COCONUT BREEDING AND MANAGEMENT

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Proceedings of the National Symposium on Coconut Breeding and Management held at the Kerala Agricultural University, Trichur, India from 23rd to 26th November, 1988

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FOREWORD

Research on coconut has a long history in India dating back to 1916 when three Research Stations were established at Pilicode, Nileswar and Kasaragod in the erstwhile Madras Presidency. The development of hybrid varieties involving tall and dwarf types possessing prolificity and precocity is a major landmark in the annals of coconut improvement. It was the pioneering work of Dr.J.S. Patel and his team of scientists that paved the way for the exploitation of heterosis in coconut.

To commemorate the Golden Jubilee of the establishment of the first ever coconut hybrid plantation in the world at the Nileswar station which is now under the Kerala Agricultural University, a National Symposium was held on Coconut Breeding and Management during 23-26, November 1988 at the University Headquarters at Vellanikkara. The aim of the symposium was to bring together research, extension and development personnel working on the research and development aspects of the crop so that their interaction in the light of research experience could lead to the formulation of future strategies. Delegates from India, Sri Lanka, Malaysia, the Philippines, Bangladesh, Ivory Coast, France and the United Kingdom and international organizations such as IBPGR participated in the symposium. Indepth discussions were held on the cardinal aspects including breeding for higher yield and disease resistance, crop management, biotechnology and processing technology. Based on research results and deliberations certain important recommendations were drawn up in the plenary session of the symposium.

The proceedings of this symposium brings together a considerable quantum of scientific information on various aspects of coconut breeding and management. Status papers evaluate the current state of coconut research throughout the world and the future lines of work envisaged.

During the Inaugural Session of the symposium, a few pioneers of coconut research in India were honoured. They were Dr.J.S. Patel, Dr.K.M. Pandalai, Mr.A.P. Anandan, Mr.P.M. Sayed, Dr.C.A. Ninan, Mr.K.P.P. Nambiar, Prof.K. Kannan and Mr.K. Satyabalan. I am thankful to them for accepting the honour offered by the Kerala Agricultural University in recognition of their contributions in the field of coconut breeding and management.

I gratefully acknowledge the co-operation extended by the Central Plantation Crops Research Institute (CPCRI), Kasaragod, Coconut Development Board, Cochin, Council of Scientific and Industrial Research (CSIR), New Delhi, Department of Biotechnology, New Delhi, Kerala Kerakarshaka Federation (KERAFED), Trivandrum, Kerala State Coconut Development Corporation, Trivandrum, State Committee on Science, Technology and Environment (STEC), Trivandrum and the State Department of Agriculture, Trivandrum in organizing the symposium. I also wish to convey my sincere thanks to the participants of the symposium and to all those who made the symposium a success.

E.G. Silas
Vice-Chancellor
Kerala Agricultural University

PREFACE

Hybridization programme on coconut was commenced in early thirties at the Coconut Research Station, Nileswar (now the Regional Agricultural Research Station, Pilicode under the Kerala Agricultural University) and the earliest plantation of Tall x Dwarf hybrids was established at Nileswar. These hybrids continue to give satisfactory performance even after 50 years. Considerable progress has been made on coconut breeding and management ever since the first production of T x D hybrids at Nileswar. In order to commemorate the Golden Jubilee of the establishment of hybrid coconut plantation, the Kerala Agricultural University organized a National Symposium on Coconut Breeding and Management from 23rd to 26th November, 1988 at the Main Campus, Vellanikkara, Trichur in collaboration with the Central Plantation Crops Research Institute, Kasaragod, Coconut Development Board, Cochin, CSIR, New Delhi, Department of Biotechnology, New Delhi, KERAFED Trivandrum, Kerala State Coconut Development Corporation, Trivandrum, State Committee on Science, Technology and Environment, Trivandrum and the State Department of Agriculture, Trivandrum. Delegates from various countries and international organizations participated in the symposium. This publication consists of status papers and contributory articles presented at the symposium in different technical sessions.

We are thankful to Mr.V.V. Raghavan, Minister for Agriculture, Government of Kerala for inaugurating the symposium, to Dr.E.G. Silas, Vice-Chancellor, KAU for presiding the Inaugural Session of the symposium and to Dr.M.V. Rao, Special Director General, ICAR, New Delhi for delivering the keynote address. We are also thankful to the eminent coconut workers honoured at the Inaugural Session of the symposium for accepting the recognition offered by the Kerala Agricultural University. The efficient conduct of the various technical sessions by the chairmen, conveners and rapporteurs is gratefully acknowledged. We are deeply indebted to the conveners and members of the various committees whose dedicated efforts made the symposium a success. We are also thankful to the delegates who participated in the symposium and the organizations which co-sponsored the symposium.

The inspiration and the guidance received from our Vice-Chancellor in the organization of the symposium and in streamlining this publication is gratefully acknowledged. We are also thankful to Mr. Babu Jose, Comptroller, KAU for his interest in bringing out this publication. The computer based type-setting by Mr. P. Sreekumar, cover designing by Mr.V. Chandranandan, manuscript typing by Mrs.K.M. Mary and off-set printing by M/s SB Press, Trivandrum are thankfully acknowledged. We are also grateful to our colleagues who helped us in bringing out this publication in a befitting manner.

Editors

CONTENTS

Lakshaganga (LO x GB) released by KAU

Anandaganga (AO x GB) released by KAU

Keraganga (WCT x GB) released by. KAU

World's first T x D plantation at Pilicode (KAU)

Inaugural Session

INAUGURAL ADDRESS

V.V. Raghavan
Minister for Agriculture, Government of Kerala, Trivandrum, India

Special Director General of ICAR Dr. M.V. Rao,
Vice Chancellor Dr. E.G. Silas and Scientists,

Kerala is the land of coconuts and the socio-economic development of Kerala state is very much dependent on the fortune of this crop. In fact, nowhere in the country a single crop exerts so much influence on the economy of the state as coconut does in Kerala. Annually, the state produces 3068 million nuts from an area of 0.68 million hectares, which account for nearly half the production in the country. It contributes 9.29 per cent of the total income and 26.82 per cent of the agricultural income of the state. About 10 million people depend directly or indirectly on coconut culture and industry for their livelihood. Even the smallest holding in Kerala will have a few coconut palms and for a small farmer, coconut is considered equivalent to cash in hand as he depends largely on the crop for his daily cash requirements. Out of 5 million coconut holdings in the country, 2.5 million holdings are in Kerala and 98 per cent of the holdings are below 2 hectares in extent. Obviously, it is a small farmers crop and dictates the rural economy of the state.

Coconut research in India has a history of over half a century. Fundamental and applied research in this field have produced valuable results of practical significance. The early efforts were focussed at the evolution of genetically superior planting materials. A large number of indigenous and exotic cultivars have been evaluated in the different research stations of the country for comparative assessment of the yield performance and promising cultivars have been identified. The evolution of Tall x Dwarf and Dwarf x Tall hybrids has been the most outstanding achievement of coconut research in the country. India was the first to produce coconut hybrids in early thirties at the Coconut Research Station, Nileswar, now the Regional Agricultural Research Station, Nileswar (Pilicode) under the Kerala Agricultural University. Since then elaborate studies have been made for the genetic improvement of the coconut palm. Results emanated from these studies have established the superiority of the released hybrids compared to the local cultivars in terms of yield and quality attributes. Remarkable achievements have been accomplished in the area of crop management during the last few decades. The most conspicuous among these are the findings on the response of the crop to manuring and irrigation and also on the economic utilization of interspace in coconut gardens.

Though the research accomplishments are commendable, the productivity of coconut in the state is on the decline. Among the various factors responsible for the low productivity, the prevalence of the root (wilt) disease is the most important one. The annual reduction in yield due to this debilitating disease has been estimated to be 968 million nuts costing Rs 200 crores in addition to the loss in the number and quality of leaf, copra weight and oil content. The other factors attributed to the low productivity are lack of irrigation, inadequate manuring, retention of a large proportion of senile and unproductive palms, low genetic potential of the native palms, the cultivation of coconut even in marginal and unproductive lands and the poor infrastructural facilities available for the marketing of the produce. Irrigation and proper manuring of the existing gardens can double the present production. The spread of the disease could be prevented by the systematic destruction of diseased palms in the border areas of the disease affected districts and by adopting domestic quarantine measures. There should be specific recommendations for the management of the diseased palms. Rehabilitation of the existing plantations will lead to heavy demand for good quality seedlings and therefore availability of the quality planting materials has to be assured.

The measures to improve the productivity of the crop will involve heavy financial investment specially for the rehabilitation of the diseased palms and for establishing irrigation. Majority of the coconut farmers of the state are small and marginal and hence measures to improve productivity could be realized only with financial support on a long term basis. Prevalence of the devastating root (wilt) disease of coconut should be treated as a national calamity and the coconut farmers should be financially assisted at the national level in improving the productivity of this perennial crop. About 45 per cent of the total production of coconut in the country is utilized for oil extraction. The annual output of coconut oil is 215 thousand tonnes which is almost on par with some of the major oilseed crops grown in the country such as sesamum, sunflower, linseed etc. and accounts for 7 per cent of the total production of vegetable oils in the country. Still, coconut is treated only as a horticultural crop rather than an oilseed crop in the commodity development programmes. Coconut really deserves a better patronage as an oilseed crop in India.

The prices of coconut products, particularly fresh nuts and copra are dependent on the price of coconut oil which in turn is subject to influence by the over all availability of fats and oils in the country and their price behaviour. Due to continuous price fluctuations, premium price and short supplies in essential sectors, coconut oil is slowly losing its pre-eminence in many end uses resulting in unexpected price falls and hardships to farmers. Therefore, it is necessary to introduce a viable price stabilization programme in order to curtail price fluctuations and to maintain a price range for coconut oil which will be remunerative to the coconut grower. This will also facilitate the re-entry of coconut oil in its traditional markets and will promote new end use markets.

Product diversification and byproduct utilization is another area where more attention is required. The present dependence of coconut industry on coconut oil alone causes much hardship to the farmers and processors at times of price fall often exhibited by coconut oil. Product diversification and byproduct utilization will definitely result in more economic use of coconut and will help to stabilize the price independent of the demand for coconut oil. The research and development in this branch of study have to be strengthened to attain the desired results within a reasonable period of time.

I hope that this National Symposium on Coconut Breeding and Management organized by the Kerala Agricultural University will formulate ways and means of overcoming the constraints of increasing the production and productivity of coconut in the country.

I am happy to inaugurate this symposium and wish the symposium all success.

PRESIDENTIAL ADDRESS

E. G. Silas
Vice Chancellor, Kerala Agricultural University, Vellanikkara, Trichur, India

Hon'ble Minister for Agriculture Sri. V. V. Raghavan, Special Director General of ICAR Dr. M. V. Rao, Distinguished Delegates, Ladies and Gentlemen,

The coconut palm known as *Kalpa Vriksha* or tree of heaven is of great antiquity in India. Every part of the tree is useful to man and it provides livelihood for millions of people in the country. India is the third largest coconut producing country in the world contributing 18 per cent of the global nut production. The annual production is 6404 million nuts from an area of 1.23 million hectares and about half of the total production is from the state of Kerala.

Coconut research in India gained momentum when the Government of the then Madras Presidency established three coconut research stations at Nileswar and one at Kasaragod in 1916 which are now located in the Kasaragod district of Kerala. With the constitution of the Indian Central Coconut Committee, the Kasaragod station was handed over to the Committee in the year 1947 and later became the Central Plantation Crops Research Institute under the Indian Council of Agricultural Research. Another research station was set up at Kayamkulam in 1948 which now forms the Regional Station of the CPCRI. Two research stations were started at Kumarakom and Balaramapuram under the State Department of Agriculture, Travancore during the year 1947 and 1948 respectively. In 1972, when the Kerala Agricultural University was formed, two research stations of Nileswar and the research stations at Kumarakom and Balaramapuram were handed over to the University.

Efforts to collect, conserve and multiply germplasm from all possible sources have been in progress since the commencement of research on coconut in 1916. The present Indian germplasm consisting of 86 exotic and 41 indigenous accessions is one of the world's largest collections of this crop. Research on varietal improvement undertaken during the last three decades has enabled evolution of high yielding cultivars. Identification of elite palms and selection of prepotent West Coast Tall palms based on progeny testing resulted in considerable improvement of the traditional cultivar. Perhaps, the most outstanding achievement in coconut research was attained by the advent of hybrid vigour in crosses involving talls and dwarfs. The hybridization programme was started in early thirties and India was the first to produce coconut hybrid in 1932 at the Coconut Research Station, Nileswar. The earliest plantation of coconut hybrids (T x D) in the world established at Nileswar continues to give very satisfactory performance even after fifty years. Further research on hybridization made possible to release a number of Tall x Dwarf and Dwarf x Tall hybrids which give yields up to 65 per cent more than the West Coast Tall. Some of them perform well under drought conditions also.

