objective of plantation enterprises is to get maximum production per unit area, in order to reduce increasing costs of production, or to compete with synthetic material involved. Breeding is only one factor in this complex system of farming, other biological methods of assay are important. Out of these, control of pests and diseases need special mention as they could wipe out the entire industry within a short period, unless controlled in time. Powdery mildew *(Oidium* leaf disease) prevalent on rubber in Ceylon, which threatened the industry, was controlled by sulphur dusting. *Phytopthora* leaf disease common in South India and the Philippines has been controlled by fungicide sprays (Baptiste, 1952).

Persistent use of insecticides tend to develop strains of the pests resistant to the chemicals used. This has happened recently in Ghana, where resistance to Lindane and other pesticides developed on mirid pests, so that methods of control had to be revised.

CONCLUSIONS

It is difficult to assess in quantitative terms the contributions made by commodity research stations towards the industries they are associated with. But the fact remains that production has increased during the last 10 to 15 years, in spite of many vicissitudes that some industries had to undergo. Increased production is the cumulative effect of a number of factors: efficient management, use of improved agronomic practices and others. The full impact of cultivation of improved strains on production has not been felt yet, as they have not reached optimum production, except in the case of rubber industry in Malaya.

Increase in total production per year of the three major crops grown in Ceylon over a 10 year period is indicated below:

	1951 to 1954	1961 to 1964	Increase (%)
Tea	338,223,000 lb.	472,146,927 lb.	30.6
Coconuts	2,420,000,000 nuts	2,910,000,000 nuts	20.2
Rubber	98,511 tons	102,837 tons	4.4

The low increase for rubber is largely due to a large extent of senile rubber trees that have been replanted with new clones during the period under review.

A number of tropical countries depend on export of their agricultural products, their value in relation to the total export trade for the year 1956 is given below (FAO, 1957).

Ceylon	-	92.3 per cent
Nigeria	-	89.7 ..
Ghana	-	79.9 ..
Indonesia	-	65.8 ..
Malaya	-	62.5 ..

The sources of foreign exchange earnings in these countries are mostly the crops discussed so far. In each country there are specialised crop stations to work on major crops important to them. Impact of these stations on the national economy is clear from the following statement, "It should be remarked that the swollen shoot viruses, in their sheer virulence, would have wiped out the cocoa industry by now in Ghana. Instead, in spite of so many diseases and pests of the crop, production in Ghana has steadily risen from about 210,000 long tons per annum within six years ago to over 430,000 long tons in 1961 to 1962" (Quansah, 1965).

I should conclude this discussion with a warning to Plant Breeders. Earlier I mentioned that as much variability as agricultural circumstances allow should be maintained. Unfortunately, this factor has been overlooked, and the tendency has been to eliminate variability and produce uniform crop populations. "The very notion of heterogeneous crop populations is now unfamiliar in Europe and North America, because these regions have long been dominated by the clone and the inbred line (Simmonds, 1962). Even in a small area, a number of distinct clones or a mixture of seed should be used in re-planting and new planting, or in other words maintain a series of populations to make maximum use of induced variability.

REFERENCES

Baptiste, E.D.C. 1952. Progress in Malaya in the breeding and selection of clones of *Hevea brasiliensis. Rep. 13th Int. Hort. Cong. 2.*

Harland, S.C. 1957. The improvement of the coconut palm by breeding and selection. *Bulletin No. 15,* Coconut Research Institute, Ceylon.

_______ and Sakai, K.I. 1960. Heritability of certain yield characters of the coconut palm. *J. Genet. 57.*

Planting material used on estates in Malaya. 1963. *Planters' Bulletin.* R. R. I, Malaya.

Quansah, S. T. 1965. Role of cocoa research in Ghana's economy. *World Crops 17.*

Ramiah, K.G and Panse, V.G. 1941. Growing of mixtures. *Report II, Conf. Cotton Growers Problems,* India. (Indian Centr. Cott. Comm.)

Simmonds, N.W. 1962. Variability in crop plants, its use and conservation. *Biol. Rev.* 37.

Tempany, H. and Grist, D.H. 1958. *An Introduction to Tropical Agriculture.* Toronto, Longmans.

Wrigley, G. 1961. *Tropical Agriculture.* London, Batsford Ltd.