A comprehensive programme to set up a net work of seed gardens in different states and to produce high yielding varieties and hybrids has been planned and is now under various stages of implementation. The approach adopted is to have appropriate dwarfs as females in required areas in large blocks and the selected talls in another block away from dwarf. Adopting a simplified pollination technique, massive production of hybrid seeds in such gardens is now possible. Multiplication of elite palms through seed has inherent limitations. Same is the case with plants which are resistant to diseases. Tissue culturing of coconut, research on which is already in progress, should be made into a reality so as to propagate palms of high genetic potentials as well as disease resistance.

The response of coconut to different management practices has been studied under a variety of situations. Substantial increase in yield may be made by adopting the recommended management practices. Similarly, the beneficial effect of irrigation on nut production has been quantified to range from 74.2 per cent to 209 per cent in various types of soils. The enhanced coconut production due to the favourable interaction between irrigation and manuring is indeed substantial. With a view to maximising production per unit area, coconut based farming systems have been studied and systems suitable for various situations have been evolved.

In spite of the above accomplishments, statistics on coconut production in the country reveals that the production remains rather stagnant since seventies and the present production is only marginally higher than the production level of 1970-71. The demand for coconut in the country by 2000 AD is estimated at 12172 million nuts, roughly 100 per cent more than the present production. To achieve this projected demand, the growth rate of coconut production has to be reasonably high. The genetically superior hybrids and cultivars have to be fully utilized to attain this desired goal. The present rate of production of hybrid seedlings appears to be inadequate to meet the increasing demand. Every effort should be made to overcome this constraint by streamlining the present systems of generating planting materials, full utilization of existing mother palms and establishing more seed gardens in the coconut growing states. The technique of micropropagation through tissue culture should be perfected.

Kerala being the major coconut growing state, the over all increase in production will mainly depend on the performance of the crop in this State. About 40 per cent of the area under coconut in Kerala is in the grip of the root (wilt) disease and therefore production and productivity programmes in the country should give considerable importance to disease management. Management practices, irrigation, expansion of area to the extent possible, product diversification and byproduct utilization are other areas requiring immediate attention for necessary improvement.

I hope that the deliberations of this National Symposium on Coconut Breeding and Management organized by the Kerala Agricultural University will provide solutions for the above constraints and will help to increase the production and productivity of the crop in the country.

KEYNOTE ADDRESS

COCONUT RESEARCH IN INDIA

M.V. Rao
Special Director General, Indian Council of Agricultural Research
New Delhi 110 001

Hon'ble Minister, Vice Chancellor and Scientists,

It gives me immense pleasure to be with you today to participate in the National Symposium on Coconut Breeding and Management and to share my thoughts with you. I would like to congratulate Dr. E. G. Silas, Vice Chancellor, Kerala Agricultural University for organizing this National Symposium in collaboration with the Central Plantation Crops Research Institute and other agencies involved in coconut research and development in the country.

Among the world's approximate 2700 species of palms, coconut is the most versatile providing edible and industrial oil, protein rich milk and invigourating water and also valuable source of timber, fibre, roofing and matting material and also a number of products from its shell. Coconut fibre is valued for its elasticity and resistance to mechanical wear and dampness. Byproducts of coir industry such as pith, fibre, dust etc. are put to a variety of uses for improving the soil tilth and conserving moisture. The tree is rightly called the tree of heaven *Kalpa Vriksha* as very few other cultivated plants have such highly diversified utility as the coconut.

Coconut is grown in more than 90 countries of the tropics and India occupies the third position in terms of production among the countries next only to Philippines and Indonesia with an annual production of 6484 million nuts. An analysis of the trend of production and area in the country shows that the area increased from 0.59 million hectares in 1949-50 to 1.23 million hectares in 1986-87 and the production during the same period increased from 3448 million to 6484 million nuts. However, let us not be carried away by the magic of figures, since an area increase of 108 per cent has given us only 88 per cent increase in production. The per capita availability in India is estimated to be 11 nuts in comparison with 220 nuts in Philippines and 200 nuts in Sri Lanka. This only shows the need to raise our per capita availability by increasing the productivity of palms. Even though the productivity of coconut per hectare is comparable with yields of other coconut growing countries, the per palm productivity is also low i.e., about 35 nuts/palm/year.

Traditionally Kerala accounts for the lion's share in coconut production with 56.8 per cent of area and 47.5 per cent of total production in the country (1985-86). It has been estimated that in Kerala there are 170 million coconut palms with a palm density of 229/ha. I have been told that about 10 million people depend directly or indirectly on coconut culture and industry for their livelihood. Coconut cultivation alone provides 78 mandays work/ha/year, which works out to about 75 million mandays per year.

Unlike other commercial crops, coconut is essentially a small-holder's crop. It is mostly grown in homesteads and small farms. There are about 5 million coconut holdings in the country with 98 per cent of them less than 2 ha in extent. In Kerala

State alone it has been estimated that there are about 2.5 million holdings.

Coconut contributes to about 7 per cent of the total vegetable oil production in the country. Annual per capita consumption of vegetable oil in the country is only 5-6 kg compared to 20 kg in developed countries. The available oil production from traditional annual crops in India is highly inadequate to meet its increasing demand. India has imported 1.6 million tonnes of edible oil during 1986-87 and about 2 million tonnes during 1987-88 at an estimated foreign exchange worth Rs 1400 crores. As the gap between demand and supply is widening every year, the monetary drain due to import of vegetable oil will also increase unless we resort to drastic action immediately. The role of perennial oil yielding crops like coconut, oil yielding tree spices and oil palm to bridge this gap is obvious. Realizing this we have included these crops under the Technology Mission on Oilseeds.

Research on coconut improvement and management in India started in 1916 with the establishment of four centres, one each at Kasaragod and Pilicode and two at Nileswar in the west coast under the erstwhile combined Madras State. India was the first country in the world to initiate coconut hybridization programme in the early 30s at the Central Coconut Research Station, Nileswar and Central Coconut Research Station, Kasaragod. It is to the credit of pioneers like Dr. J. S. Patel that the exploitation of hybrid vigour was conceived and implemented in coconut more than half a century ago.

Inspite of having an early start in terms of research efforts to improve the coconut production and productivity we will have to admit that the progress has been slow till recently. The perennial nature of the crop combined with inherent difficulties in studying the successive generation and the long juvenile phase are some of the major factors responsible for this slow progress.

The initial programmnes on coconut research included standardisation of selection procedures for mother palms including identification of prepotent palms and perfecting seedling selection criteria. Criteria for selection of mother palms/seednuts and seedlings established by the research workers have proved helpful in producing quality planting materials. The germplasm collection and conservation programme initiated in the early 1930s received further impetus with the support of IBPGR during 1970s. The coconut germplasm at CPCRI consists of 86 exotic and 41 indigenous cultivars and under the Kerala Agricultural University we have 29 exotic and 34 indigenous types. The germplasm at CPCRI includes 24 accessions from six Pacific Ocean Islands collected with the support of FAO/IBPGR in 1981 and maintained at the World Coconut Germplasm Centre in Andamans. Thus the Indian germplasm holding collected from more than 25 countries represents the largest holding of coconut germplasm, though the Ivory Coast collection with about 70 trees in each of the 32 accessions is the biggest population of coconut germplasm. Evaluation of the germplasm has led to the identification of high yielding cultivars like Andaman Ordinary and Laccadive Ordinary (indigenous) and Philippines Ordinary and SS Green (exotic) with 25 to 30 per cent higher yield in terms of nut compared to the local cultivars. As all of you are aware based on the performance, Laccadive Ordinary has been released as Chandrakalpa and accepted for large scale cultivation in Kerala State.

The most significant contribution in coconut breeding in this country has been the production of coconut hybrid between West Coast Tall and Chowghat Orange Dwarf and its reciprocals. These hybrids when raised under available conditions and with proper management, have been found to bear earlier and yield more number of nuts and higher copra out-turn than the local cultivar, West Coast Tall. However, further analysis of the performance has indicated considerable variation in yield of progenies derived from cross combinations indicating the need for selection of individual parental palms in hybridization programme. I am happy to note that the breeders at the Central Institute, Kerala Agricultural University and Tamil Nadu Agricultural University have been continuously producing and testing the performance of various hybrids and in recent years they have released hybrids Chandrasankara (COD x WCT), Chandralaksha (LO x COD), Lakshaganga (LO x GB), ECT x DG (VHC 1) and ECT x MDY (VHC 2) with an increase in yield ranging from 23.3 to 82.8 per cent over West Coast Tall. Though this development is commendable, I cannot help but mention the reluctance on the part of scientists in releasing high yielding varieties and hybrids in coconut. Dr. J. S. Patel reported the manifestation of hybrid vigour in coconut in 1932 and the first Tall x Dwarf (T x D) was planted at the Research Centre at Nileswar in 1934 and the first natural cross dwarf (NCD) (which later presumed to be DxT) was planted at Kasaragod in 1939. It took another 46 years for the scientists to come out with recommendation for release of the three hybrids about which I mentioned earlier. However, I am happy to note that after 1985 five hybrids have been released and the Kerala Agricultural University is likely to release another two hybrids, namely, Andaman Ordinary x Gangabondam and West Coast Tall x Gangabondam shortly. All these show that after considerable stagnation in coconut breeding, in recent years we are proceeding in the right direction and earnest efforts are being made to identify the best hybrid combinations and thereby contribute to increasing production and productivity of coconut.

It will be pertinent to analyse the availability of planting materials in these elite hybrids and varieties released in recent years. It has been estimated that the total production of planting materials in the country is about 10 million seedlings every year. Out of this, about 6 million seedlings are produced at various State Government nurseries, seed gardens etc. and balance of about 4 million seedlings are produced by private nurseries and coconut growers. Among these, only about 0.3 million TxD hybrid seedlings and a few thousands of DxT seedlings are produced at present. Though large scale production of TxD hybrid seedling programme was initiated in the 60s in the states of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and Orissa, the desired impact of these seed gardens in terms of seedling production has not been achieved. A national group meeting called by my colleague Dr. K. L. Chadha (Deputy Director General, Horticulture) on "The strategy for production of planting materials in coconut" at Kasaragod in January, 1988 has estimated that the total demand for the planting materials in the country is about 15 million/year which include seedlings required for (a) 30,000 hectares of new planting, (b) replanting and under-planting for rehabilitation of root (wilt) affected areas in Kerala and (c) replanting and under-planting of about 2 per cent of the area in other states. A look at the present infrastructural facilities available for production of hybrid seedlings shows that among major coconut growing sates we have established about 960 hectares of seed gardens and another 80 hectares of seed gardens are proposed to be established in the states of Assam, Bihar, Madhya Pradesh and Orissa. The seed gardens in Karnataka, Tamil Nadu and Orissa established in the late 70s have not achieved full scale commercial production due to various reasons. Repeated replanting had to be undertaken in many of these seed gardens due to lack of infrastructural facilities and financial resources. When all these seed gardens attain the full production level it is expected that the country will be in a position to produce about 1.5 million hybrid seedlings in the course of next five years.

I need not emphasise to this group here that evolving varieties and hybrids has to be a continuous process not only to achieve higher yield but also to develop tolerance to diseases like root (wilt), tatipakka, Thanjavur wilt, and other stress factors.

Out of a total area of 0.7 million hectares under coconut in Kerala State, approximately 0.4 million hectares in the eight southern districts are affected by root (wilt) disease. A recent survey by CPCRI in collaboration with the Department of Agriculture and other sister institutions has indicated that the total annual loss due to the disease is about 968 million nuts. The causal agent for coconut root (wilt) disease has been established as mycoplasma-like organisms on the basis of consistent association of the MLOs in the disease affected palms and its total absence in the disease free palms, in the transmission studies and location of MLOs in the phloem tissues of the vector. All of us are aware that it will not be possible to offer a cure to the root (wilt) disease by way of plant protection measures. Application of tetracycline has indicated temporary remission symptoms. However, this chemical cannot be used for curing mycoplasmal disease of plants in view of the need for repeated administration to get the desired effect, the cost and accumulation of residues in the system. The strategy for the highly diseased contiguous belt has already been spelt out by my colleagues at CPCRI in terms of proper management. Similar strategy has also been formulated for the mildly affected areas. However, as a permanent solution it is imperative to evolve varieties tolerant/resistant to the disease.

In the case of root (wilt) disease which is only debilitating but not lethal, the health and yield of affected palms can be improved through adoption of integrated management practices consisting of application of balanced fertilizers, addition of organic matter by raising green manure crops in the basins, summer irrigation etc.

Research programmes have been initiated by the breeders working on coconut by way of screening the available germplasm in disease endemic areas, collection and evaluation of germplasm from Pacific Ocean group of islands and also exploiting the genotypes which show field tolerance by appropriate breeding methodology. I am glad to note that, though belatedly, a dynamic breeding programme has been initiated at the Kayamkulam Regional Station of CPCRI to exploit the available field tolerant types. It is in this context that the ICAR is contemplating collaboration with Mauritius and Maldives for exchange of coconut germplasm. The major objective of the programme is to locate resistance/tolerance to root (wilt) disease. It is understood that very little work has been carried out to conserve the variability in coconut germplasm in these countries. Therefore, the present collaboration proposed will benefit both India and host countries in documenting and conserving the available variability in these two countries.

Another major production constraint felt in recent years is increasing drought situation in the coconut producing states. I am told that during the severe drought in 1986-87 many of the coconut plantations under un-irrigated condition suffered. The drought tolerant nature of recently released hybrids, namely, Lakshaganga and Chandralaksha has been proved by laboratory screening tests and this information has been further supported from the field data. Likewise, the susceptibility of Chandrasankara to drought has been revealed through systematic studies. I am also happy to note during my recent visit to CPCRI that Dr. V. Rajagopal and his group have already identified the desirable traits for drought tolerance and based on the methodology developed a few genotypes have been identified which are being effectively utilized in the breeding programme.

I am happy to note that the research workers in coconut have come out with a number of recommendations in the past which if adopted can definitely increase the yield and income from the coconut palm. A four-fold increase by cultivation and manuring and six-fold increase by manuring and irrigation in yield have been achieved in the case of West Coast Tall. Nutrient uptake studies have indicated that the hybrids are more efficient convertors of applied nutrients than West Coast Tall. The drip irrigation technique developed for coconut gardens ensures supply of daily requirement of water to the root zone eliminating loss through evaporation, percolation and seepage. This also helps in saving of 40 per cent of water than the basin irrigation system, with considerable other advantages. These management practices if adopted properly, in the long way, will double the coconut yield from existing plantations.

At CPCRI, the economic evaluation of the hybrid CODxWCT under rainfed conditions showed that the pay-back period in the case of this hybrid is 8 years as against 10 to 12 years in the case of WCT. The fertilizer response of the same hybrid indicated that 500 g N + 300 g P_2O_5 + 1000 g K_2O/palm/year gives higher net return than higher levels of fertilizers under rainfed condition in sandy loam soil suggesting that this hybrid is an efficient convertor of energy, thus, most suited to small-holder environment.

The cropping system models at CPCRI, Kasaragod have attracted the interest all over the world because of their relevance to the present environment. Under rainfed condition, coconut + elephant foot-yam combination could fetch highest return followed by coconut + ginger. However, under irrigated system the multistoreyed cropping involving coconut + pepper + cocoa + pineapple could generate a net return of Rs 23000/ha compared to Rs 6900 from rainfed coconut monocrop and Rs 11400 from irrigated coconut monocrop. Similarly, coconut-based mixed farming system involving production of fodder grass in the interspaces of coconut, training of pepper on coconut trunk, raising of fruits and vegetables around farm house, rearing of rabbits and maintaining 5 units of cross-bred cows in 1 ha coconut garden could yield a net return of Rs 14500/ha/year. When we consider the family labour involvement, the earnings to the family as a whole could be as high as Rs 35000/ha/year from this system. It is therefore considered as a self-reliant small-holder model.

During the past 70 years, studies conducted in different research centres on various aspects of the coconut palm in the country have produced valuable results of practical significance. In the process of field application of valid research findings, the research is also fed back with problems from the field. However, the feed back was not always complete, so also the transfer of technology available at research centres. Many useful research are often left unutilized and un-observed in the strategy of coconut development.

I find from the programme that most of the problems connected with breeding for higher nut and copra production, better quality attributes, breeding for pests, diseases and environmental stress, crop management, biotechnology and processing technology are to be discussed in this symposium. While these programmes are drawn with considerable thought, I am sure that the symposium will give serious consideration to the following points which require attention.

1. The constraints in availability of quality planting materials have been indicated by me earlier. Even with the full production potential of seed gardens in the country, we may be able to meet only 1/10th of the planting material requirement annually. Considerable attention will have to be given by the Coconut Development Board and other agencies concerned for encouraging the production of quality planting materials.

2. I understand that though the hybrids have high production potential, the recovery of hybrids is only in the range of 40 per cent in any particular cross combination. This obviously indicates that both talls and dwarfs are heterogeneous in their genetic make up and breeders will have to bestow their attention to identify parents, specially dwarfs, which are likely to give high hybrid recovery. I am rather surprised to note that no attempt has been made so far for effective inbreeding programme specially in dwarf coconuts. It will be advantageous to go for an inbreeding programme to develop homozygous dwarfs which in turn can be utilized for exploitation of hybrid vigour to the maximum extent.

3. Coconut tissue culture work initiated at CPCRI a few years back has enabled the production of coconut plantlets for the first time from tender leaf segments of West Coast Tall and T x D hybrid seedlings. However, the result has been inconsistent indicating the need for perfecting the technique. The ICAR with the financial assistance from the Department of Biotechnology has strengthened the programmes in recent years. Even the limited success achieved so far is from the leaf tissues of the seedlings and hence our efforts in this direction should be towards perfecting a technique for culturing tissues from adult palm so that high yielding elite palms and disease resistant genotypes expected to come out from the breeding programme, can be subjected to micropropagation.

4. Our experience in collecting germplasm from the Pacific Ocean Islands in the past has shown that collection of nuts is cumbersome and expensive. Our strategy in this direction will have to be germplasm collection and conservation by *in vitro* methods by using zygotic embryos followed by cryopreservation.

5. Another exciting field where there is immense possibility in the breeding programme is anther culture for production of haploids and homozygous diploids. Production of isogenic lines by this process specially in dwarf cultivars will ensure production of uniform hybrids, which is not practicable at present.

Our ultimate goal is to increase the income of the coconut farmers and simultaneously contribute substantially to the vegetable oil pool of the country. We have to work out a choice of most compatible crop combination with coconut as the base crop, with optimum management practices for stability and risk avoidance due to natural as well as man made problems. If the precise constraints in each of the areas are identified, the present extension gap can be narrowed to the extent the available resources will permit and thereby increase the capacity to mobilise and use inputs.

I am sure that the four-days symposium will be most interesting and action oriented and will give thrust on developing breeding technology for improvement of coconut farming. I would urge the breeders to initiate follow-up action on the recommendations that emerge out of this national symposium. I would like to express my sincere thanks and gratitude to Dr E. G. Silas, Dr. M. Aravindakshan and other colleagues from the University for having given me an opportunity to be with you today and share my thoughts with the coconut research workers of the country. I wish the symposium all success.

Technical Session 1

BREEDING FOR HIGHER NUT AND COPRA PRODUCTION AND BETTER QUALITY ATTRIBUTES

COCONUT BREEDING – PAST ACHIEVEMENTS AND FUTURE STRATEGIES*

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Abstract: Early efforts of coconut breeding in India included collection and conservation of germplasm initiated in 1930s which received further support of FAO/IBPGR during 1980s. The present Indian germplasm holding with 86 exotic and 41 indigenous accessions is one of the world's largest assemblage of the crop. Based on the evaluation of indigenous germplasm accessions, two cultivars viz., Laccadive Ordinary (Chandrakalpa) and Banawali Green Round have been released for cultivation.

Selection of the prepotent West Cost Tall palms based on progeny performance as well as identification of elite palms gave a new thrust to improve traditional cultivars. The most significant impact was made by the advent of hybrid vigour in crosses involving talls and dwarfs. Research in this line during the last four decades made it possible to release three hybrids viz., Chandrasankara (COD x WCT), Chandralaksha (LO x COD) and Lakshaganga (LO x GB) hybrids. These gave much higher yields than the West Coast Tall (up to 83 per cent in terms of nut and up to 103 per cent in terms of copra out-turn). LO x COD and LO x GB were found to perform well under drought conditions also. Non-availability of sufficient planting materials has been the main constraint in realising the full field impact from these released varieties and hybrids. Efforts have been made to overcome this by establishing a chain of seed gardens in the coconut growing states.

Characterization and evaluation of the available germplasm, production of inbred lines followed by hybridization to exploit hybrid vigour to the full extent, exploitation of field tolerance to breed varieties tolerant to root (wilt) disease and Thanjavur wilt and perfecting the technique of developing plantlets through tissue culture for micro-propagation are some of the breeding strategies to achieve the desirable results in coconut breeding.

INTRODUCTION

Though research efforts to improve coconut production and productivity were started in the early part of the century in India, the progress has been slow because of its unique problems such as perennial habit, breeding system, long pre-bearing age, heterozygous nature, the time-lag involved in the study of progenies and the large area required for experimentation. Inspite of all these limitations, substantial progress in coconut breeding has been achieved in the country by concerted efforts and organised breeding approaches by the breeders at the erstwhile Central Coconut Research Station, Kasaragod under Madras State (Now the Central Plantation Crop Research Institute and its research centres, now under the Kerala Agricultural University). An attempt is made in this paper to record the breeding approaches employed and progress achieved so far and to outline future strategies contemplated for their rapid improvement with inbuilt resistance for pests, diseases and drought.

GERMPLASM AND VARIETAL IMPROVEMENT

Systematic research on crop improvement programme in coconut was perhaps started first in India in 1916. The earliest exotic introductions into India were in 1924 from the Philippines,

* CPCRI contribution No. 726

Malaysia, Fiji, Indonesia, Sri Lanka and Vietnam which formed the nucleus population for many of the research programmes. The germplasm exchange programme was further intensified in 1952 and in 1958 survey for collection of indigenous germplasm was started. At present, the Central Plantation Crops Research Institute, Kasaragod is maintaining the world's largest assemblage of germplasm of 41 indigenous and 86 exotic cultivars. The exotic collections from 22 countries of South and South East Asia, Carribean Islands, Indian Ocean, Pacific Ocean islands and African countries comprise of 52 talls, eight dwarfs, one semi-tall and one hybrid. The indigenous collections from eight states and two union territories comprise of 26 talls, eight dwarfs and one semi-tall. Besides, 24 exotic collections (20 talls and four dwarfs) were made from six countries in the Pacific Ocean regions in 1981 under FAO/IBPGR funded expedition. These exotic collections have been planted at the World Coconut Germplasm Centre, Andamans for quarantine considerations (Rao and Koshy, 1982). Some of these have been initiated for generating seedling material for planting in the main land.

Germplasm collections are also being maintained at Pilicode under the Kerala Agricultural University and four co-ordinating centres in Tamil Nadu (Veppankulam), Karnataka (Arsikere), Andhra Pradesh (Ambajipet) and Maharashtra (Ratnagiri) to assess their regional adaptability. These germplasms are being systematically evaluated for their yield and tolerance to pests and diseases in comparison with the local cultivars.

Among the exotic cultivars Fiji Tall, Fiji Longtonwan from Fiji island, Philippines Ordinary, Philippines Laguna and San Ramon from Philippines and Strait Settlement Green (SS Green) from Malaysia are superior to others. Among the indigenous cultivars Kappadam, Andaman Ordinary and Lakshadweep Or-

Table 1. Performance of promising coconut cultivars at CPCRI, Kasaragod, India

Cultivar	Bearing age (years)	Mean nuts/year/palm		Copra weight			
		No.	(17-20 years) % over WCT	Nut (g)	Palm/year (kg)	% over WCT Nut	% over WCT Palm/year
Exotic							
Fiji Tall	6	106	30.86	199.1	21.1	48.59	65.2
Fiji Longtonwan	8	104	22.12	210.5	22.0	54.92	66.0
Philippines Ordinary	5	108	33.33	196.1	21.1	48.59	66.0
Philippines Laguna	6	88	8.64	258.9	22.7	59.86	66.5
SS Green	6	108	33.33	186.1	20.1	41.55	67.0
San Ramon	6	64	–	349.6	22.4	57.75	68.0
Indigenous							
Kappadam	6	90	11.11	283.50	25.5	79.58	67.0
Andaman Ordinary	5	94	16.05	160.2	15.1	6.34	66.0
Laccadive Ordinary	6	98	20.99	176.3	17.3	21.83	72.0
West Coast Tall	7	81	–	176.0	14.2	–	68.0

Table 2. Comparative performance of hybrids (December, 1987)

Hybrid	n	Cumulative yield of nuts up to 21st year		1984 yield of nuts (18th-21st year)		Copra out-turn	
		Mean/ tree	% over WCT	Mean/ tree	% over WCT	Mean/ tree (kg)	% over WCT
COD x WCT (Chandrasankara)	11	1200	42	99.8	36	20.8	52
WCT x COD	11	1019	21	88.4	20	17.5	28
WCT x GB	13	822	-2	65.7	-11	12.4	-10
LO x COD (Chandralaksha)	11	1016	21	99.3	35	19.4	42
LO x GB (Lakshaganga)	10	1089	28	101.5	38	19.8	45
WCT	18	840	–	73.5	–	13.7	–

dinary have higher yield potential than the local West Coast Tall. The performance of promising cultivars of exotic and indigenous origin is given in Table 1. Based on the overall performance in the four co-ordinating centres in Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra and at CPCRI Kasaragod, Lakshadweep Ordinary has been recommended for release under the name 'Chandrakalpa'. This cultivar gave 25 per cent more yield in terms of nuts and 33 per cent more copra yield at stabilized bearing period (Anon., 1985).

Recently Benawali Green Round with a mean number of nuts of 151 and copra out-turn of 22.8 kg has also been released. Characterisation of varieties has been a problem faced by the breeder. To overcome this Pillai *et al.* (1986) has developed a descriptor using important traits like stem characters, breeding behaviour and nut characters.

Evaluation of coconut germplasm is a long drawn process due to its long juvenile phase and also time taken for stabilisation of yield. For evaluating at the nursery stage, seedling characters such as the sprouting period of seednuts, number of leaves, girth at collar and seedling height are generally used (Satyabalan and Mathew, 1976). Most of these characters have correlation with the adult palm bearing. An index was developed by Rao and Mathew (1981) using mean and CV of these characters for evaluation and characterisation of coconut germplasm at the nursery stage. The number of days taken for germination has negative and significant correlation with yield and mean values for this character were ranked in ascending order and characters with positive correlation were ranked in descending order. The graph with mean on X axis and CV on Y axis has been arbitrarily divided into four sectors, taking the mid-values on both axes. The cultivars in sector 1 are with high mean values for characters scored and low variability. Their low CV indicated relative homozygosity. Sector 4 accounts for cultivars with low mean value and high variability indicating highly heterozygous nature of these cultivars. Those cultivars falling in group 1 can be considered as promising. Usually the performance of a cultivar is evaluated against the local material only after stabilization of yield which may take

15-20 years after planting. However, Rao *et al.* (1978) found that it is possible to evaluate the germplasm accession at an early stage as the cumulative yield of the first eight years had high correlation (R^2 = 0.95) with the stabilized yield.

SELECTION

This method of improvement was being practised by cultivators for ages through their experience as an art rather than from a scientific angle. Later the technique was given due attention by the coconut breeders. One of the selection programmes contemplated for yield improvement was identification of high yielding mother palms based on seedling and growth characters. Research workers like Lakshmanachar (1959), Liyanage and Sakai (1960), Nambiar *et al.* (1970), Narasimhayya and Sukumaran (1978) have tried to workout the heritability of yield and yield attributes in coconut. For yield, these estimates varied from 0.48 to 0.63 whereas for the yield attributes like number of spathes, female flower production, setting percentage etc., the estimates were still higher indicating the advantages of selection based on these characters. These informations have been used for yield improvement programme by identification of high yielding mother palms based on seedling and growth characters. The prepotency in coconut was suggested by Harland (1957) which presumed that in these palms the gene combination reponsible for high yield potential tends to be transmitted *en bloc* to progeny even under random mating. Satyabalan *et al.* (1975) reported that it may be possible to identify palms of superior genetic value (prepotent) based on collar girth and leaf production in the nursery. It is possible to identify these palms even at the fifth month based on these two growth characters of the progeny (Satyabalan and Mathew, 1976).

Liyanage and Sakai (1960) worked heritability values for nut weight and copra and reported high heritability values of 0.67 and 0.95 respectively indicating that the yield of copra could be considered as the best selection criterion. Studies on the relationship between yield of nuts, copra content per nut, total yield per palm and yield of oil per palm showed that in WCT, the mean copra content, though negatively correlated with yield, did not affect annual copra out-turn per palm, the threshold value being 162.6 nuts, and that the yield of oil per palm and yield of nuts were significantly and positively correlated indicating the necessity for exercising selection pressure towards copra per nut and oil per cent in addition to number of nuts (Bavappa and Sukumaran, 1976).

HYBRIDIZATION

A new dimension to coconut improvement was added with the discovery of manifestation of hybrid vigour by Patel (1937) in crosses between West Coast Tall and Chowghat Dwarf Green. Subsequently, many workers (John and Narayana, 1949; Rao and Koyamu, 1952; Satyabalan, 1956; Liyanage, 1956 and Bhaskaran and Leela, 1964) confirmed the heterotic effects in the intervarietal and intra-varietal crosses. Till middle 1950s the emphasis was on the production of Tall x Dwarf (T x D) hybrids. These hybrids were precocious and high yielding compared to West Coast Tall only under good management. Satyabalan *et al.* (1970) found that among different dwarfs, Chowghat Orange Dwarf and Gangabondam were preferable as pollen parents compared to Chowghat Green Dwarf. Another finding of significance was the differential field performance of hybrids derived from different cross combinations of talls and dwarfs due to differential combining ability of the parents. Therefore, emphasis for specific combinations involving selected individual dwarfs and talls was stressed. The off type palms obtained from open pollinated progenies of Orange Dwarf coconuts were found to be superior to West Coast Tall palms in yield of nuts and copra content per nut (Rao and Koyamu, 1955). They were believed to be natural cross hybrids between Chowghat Dwarf Orange (female) and West Coast Tall (male) parents. The hybrid COD x WCT was found to be superior to the tall parent as well as to its reciprocal in yield of nuts and out-turn of copra (Ninan and Satyabalan, 1964).

It has been reported by IRHO that Malayan Dwarf Yellow x West African Tall gives over 95-97% recovery of hybrids MAWA (PB 121). The same could not be realized in COD x WCT hybrid combinations where the hybrid recovery was only about 30% on an average. However, the study by Satyabalan and Rajagopal (1987) has shown that by proper selection of parents on nut characters (dwarf palms having shell content less than 20% of husked weight are to be pollinated with tall palms which have a husk content of less than 50% of fruit weight and more than 150 kg of copra/nut) maximum recovery of hybrids could be obtained.

In view of the superior performance, the VII Workshop of All India Co-ordinated Coconut and Arecanut Improvement Project recommended the release of hybrids COD x WCT (Chandrasankara), LO x COD (Chandralaksha) and LO x GB (Lakshaganga) for cultivation in Kerala. The comparative performance of hybrids is given in Table 2. Hybrids VHC 1 (East Coast Tall x Dwarf Green) and VHC 2 (East Coast Tall x Malayan Yellow Dwarf) were released by the Tamil Nadu Agricultural University for cultivation in Tamil Nadu during 1981 and 1988 respectively. These two hybrids gave 16.4 and 26.7% more yield over East Coast Tall. Hybrids involving LO x COD and LO x GB showed less fluctuation in yield due to drought compared to COD x WCT.

A total of 87 cross combinations involving promising cultivars were planted in different periods at CPCRI, Kasaragod and are being evaluated for yield and other attributes. These include 21 talls x dwarfs, 10 dwarfs x talls, 51 talls x talls, 4 dwarfs x dwarfs and one three way hybrid.

REFINEMENT OF HYBRIDIZATION TECHNIQUE

Considering the tedium involved in the traditional method of hybridization, refinements have been brought out in the hybridization technique. A simple hybridization technique for the commercial production of coconut hybrids has been standardized. This technique involves emasculation of the male flowers before female flowers come to receptivity, collection of mature male flowers from selected tall parents, extracting the pollen, mixing of pollen with diluents in the ratio of 1:9 and dusting this mixture using a pollen dispensor (Pillai and Rao, 1984).

SEED PRODUCTION

Based on the National Group Discussion on Strategy for Planting Materials held at Kasaragod in January 1988, the annual planting material required in the country has been estimated as 15 million seedlings. This includes seedlings required for new planting to the extent of 30,000 ha per year (four lakh ha already been identified as suitable for coconut cultivation by Coconut Development Board), replanting and under-planting in other areas. Taking into consideration the performance of talls and dwarfs, the group also identified parents such as COD, MOD, LO, ECT etc. suitable for hybrid seed production in different states.

For the large scale production of hybrids, hybrid seed gardens have been established in Kerala, Karnataka, Tamil Nadu and Orissa (Pillai and Nayar, 1979). A total of 1.5 million hybrid seedlings are expected to be produced annually from these seed gardens. Earlier, planting of alternate rows of talls and dwarfs was recommended. Since only two hybrid combinations are produced in this method, compact block planting of pure dwarfs is being preferred. All the palms in this block are emasculated and assisted pollination is carried out using the desired pollen. In this way many desirable hybrid cor binations can be obtained.

TISSUE CULTURE

Another recent approach is clonal multiplication through tissue culture. Recently Raju *et al.* (1984) have succeeded in producing clonal plantlets directly from tender leaf segments of WCT and T x D hybrid seedlings through direct somatic embryogenesis. They could obtain from a single leaf explant measuring 5 mm as many as 48 embryoids. However, the response was found to be erratic and repeatability was found to be extremely low. Current efforts are directed towards perfecting this technique and also to use adult palm tissues.

SCREENING FOR DROUGHT TOLERANCE

A method for screening coconut cultivars for their tolerance to drought using sensitive parameters like stomatal resistance, epicuticular wax content, leaf water potential etc., has been standardized. Out of the genotypes screened, ten have been identified to possess the desired traits to withstand drought (Rajagopal *et al.*, 1988).

FUTURE STRATEGY

Though India has one of the largest and best germplasm accessions, the collections cannot be considered as comprehensive as the total variability represented is very narrow. Screening so far shows that none of the germplasm is resistant/tolerant to root (wilt) disease which is a major production constraint. The fact that coconut belongs to monotype genus also limits the possibility of tapping gene-pools from related sources. In view of this, broadening the genetic base through collections from Melanesia, Micronesia and Indian Ocean islands which are known to have wide variability should receive top priority. Similarly the indigenous collections are not representative of the total variability in the country. Collections from Orissa, West Bengal and North Eastern Region should also receive top priority.

It is necessary to have a sizable population (minimum 10 palms per accession) of the collections maintained preferably at more than one location, their characters described and evaluation records are maintained so that the breeders can utilize them for introgression of any one of the desirable features in the breeding programmes. Maintenance of duplicate set would help in meaningful evaluation and also as a stand-by in case of a disease threat. For the initial evaluation trials, a well laid out statistical design preferably RBD with three replications and six palms/cultivar is desirable. Such preliminary evaluation will help in reducing time lag since the promising ones from these trials can be multilocationally tested for their adaptability and yield. The co-ordinating centres could be used for such trials.

In Sri Lanka and Indonesia selection of phenotypically superior palms met with some success in realizing higher mean yield in the progenies. Since it is possible to identify prepotent palms based on progeny performance all the traditional cultivars must be screened for prepotency for use in breeding programmes as well as in replanting and underplanting programmes.

INBREEDING

Inbreeding and developing pure lines have not received adequate attention from the breeders. The possibility of developing superior hybrids by inbreeding followed by hybridization needs to be explored. Where inbreeding depression is apparent, introgression with other palms should be attempted to correct the weakness after which a second phase of selection of inbreeding may be attempted.

EXPLOITATION OF HETEROSIS

The experience from Ivory Coast on the performance of MAWA (PB 121) hybrids and also on the performance of different hybrids in other countries clearly shows that it is necessary to select dwarfs and talls based on combining ability of the individual palms within an accession/cultivar before resorting to hybridization. A systematic study of the combining ability of the diverse sources of dwarf germplasm with pollen from prepotent tall must be initiated. The homogeneous dwarfs thus identified must be planted in the elite seed gardens of the country for mass-production of hybrids. Malayan Yellow Dwarf which appears to be much more homogeneous due to its self-pollinating nature may prove to be a good female parent in crosses with promising talls in realising high recovery of superior performing D x T hybrid seedlings. The high out-turn of copra realised in T x T crosses in Indonesia indicates the possibility of upgrading talls. Efforts must be made to utilize all the promising talls like Laccadive Ordinary, Philippines Ordinary and Andaman Ordinary besides West African Tall and Renell Tall in the production of T x T crosses.

RESISTANCE BREEDING

The role of MLO in the etiology of root (wilt) disease has been conclusively proved. In view of the fact that effective control measures are not likely to emerge against this disease, breeding tolerant/resistant cultivars should be taken up on a war-footing. The first step in this direction must be to screen the *inter se* progenies of the exotic germplasm (Pacific Ocean collections) available at the World Coconut Germplasm Centre, Andamans and also to utilize the 35 tolerant palms identified in the farmers field in disease affected areas in the breeding programme. Survey for more tolerant palms in the endemic areas also must be taken up simultaneously. While breeding resistant varieties, attempts should be made to incorporate preferably polygenic resistance into improved varieties/hybrids. This is of vital importance as improved varieties/hybrids will have to remain resistant tolerant for over 60-80 years. A similar effort must be taken up to breed resistant/tolerant cultivars against Thanjavur wilt, thatipakka and stem bleeding diseases.

TISSUE CULTURE

Efforts are to be directed towards perfecting the production of clonal plantlets directly from seedling leaf tissues to adult palms and also to standardize transfer of plantlets from test tube to soil through the process of hardening of the root system using hydroponic methods. The next step, should be micropropagation for mass multiplication of high yielding elite palms.

IN VITRO CONSERVATION

Embryo culture technique has been standardized by Assy-Bah *et al.* (1988) and at CPCRI and this can be effectively utilized for germplasm collection specially from exotic sources. To supplement the 'field genebanks' cryopreservation for long term storage in *in vitro* banks also should be explored.

ANTHER CULTURE

Preliminary studies at CPCRI have resulted in multicelled pollen embryoids. Anther culture for the production of haploids and homozygous diploids should be an exciting and rewarding attempt in realising the production of isogenic coconut genotypes. If isogenic dwarf and tall could be obtained, this would assure 100% recovery of hybrids in compatible combinations.

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COCONUT HYBRIDS - INTEREST AND PROSPECTS; IRHO* CONTRIBUTION TO RESEARCH AND DEVELOPMENT

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Abstract: Indian researchers were pioneers in coconut hybrid research, followed fifteen or so years later by the Sri Lankans. Despite the interest stirred up by this initial work, hybridization research programmes remained modest for a long time and their impact on development was very low.

As early as 1960, IRHO started taking interest in hybrids and, along with its partners, gradually set up a vast coconut improvement research programme, based on hybridization, at research stations and test points. This programme involves collecting strains or varieties of distant geographical and, if possible, genetic origins; study of character variability, study of combining ability between ecotypes, improvement of the best hybrids by carrying out research into individual combining ability, improvment of selected ecotypes, based on the performance of their progenies and recombination of these ecotypes so as to begin a new improvement cycle.

Results have revealed the interest of a certain number of hybrids between ecotypes, which produce at least twice as much as the tall coconuts to which they have been compared. Certain of them are adapted to a wide range of edapho-climatic conditions (PB 121), others have been created for their own particular soil or phytosanitary environment (eg. Brazilian Green Dwarf x Rangiroa Tall for atolls, Vanuatu Red Dwarf x Vanuatu Tall against FDMT disease). Choosing the best individuals now enables additional yields of around 20% to be achieved.

IRHO did not stop at merely creating good hybrids, but developed new mass seed production techniques and has widely distributed these seeds throughout the world.

The results obtained in other fields, especially mineral nutrition and crop techniques, have enabled IRHO to valorize its results in genetic improvement, giving rise to considerable interest in hybrids in most of the major coconut development projects. Despite certain planning errors and numerous critics, the results are such that the role of the hybrids seems to be recognized once and for all.

For several years now, interest in hybrid research has experienced a clear revival, particularly in the Philippines, Indonesia, India, Thailand and the Pacific. This interest is concentrated on finding solutions to specific problems (disease resistance, adaptation to drought, etc.). Nonetheless, among the basic objectives, increased yields and the search for ortets among hybrid x hybrid type crosses should not be forgotten.

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INTRODUCTION

It was in Fiji in 1928 that H. Marechal carried out the first coconut inter-ecotype cross: Malayan Dwarf x Niu Leka Dwarf (Marechal, 1928). There is no precise information available as to the value of this cross, but the hardly encouraging results obtained in Cote d'Ivoire on this hybrid explain, perhaps, why this work was not continued. A few years later (1932), J.S. Patel created *the first tall x dwarf hybrid* (West Coast Tall x Chowghat Dwarf Orange) in India (Patel, 1937). In doing this, he opened up channels which were subsequently to prove of considerable interest for the genetic improvement of coconut palms. It is this pioneering role played by Indian researchers in the 1930s that we are here to celebrate today. Nonetheless, the results of this research were not immediately applied in practice and, for a long time, development programmes did not benefit from them. The Second World War was certainly at the root of this delay, but there was probably also the fact that mass production techniques for seeds had not been developed at that time and agronomical research was not directed towards making use of this type of planting material. It was only at the beginning of the 1960s that hybrid research and development took off. Four organizations, CRI in Sri Lanka, the Coconut Industry Board in Jamaica, JCRS in the Solomons and IRHO on its stations played an important role, but it is IRHO, along with its partners, that has put in the greatest effort in this field; at the same time as it was developing a vast genetic improvement programme, it perfected mass production techniques for hybrid seeds, along with seed bed and nursery techniques and studied hybrid fertilizer requirements and phytosanitary problems. It is this contribution made by IRHO to research and development that is described in this paper.

IRHO GENETIC IMPROVEMENT RESEARCH ON COCONUT

1. Selection scheme

Knowledge of coconut genetics is limited, mostly because of the constraints associated with the plant's biology. Nonetheless, work carried out prior to that undertaken by IRHO has made it possible to bring out a few broad outlines:

* *Mass selection has never led to any spectacular increase in yields* and has often been ineffective. Moreover, this result has been confirmed through heritability calculations; whilst the estimated heritability of each of the yield components (number of nuts/tree and copra/nut) is quite high, the estimated heritability for yields themselves is low due to the negative correlation that exists between these characters (Liyanage and Sakai, 1961; Meunier *et al.* 1984b)

* The progress made in within-population selection has remained limited due to insufficient genetic variability in the local strains used and also because of a more or less high rate of inbreeding (too small a number of individuals used at the outset).

* *The initial trials involving crosses between phenotypically and geographically differing coconuts brought out the importance of these hybrid vigour effects* and led to a substantial increase in yields (Liyanage, 1956).

All these elements led IRHO to draw up an improvement scheme adapted to coconut (Gascon and Lamothe, 1978; Meunier *et al.*, 1984a) which can be summarized as follows:

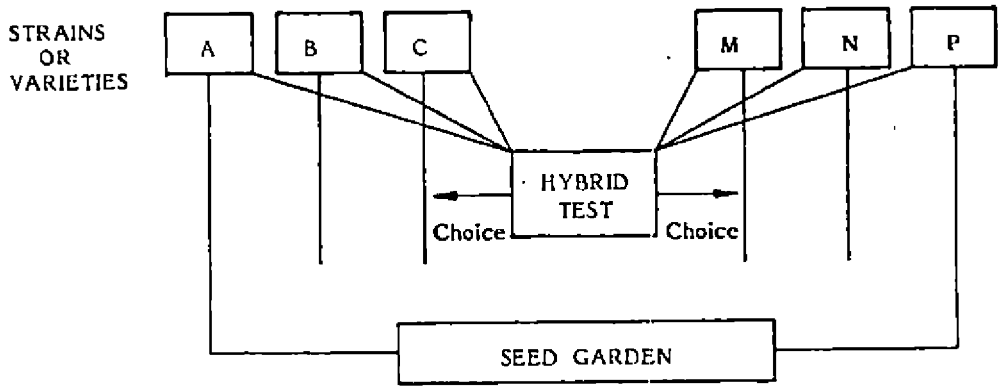

Fig 1. Combining ability between ecotypes

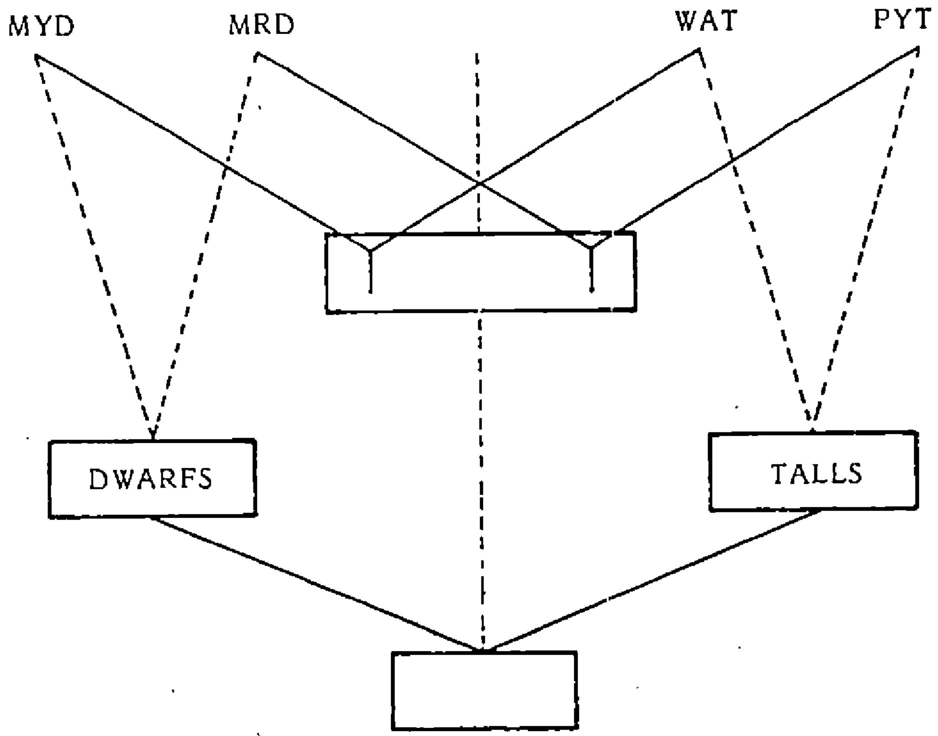

Fig 2. Example of selection recombining the parents of two good Malayan Yellow Dwarf x West African Tall and Malayan Red Dwarf x Polynesia Tall hybrids.

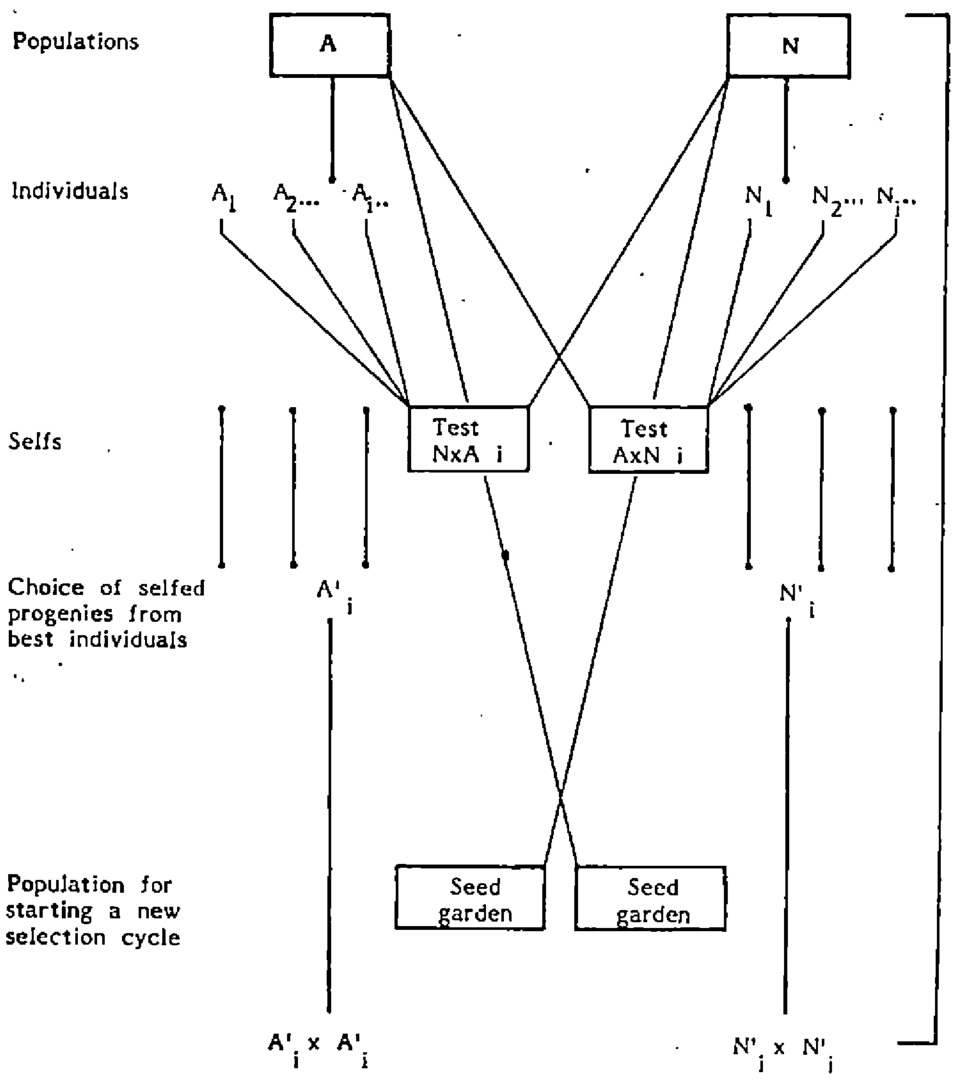

Fig 3. Improvement of best hybrids combining ability of inviduals

(1) Genetic variability surveys and collection.

(2) Search for the best combining ability between ecotypes (Fig 1). Phenotypically different ecotypes are crossed and the performance of the hybrids is assessed in comparative trials. The best of them are reproduced in seed gardens.

(3) Improvement of selected ecotypes, based on the performance of their progenies and recombination of these ecotypes to start a new improvement cycle in accordance with a scheme derived from reciprocal recurrent selection used by Comstock *et al.* (1949) on maize (Fig 2).

(4) Improvement of the best hybrids through selection based on the hybrid progeny of the best individuals in the parental populations. Reciprocal recurrent selection (Fig 3).

This general scheme was subsequently completed by schemes specific to particular objectives, such as wide based crosses to increase variability with a view to cloning, or back-crosses and selfs, so as to transfer disease resistance or reproduce a cross.

2. IRHO experimental network

The Marc Delorme Station in Cote d'Ivoire and Saraoutou in Vanuatu form the basis of the IRHO experimental design. They have very large planting material collections containing strains or varieties from *more than 20 countries on four continents* = 36 types of talls and 17 dwarfs at Marc Delorme and 11 types of talls and 13 dwarfs at Saraoutou (50 to 100 trees or more per strain). A study of these collections has made it possible to get an idea of the genetic variability of the strains and has served as a guide in the choice of hybrids to be studied.

These two stations in Cote d'Ivoire and Vanuatu have tested or are still testing 110 types of inter-varietal hybrids in 30 comparative trials, 399 hybrid progenies in 21 individual combining ability trials and six types of hybrid x hybrid crosses, so as to obtain exceptional individuals for use as ortets once tissue culture has finally been perfected.

Many of the inter-varietal combinations studied at Marc Delorme and Saraoutou have also been tested in other ecologies on public or private research stations or test points with which IRHO collaborates. Certain of them, the Malayan Yellow Dwarf x West African Tall, or PB 121, for example, have been planted in several dozen countries and different ecologies.

Starting in 1989, IRHO and the Saraoutou Station will be in the forefront of a regional coconut improvement programme in the Pacific. The aim is to test local strains in hybrid comparative trials to determine their combining ability and set up seed gardens capable of reproducing the best combinations. Nineteen countries from the region will be participating in the project.

3. Results

3.1 *Inter-ecotype hybrids*

¤ Dwarf x Tall Hybrids

Over the last 15 years, emphasis has been placed upon crosses between dwarf coconuts, whose good homogeneity (associated with their autogamy) and excellent precocity has been demonstrated, and tall coconuts, which are hardy and have higher copra/nut. This has resulted in precocious hybrids, certain of which have proved to be very high-yielding. With this better *precocity*, trees start bearing 12 to 24 months sooner and reach a production plateau in a shorter time. Table 1 shows that dwarf x tall hybrids start producing much sooner than talls, whatever the tall's origins and location. In Vanuatu, they are virtually as precocious as the Malayan Red Dwarf. This better precocity is a considerable advantage in the cultivation of a perennial plant with a non-productive phase as long as that of the coconut palm.

Even if it is not the determining factor, it certainly makes it easier to obtain loans for creating plantations. Indeed, it is obvious that project profitability will differ considerably depending on whether yields of 7.5 tonnes of copra/ha (cumulated at 6 years for hybrids) are expected, or 0.9 tonnes for talls of the same age.

They are of such interest to small-scale growers that, in certain provinces in Indonesia where both types of seeds are offered, almost total disaffection with tall seeds has been noticed (Communication from the Smallholders Coconut Development Project in Indonesia).

The superiority of dwarf x tall hybrids is not limited to precocity. They are obviously all not as productive as each other, but the best ones produce much more than the traditional varieties. Table 2 shows the production in Cote d'Ivoire and in a few other centres of hybrids created at the Marc Delorme Station. At an age that can be considered to be around adulthood, they produce from 147 to 226% of local tall coconut production, depending on the site in question. The production of the first hybrids planted 25 years ago in Cote d'Ivoire (435 trees) has fallen over recent years due to a substantial drop in the water table; despite this, their average yields between 20 and 25 years was 3.4 t/ha/yr, as opposed to 1.6 t/ha/yr for WATs under similar conditions (Anon.,1987). Under good conditions, their production exceeds 5 t of copra.

¤ Tall x Tall Hybrids

Tall x tall inter-ecotype hybrids are less precocious than dwarf x tall hybrids, but reach the production plateau corresponding to adult age more rapidly than their parents. Whilst the dwarf x tall hybrids currently seem to be superior to the tall x tall, these latter hybrids are not without interest, because they often have good copra/nut and, more particularly, greater genetic variability, which increases the possibility of improving them. In addition, preference may be given to certain of them when intercropping under coconut is being considered. Hence, the WAT x RLT, which gives just as high yields per hectare when it is planted in 10 m triangles as when it is planted at 9 or 8 m, seems to be well suited to this type of cultivation (less intercepted light) (Lamothe, 1989).

¤ Dwarf x Dwarf Hybrids

The results obtained in Cote d'Ivoire have shown the interest of certain dwarf x dwarf hybrids, eg., Malayan Yellow Dwarf x Brazilian Green Dwarf (Saint & Lamothe, 1987). They are as precocious as the dwarfs and give better copra/tree (mainly due to their better copra/nut). Their low vegetative bulkiness makes it possible to plant them at high densities: 205 or even 235 trees/ha (7.5 or 7 m triangle) and thereby obtain high yields per hectare. In Cote d'Ivoire, at a density which is still relatively low (170 trees/ha), 4 t/ha/year were obtained on average between 9 and 15 years. Two trials underway in Indonesia should confirm the conclusions obtained in Cote d'Ivoire. On the other hand, this type of hybrid only has a limited chance of being significantly improved, because it comes from the crossing of populations with a high autogamy rate.

Adaptation to particular environments

Certain hybrids, such as the PB 121 which has been tested in over 40 countries (Lamothe, 1985), have a broad adaptation spectrum; under conditions less than optimum or even marginal, they come out on top, even though their yields in such a case are relatively low. Thus, in Cote d'Ivoire, in a zone with a high water deficit (Daloa), the PB 121 has produced 1.9 t copra/ha/year on average between 8 and 12 years, whereas the WAT only produced 0.8 t (Anon., 1987).

Other hybrids are more particularly adapted to a type of environment. Such seems to be the case with the PB 121, or with Rennell hybrids which can outdo the PB 121 on well drained soils with no water deficit. Finally, certain hybrids have been created for a given environment; this is the case, for example with the Vanuatu Red Dwarf x Vanuatu Tall, which is resistant to leaf decay due to *Myndus taffini* (FDMT) (Calvez *et al.*, 1985) or the Brazilian Green Dwarf x Rangiroa Tall which gives good yields on atoll soils with a pH of 9.

3.2. *Improved hybrids*

In order to improve the best hybrids, individuals are chosen from one of the parent populations (or both); a study is made of the progenies of these individuals in crosses with the other population. The individuals that reveal the best combining ability are reproduced and multiplied by selfing and inter crossing to give the basic population for a new selection cycle.

Ten types of intervarietal hybrids are being improved in Cote d'Ivoire and two in Vanuatu. They were selected according to their performance and the assumed genetic variability of the parent populations; thus, attempts are being made to improve certain tall x tall crosses, which are a little less productive than the PB 121 or the PB 111, but whose parent populations are variable enough for there to be a good chance of finding excellent individual combinations.

The initial results from the trials in Cote d'Ivoire are very promising. The PB 121, whose West African Tall parent is not very variable, is improved by 14% between 4 and 10 years if the 13.4% best parents are chosen, whereas the MYD x PYT hybrid, whose tall parent is very variable, is improved by 22% between 4 and 11 years for the same parental selection rate (13.4%).

The PB 213 hybrid (WAT x RLT) produces slightly less than the PB 121, but if the Rennell parents are selected according to the performance of their progenies, an improved PB 213 is obtained which produces 14% more than the PB 121 between 7 and 8 years; likewise, the MRD x RLT, which produces around 10% less than the PB 121 in Cote d'Ivoire, would appear to produce 10% more when 13.4% of the best parents are chosen.

There are a few indications that tend to show that this combining ability is a general ability and that the best Rennell parents would remain the best whatever the combination (Anon., 1987).

This research channel is still only in its early stages, but the initial results reveal its utility; under the best edaphoclimatic conditions, it will make it possible to attain, or even exceed, yields of 6 t of copra/ha.

3.3 *Ortet research*

In a few years, vegetative propagation by tissue culture will certainly be perfected. It will then be necessary to have genetically superior trees which will be multiplied. Given the high cost price of *in vitro* plantlets, their use can only be considered if the gains in production are substantial. This is why IRHO has launched an ortet research programme. The best individuals are selected from two hybrid populations based on the most heritable characters and 4-way hybrid x hybrid crosses are carried out. It is hoped, in this way, to obtain a few remarkable individuals which combine the favourable characters of the four populations existing at the outset.

CONTRIBUTIONS TO DEVELOPMENT

When Cote d'Ivoire decided in 1968, almost 30 years after J.S Patel's work, to undertake a vast hybrid coconut planting programme, with the financial assistance of various organizations, including the World Bank and the European Development Fund, it was the first country to head off in this direction

It was in a position to do so, because work carried out by IRHO provided it with the technical means required: production of large quantities of good quality hybrid seeds and adapted agronomical techniques (nursery, planting, nutrition, crop protection).

1. Seed Production

Hand pollination, with isolation of inflorescences in pollen-impermeable bags, is a very expensive technique which gives low seed yields; it is essential for research purposes, but it cannot be used for seed production. Only the seed garden technique enables the millions of seeds required for development projects to be produced at a reasonable cost.

The first coconut seed garden was planted in 1956 by CRI in Sri Lanka; the regularly emasculated mother-trees are interplanted with the trees chosen as male parents in a place separated off from any other coconuts by a plant barrier several hundred metres thick; pollination is of the so-called directed open type.

Thereafter, IRHO perfected the technique using "assisted pollination" (Wuidart and Rognon, 1981). Only the mothertrees are planted in the isolated seed garden; the pollen is gathered from male parents which may be planted some distance away. It is then dusted on to the female flowers of the mother-trees. The advantage offered by this technique, compared to the previous one, lies in the flexibility it gives to the running of seed gardens. Instead of being obliged to use interplanted male parents, pollen from the best trees can be used in assisted pollination. It thus becomes possible to:

* change the variety of pollen used if the latest research results show this to be advantageous,
* be stricter in the choice of trees used as male parents (one male parent for 20 mother trees instead of 1 to 6 or less).

Tens of millions of inter-ecotype hybrid seeds have already been produced by *"assisted pollination"* in Africa, Brazil, Indonesia, Malaysia, the Philippines, French Polynesia and Thailand, etc.

Seed quality is excellent (germinating capacity and legitimacy); thus, in Indonesia, the P.T. MULTIAGRO seed garden produces almost 2 million seeds per year, with legitimacy which has always been over 98%. The cost price of these seeds only marginally exceeds that of hybrid seeds produced by directed open pollination.

Table 1. Hybrid precocity - production in tonnes of copra/ha

1/ DWARF x TALL HYBRIDS

Age	Cote d'Ivoire						Indonesia					Thailand		Vanuatu	
	PB-GC 5			PB-GC 11			B BG-01		B BP-01			Sawi (3)		VT-GC 7	
(yrs)	WAT	PB 121	PB 132	WAT	PB 111	PB 123	WAT	PB 121	Bali Tall	PB 111	PB 121	THT	PB 121	MRD	PB 111
3-4												-	-	0,08	0,04
4-5				0,01	2,88	2,23	0,03	1,88	-	1,46	0,75	0,01	0,30	1,55	2,35
5-6		2,53	2,35	0,88	4,62	4,30	0,03	3,51	-	3,35	3,10	0,08	1,13	1,47	2,79
6-7	0,42	2,38	2,22	2,01	4,32	3,81	0,52 (2)	1,26 (2)	-	2,90	3,10	0,31	1,65	2,62	5,14
7-8	1,88	3,88	3,94	1,47 (1)	2,39 (1)	3,17	0,75 (2)	1,44 (2)	0,05	3,44	3,32	0,99	2,55		
8-9	1,77	4,12	3,94	1,24 (1)	2,49 (1)	3,58	0,79	3,59	0,39	2,54	2,76	0,39	0,79		
	4,07	12,91	12,45	5,61	16,70	17,09	2,12	11,68	0,44	13,69	13,03	1,78	6,42	5,72	10,32
%	100	317	306	100	298	305	100	551	100	3111	2961	100	360	100	180

2/ TALL x TALL HYBRIDS

	Cote d'Ivoire				Thailand	
	PB/GC 3/2		PB-GC 8/1		Sawi (3)	
	WAT	WAT x RLT	WAT	WAT x VTT	THT	THT x WAT
4-5	0,19	0,60			0,01	0,07
5-6	1,44	4,05			0,08	0,42
6-7	1,99	4,08	0,29	2,26	0,31	1,21
7-8	2,19	4,16	1,03	3,33	0,99	1,96
8-9			1,22	2,91	0,39	0,77
9-10			1,43	3,45		
	5,81	12,89	3,97	11,95	1,78	4,43
%	100	222	100	301	100	249

VTT = Vanuatu Tall
THT = Thailand Tall
WAT = West African Tall
PB 121 = Malayan Yellow Dwarf x WAT
PB 132 = Malayan Red Dwarf x Polynesia Tall
PB 111 = Cameroon Red Dwarf x WAT
PB 123 = Malayan Yellow Dwarf x Rennell Tall
(1) Heavy *Pseudotheraptus* W. attacks
(2) Serious drought in 1982 and 1983
(3) Results from HRI in Thailand

Table 2. Hybrid productivity in tonnes of copra/ha

1/ DWARF x TALL HYBRIDS

	Cote d'Ivoire				Thailand		Malaysia		Vanuatu	
	PB-GC 5		PB-GC		Sawi		HRU III		VT-GC 3	
	9-15 (6 yrs)	%	9-14 (5 yrs)	%	8-12 (4 yrs)	%	9-13 (4 yrs)	%	7-10 (3 yrs)	%
WAT	1,81	100	1,99	100						
MLT							2,55	100		
THT					1,19	100				
MYD									1,80	100
PB 111			4,24**	213						
PB 121	3,70**	204			2,00**	168	3,74**	147		
PB 132	3,81**	210								
MYD x RLT			4,50**	226					4,76	264

2/ TALL x TALL HYBRIDS

	Cote d'Ivoire				Thailand	
	PB-GC 3/2		PB-GC 8/1		Sawi	
	9-13 (4 yrs)	%	9-14 (5 yrs)	%	8-12 (4 yrs)	%
WAT	2,48	100	1,46	100		
THT					1,19	100
WAT x RLT	4,64**	187				
WAT x VTT			3,29**	225		
THT x WAT					1,91**	161

3/ DWARF x DWARF HYBRIDS

	Cote d'Ivoire - PB-G4 - 2-15 yrs	%
MYD	2,86	100
MYD x BGD	3,77	132

WAT = West African Tall
MLT = Malayan Tall
THT = Thailand Tall
RLT = Rennell Tall
MYD = Malayan Yellow Dwarf

PB 111 = Cameroon Red Dwarf x WAT
PB 121 = Malayan Yellow Dwarf x WAT
PB 132 = Malayan Red Dwarf x Polynesia Tall

The production of *improved hybrid* seeds is now possible by using the pollen of progenies obtained by selfing of the best parents. The Marc Delorme Station in Cote d'Ivoire has a large collection of parent progenies.

Vegetative propagation by tissue culture has not yet been perfected, but numerous laboratories are working on it, including the IRHO/ORSTOM laboratory in Montpellier, France.

2. Technological package

Large coconut development projects came into being, because seeds with high production potential and a set of agronomical techniques adapted to this new type of planting material were both available at the same time. For a number of years now, IRHO has in fact been perfecting seedbed and nursery techniques and planting and upkeep methods; it has acquired good knowledge of the nutritive element requirements of hybrids in different ecologies (role of potassium and requirements depending on water deficit, K-Mg balance, importance of chlorine, etc.) and has developed methods of controlling pests and diseases. Research is continuing to increase knowledge and further improve techniques, especially with respect to crop protection.

It is obvious that, in order to make the most of hybrid planting material, it is necessary to improve all the crop techniques involved and adapt them to the local context. The same recommendations are not given to large plantations and to small holdings; in the latter case, what is sought is the best return on the sum engaged and not the highest profit (type and quantity of fertilizers of nutritive elements, for example), but it would be a mistake to think that the efforts made in respect of planting material quality will be satisfactorily valorized without applying good crop techniques.

3. Development projects

The IRHO's initial results from trials in Cote d'Ivoire and, thereafter, in performance trials it helped to set up in numerous countries, have attracted the attention of governments and national and international financing organizations. After Cote d'Ivoire it was the Philippines, Malaysia, Thailand and Brazil, but especially Indonesia which launched development programmes using almost exclusively the hybrid coconuts created by IRHO and, in particular, the PB 121 (the Mawa in Malaysia or Sawi No. 1 in Thailand). At the present time, Indonesia has over 100,000 ha of dwarf x tall hybrids.

Certain critics accuse hybrids of having insufficient genetic variability which would make them susceptible to epidemic type diseases. In fact, this criticism has no foundation because coconut hybrids do not come from crosses between pure lines, which is the case for maize, but between populations. Every dwarf x tall hybrid has at least the same variability as its tall parent. The variability of tall x tall hybrids is superior to that of each of their parents. However, the best solution to widen the genetic variability of the new plantations and ensure protection, as far as possible, from phytosanitary incidents, consists in using several types of hybrids in the same zone (Lamothe and Rognon, 1986). These hybrids should obviously all be adapted to the ecological conditions in the zone in question. It is therefore up to researchers to define the most genetically diverse and best performing combinations for each zone and up to those in charge of seed gardens to produce the seeds.

CONCLUSION

The research stations and centres and the public and private test points that IRHO manages, or with which it collaborates, currently form a *vast informal network* for coconut research and development. The results obtained in (and outside) this network and the prospects they suggest have revived interest in hybrid research worldwide. It is now rare to find organizations specialized in coconut that are not interested in intervarietal crosses, especially dwarf x tall.

But a few hybrid comparative trials do not necessarily make a programme. Coconut improvement is long and difficult; it is essential to properly define the objectives of the research work, then choose a selection scheme and draw up a long-term programme.

Very broad and well organized international cooperation would make it possible to coordinate the various national programmes; it would prevent unworthwhile duplications and ensure rational exploitations of genetic resources existing in the world. It has to be admitted that it has been lacking up to now.

A certain number of organizations in EEC member countries, have a project to pool their efforts with organizations in producer countries, in order to assist research and development in the field of tropical perennial oil crops. A bureau will be created in 1989 which could be the first step towards wide international cooperation.

In May 1988, the Australian Centre for Agricultural Research (ACIAR) put forward a proposal to the Technical Advisory Committee (TAC) of the Consultative Group for International Agricultural Research (CGIAR) for the creation of an International Coconut Research Council; this proposal was received with interest.

It is therefore justified to be reasonably optimistic as to the future of coconut research and genetic improvement.

The topics to which priority could initially be given at international level are:

* increasing and studying the variability of collections,
* increasing productivity: search for new intervarietal hybrids (the number of nuts/tree character seems to be the dominant factor in yield determination) and improvement of hybrids by studying their individual combining ability (interest of tall x tall crosses, research into better precocity and increased productivity),
* obtaining planting material adapted to particular environments: high water deficit, coralline soils or peat, existence of pests and/or diseases, etc.

The chances of success will be excellent if the research organizations agree to cooperate with each other and if those in charge of development take steps to train growers, persuade them of the need to improve their crop techniques and provide them with the means to do it.

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THE PROMISE, PERFORMANCE AND PROBLEMS OF F_1 HYBRID COCONUTS

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Abstract: Tall x dwarf, dwarf x tall, dwarf x dwarf and tall x tall F_1 hybrids may be produced by mass controlled pollination, assisted pollination *(pollinisation assistee)* or by hand-pollination. The advantages and disadvantages of these three alternative methods of producing hybrid planting material are discussed. The relative performance of various named hybrids is still the subject of controversy and all possible combinations have not yet been tested. The selection of suitable parent types has often been based on a limited range of source material and some possible combinations may have been ignored or neglected. Three-way crosses are proposed. Except for embryo culture, new biotechnology has not yet become available to the coconut breeder.

TYPES OF HYBRID

There are four possible F_1 hybrid combinations; the tall x dwarf, such as the Lakshaganga in India; the dwarf x tall, for which the PB 121 and the Maypan may serve as contrasting examples; the tall x tall, which as yet is seen in trials rather than in commercial plantings; and the dwarf x dwarf, with the Malayan Dwarf x Niu Leka (or Fiji Dwarf) being of particular interest. Without going into detail over the relative merits of T x D, D x T, T x T and D x D which is a subject of considerable differences of opinion, there should be general agreement that the promise which farmers and research workers look for in F_1 hybrids can be considered under two heads; namely yield improvement and disease resistance. There have also been other criteria such as windstorm tolerance, drought tolerance, pest resistance and so on. Factors relating to processing and marketing of coconut products and byproducts have rarely if ever been taken into consideration. Nor have all possible parental combinations been made and tested yet. In general terms, the type of hybrid that is made, whether T x D, D x T, T x T or D x D will depend on what parent material is available. The sources of parental material may be local or exotic but it is not always safe to assume that cultivars from different geographic locations are indeed different from one another. It is hoped that germplasm transfer and exchange using zygotic embryo culture techniques instead of seednuts will give plant breeders access to a wider range of material.

HYBRID PRODUCTION METHODS

In terms of F_1 hybrid production methods, there will always be the need for controlled hand pollination, using isolation bags or similar research techniques. The high cost and low seed set of this method will not allow it to be used for commercial seed production. Yet, even when tissue culture of coconut palms finally becomes possible,such controlled pollination will continue to be the best way to generate new genetic combinations.

For production of hybrids in commercial quantities there are two similar methods, the one developed by IRHO, known as assisted pollination and the Jamaican Coconut Industry Board method, known as mass controlled pollination. The former method, originally called *pollinisation assistee* in French, is a development of the interplanted seed garden in which lines of seed parents, usually dwarf types, are alternated with a smaller number of pollen parent rows, generally tall types. As such, this method is limited to one hybrid combination because it cannot permit total isolation. The second method, mass controlled pollination, is based on the idea that all pollen is supplied to a seed garden that is totally isolated. Therefore as many hybrids can be made as there are sources of pollen which, by definition, are planted elsewhere and which can even be imported from abroad.

In both of these methods the seed gardens are surrounded by a two to three hundred metre wide barrier of non-coconut vegetation (jungle, oil palm, rubber, etc. and the individual palms are inspected daily. Those palms which have inflorescences which are nearly ready to open naturally are emasculated before they open so that no viable pollen is released to the wind or transferred by pollinating insects. No isolation bags are used (since it would be too costly to afford these for every palm). Also, daily the palms are inspected (in a separate operation from emasculation) and those on which receptive female flowers can be identified are pollinated, often mixing the pollen with talc and applied by pollen dusting machine or blower.

Three-way hybrids

There is one possible development that could be pursued by mass controlled pollination and this is the three-way cross. This could be achieved if an isolated plot of F_1 hybrid were themselves emasculated and pollinated with pollen from a third parent (preferably a tall type). Possibly, the local tall type that grows in the neighbourhood of the emasculated hybrids could be allowed to shed pollen into the emasculated hybrids, in which case the two or three hundred metre isolation belt does not apply (it would then be a variation of assisted pollination). Otherwise, pollen from individually selected tall parents would be used, as in mass controlled pollination. The resulting progeny might combine the better characteristics of all three parents. It is not clear why such a simple step has not already been taken.

Clonal hybrid seed

The other foreseeable development that will improve all three methods of pollination would be the use of clonal seed parents and clonal pollen parents when these come available, as suggested by Blake (1988). The clonal seed that would be produced would germinate to give much more uniform hybrid seedling population that can presently be achieved. At the moment biotechnology is only just starting to make an impact on coconut breeding with the practicality of transfer of germplasm as vacuum-packed pollen and as artificially cultured zygotic embryos. Cryopreservation of pollen is an established technique but needs to be developed for embryos.

HYBRID PERFORMANCE

Yield improvement

The next question to ask is whether the hybrids that have been released so far have delivered the performance which was expected of them. In terms of yield improvement it is clear that some hybrids are just as early bearing and high yielding in commercial plantings as they were in the research fields. Good results have been reported but it is also known that they do not always come up to expectations. For example, the PB 121 was sometimes rejected; by farmers in Thailand for instance, where individual fruit size is the most important factor when marketing the coconut. In another example, one particular hybrid combination, the red Malayan Dwarf x Rennell Tall grows well in the Solomon Islands and in Papua New Guinea, where some planters are very happy with them. In this instance, there have also been some poor reports on the MD x RT hybrid in Papua New Guinea. As research workers who deal with coconut management practices are well aware, F_1 hybrids or any other improved planting material, will only deliver their maximum performance if they receive the best possible attention from the start and continuously thereafter.

Disease resistance

With regard to disease resistance, whole areas of Jamaica that were devastated by lethal yellowing disease ten years ago have been replanted with resistant varieties and hybrids - specifically the Maypan - and are now in full bearing and show no significant losses. Recent reports that some dwarf and hybrid palms have died may indeed mean that the pathogen has overcome the field resistance that has been operating successfully for at least 30 years. This risk was, recognised when the hybrid was released. The in-trial losses, which ranged from 5 to 15 per cent were taken to be acceptable when set against the 100 per cent loss in the local tall variety. Commercially, losses in both dwarf and hybrid are less than one per cent. In fact the report of a breakdown in resistance deals with atypical, non-commercial areas and should no way be represented as a failure.

The risk of a new strain of the pathogen has always been present but more important is the need to stop the spread of the disease by replanting with resistant varieties in advance of the spread which cannot in any other way be limited. Recently the Caribbean MLO disease, which reached Mexico in 1981, has spread a further 150 km on the continental coast and now covers a greater area than it did when at its previous most serious extent in Jamaica. In Ghana there is an unchecked spread of MLO disease about 50 km from the Ivory Coast border (de Taffin, personal communication) and reports from Nigeria say there is renewed activity there. Delegates at this meeting do not need to be reminded of the regional threat posed by the MLO disease in East Africa and the root (wilt) disease in Kerala.

Management

Regardless of productivity and disease resistance, the problems of F_1 hybrids are much the same as the problems of any coconut planting material - they require a well drained, well aerated soil, with a good supply of ground water throughout the year or, alternatively not less than 1,500 mm annual rainfall with no dry period lasting longer than three months unless irrigation is available. They need to be planted at the correct density which will depend on what cropping system is to be adopted. They require proper weed control, regular fertilizer application and good plantation hygiene to guard against pests or leaf diseases. In fact, these are not problems but natural requirements of any plant and have to be worked out for each variety in each habitat.

SELECTION OF HYBRID PARENTS

But one problem remains unresolved and that is the need to choose the parent types from which the individual palms are to be selected that are to be used to make the cross. The selection of suitable parent types has often been based on a limited range of source material. For instance, in Ivory Coast the West African Tall was commonly available before the present variety collection was made and was the first choice as a pollen parent. Similarly, in Jamaica the Jamaica Tall, the Panama Tall and the Malayan Dwarf had been naturally exposed to lethal yellowing disease and the total susceptibility of the first type made it unsuitable as a parent. In many countries, and particularly in India, the locally available material is very diverse and it is not always easy to find criteria on which to base selection. For this reason, some possible combinations may have been unavoidably ignored or neglected.

Introgressive hybridization

The concept of introgressive hybridization explains how the variability observed in plant populations, such as coconut in India or elsewhere, has arisen and how it affects choice and selection of hybrid parents. The effects of introgressive hybridization can be observed in many aspects of the palm's performance - from the rate of germination, through growth and plant habit characteristics to resistance to diseases such as lethal yellowing (Harries, 1978).*

Fruit component analysis

In particular the technique of fruit component analysis is a useful tool, as has already been demonstrated for Indian varieties (Harries, 1982; Krishnamoorthy and Jacob, 1984). This uses the basic concept that the fruit of the original wild type coconut, which evolved without human intervention to be able to float between islands in coral archipelagoes such as the Laccadive Islands, contrasts in many ways with the fruit of the domestic type of coconut, which was selected by early man for the specific purpose of providing a fresh, unpolluted, sweet drink (long before copra production or oil extraction was ever considered). The two populations were geographically isolated from one another for many years; the wild type on islands and continental coastlines, where man had not reached, and the domestic type in Southeast Asia (Malaysia), from where early seafarers carried them to the Indian and Pacific Ocean coastlines. Sometimes the domestic form was introduced to a coast where the wild type might already be present. Or wild type coconuts floating from offshore islands would become established closely adjacent to domestic planting around coastal fishing villages. In both of those situations introgressive hybridization between the two types of coconut occurred.

DISCUSSION

It is important to understand that introgressive hybridisation involves populations of palms and not just individual palms. These populations remain distinct only so long as they are isolated from one another. In coconut this means geographical isolation since genetic incompatibility does not seem to occur in coconut. Once one population is brought into contact with another, hybridization can occur. In due course this will be followed by self-pollination between members of the new hybrid population, together with crossing and back-crossing to either or both of the two parental types. This produces a hybrid swarm in which all, or most, recombination of characters can occur. Such a hybrid swarm is represented by the concept of *Cocos nucifera* var, *typica* although there is no such thing as "typical" tall palm. Since, in most cases one of the two parents numerically outnumbers the other the introgression will tend towards that parent rather than the other. Thus introgressed populations

* The new technique of leaf polyphenol analysis, described for the first time in coconut at this symposium (Jay *et al.*, 1988) also illustrates the effect of introgressive hybridization.

Table 1. Tall phenotypes

	WILD	DOMESTIC	CULTIVATED
Predominant form	Niu kafa type	Niu vai type	Introgressed*
Where found	Uninhabited and isolated beaches	Certain isolated human settlements	Almost everywhere
Stem	Slender, curved leaf scars are irregular	Robust, erect base can be very large	Intermediate
Leaves	Long, may hang down when green	Not so long, rarely hang down	Intermediate
Flowering pattern	Cross-pollination is not absolute	Cross-pollinated but often selfed	Intermediate
Fruit	Long, angular, thick husk	Spherical, thin husk	
Nut with husk removed	Ovoid or spindle shaped, thick shell, little water, thick endosperm high oil content	Spherical to ovate, thinner shell, much water, thinner endosperm, lower oil content	All combinations possible
Germination	Slow	Fast	Intermediate
Growth rate	Slower	Quicker	Intermediate
Response to MLO diseases	Susceptible	Tolerant	Intermediate
Response to windstorm	Susceptible	Tolerant	Intermediate

* Wild and domestic types are also cultivated

can be classified as either predominantly wild type or predominantly domestic type. In India the wild type characteristics predominate (Table 1).

Neither human selection, natural selection or genetic drift will have made much impact on introgressed populations in the comparatively short period of five thousand years since the Polynesians entered the Pacific, let alone the five hundred years that the Europeans followed them or the five decades in which scientific plant breeding has been attempted. For the plant breeder this means that selection of superior individuals within a particular population will depend upon the degree of introgressive hybridization that has taken place. It will be no use slecting for early germination, thin husk or resistance to lethal yellowing in a predominantly wild type population. Nor will it be easy to select for good copra quality, high oil content of the copra or long coir fibres in a domestic type population. Hybrids, whether D x T, T x D, T x T or D x D will have more chance of combining contrasting characteristics if the selected parents come from populations in which the directions of introgression are contrasted. Fruit component analysis, and now leaf polyphenol analysis (Jay *et al.*, 1988), will be helpful in making those choices.

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EFFECTIVENESS OF HYBRID INDIVIDUAL COMBINING ABILITY TESTS IN COCONUT : INITIAL RESULTS

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Abstract: Improvement of simple hybrids between ecotypes has been undertaken by IRHO in Cote d'Ivoire. The unilateral crossing plans study inviduals from one of the ecotypes, with the other used as a tester. The intial results from six trials make it possible to estimate a genetic gain of 20 to 30% for selection of the best 7 to 8% of parents. The progress achieved is basically due to improvement in the number of nuts. Prior phenotypic selection within the ecotypes seems to be effective, but cannot replace the progeny test. The use of improved hybrids will develop substantially over the next decade.

INTRODUCTION

The first two stages in coconut improvement in Cote d'Ivoire consisted in bringing together a collection containing a large number of ecotypes, then in finding host which combined best with each other (Lamothe, 1970). This method brings out the existence of considerable hybrid vigour in coconut: whilst the heterosis effect is variable, it is very distinct overall. The results have enabled worldwide extension of the best combinations between ecotypes.

The next stage of the improvement scheme began as early as 1970 and involves the separate improvement of those hybrids with the best performance (Gascon and Lamothe, 1976). It is based on reciprocal recurrent selection (Comstock *et al.*, 1949) which is intended to simultaneously improve two populations with respect to each other. The initial results in this scheme have made it possible to estimate its effectiveness in terms of selection based on yields.

MATERIALS AND METHODS

1. Crossing plans

In theory, the test phase includes two types of comparative trial with complementary crossing plans: trees from one of these ecotypes are individually crossed with a set of trees from the other ecotype, and vice versa. A study of the half-sib families obtained in this way makes it possible to determine which parents from each ecotype combine best with the other.

When the two ecotypes revealed very unequal variability levels, the crossing plan was simplified. In fact, in genetic progress terms, it seemed more profitable to proceed with the individual testing of a large number of individuals from the most variable ecotype.

Hence, for the improvement of dwarf x tall type hybrids, testing the combining ability of a large number of tall parents was preferred even if it meant abandoning the reciprocal test. Most of the dwarfs in the Port-Bouet collection, which are self- fertilized and have probably undergone various founding effects, seem to be very close to the pure line. Under these conditions, the method is related to selection based on full-sib families.

2. Experimental designs

Lattice designs, which enable the comparison of multiple treatments, are particularly suitable for progeny tests.

One of the first improved crosses was the West African Tall (WAT) x Polynesia Tall (PYT) hybrid: 63 PYT parents have been individually tested with the WAT in three trials: PBGC-2.2, 2.3 and 13.

Trials PBGC-2.2 and 2.3 test PYT individuals in relation to a population of 384 West African Talls; the crossing plan does not make it possible to detect genetic differences between African parents, which were all used as mother trees. However, trial PBGC-13 has a bilateral design; it studies the combining ability of 24 West African Talls with the same number of Polynesia Talls. Crosses were carried out in both directions. Nonetheless, each treatment corresponds to a Polynesian parent with the WAT parents randomly distributed. The low number of parents involved led to hand pollination programmes being spread out over time, with planting over a period of two years at a rate of 75 elementary plots a year.

The other three trials improve the following combinations:

* Malayan Red Dwarf crossed with Rennell Tall
* Malayan Yellow Dwarf crossed with WAT and PYT respectively.

Table 1 summarizes the characteristics of the six trials mentioned above.

RESULTS AND DISCUSSION

1. Progeny tests

Table 2 shows the genetic progress observed for copra per tree depending on two levels of selection pressure, one high - corresponding to the choice of the best one or two crosses according to the trial (6.6 or 8.3% of the progenies chosen), the other low - corresponding to the chioice of the best 3 or 5 crosses (20% selection rate).

Table 1. Experimental designs of the six trials studied

Trial number	Planting date	Experimental design	Number of experimental plots	Number of parents tested
PBGC 2.2	WAT x PYT 1970	5x5 balanced lattice	8	24
PBGC 2.3	WAT x PYT	4x4 balanced lattice	7	15
PBGC 13	WAT x PYT 1975/76	5x5 balanced lattice	12	24
PBGC 15	MYD x WAT 1978	4x4 balanced lattice	12	15
PBGC 17	MYD x PYT 1977	4x4 balanced lattice	15	15
PBGC 20	MRD x RLT 1979	4x4 balanced lattice	12	15

Each trial includes a control : The West African Tall in trials PB GC 2.2, 2.3 and 13 and the PB 121 hybrid in the other trials.

Table 2. Genetic progress achieved through hybrid progeny tests; comparison with additional phenotypic selection

Trial number	Percentage of progenies chosen	Genetic gain (%) depending on 2 types of selection (copra/tree)	
		Based on phenotypic values of parents	Based on progeny tests
PBGC 2.2	8.3 20.8	8.0 2.0	29.6 24.6
PBGC 2.3	6.7 20.0	0.0 1.3	21.9 17.6
PBGC 13	8.3 20.8	-2.5 -1.9	28.3 22.7
PBGC 15	6.7 20.0	10.2 3.9	19.0 11.8
PBGC 17	6.7 20.0	13.4 2.3	29.5 20.4
PBGC 20	6.7 20.0	**25.1 4.2	26.0 19.5

PBGC 2.2 Number of nuts 9-12 years, copra/nut 8-11 years
PBGC 2.3 Number of nuts 9-12 years, copra/nut 8-11 years
PBGC 13 Number of nuts 8-10 years, copra/nut 6-9 years
PBGC 15 Number of nuts 4-8 years, copra/nut 5-8 years
PBGC 17 Number of nuts 4-9 years, copra/nut 5-8 years
PBGC 20 Number of nuts 4-7 years, copra/nut 5-7 years

** Estimate, as a few parents were not assessed for copra/nut

The genetic progress achieved through the progeny tests described fluctuates between 20 and 30% for high selection pressure. This estimate is based on unilateral improvement, with the individuals of the most variable ecotype being tested with the other ecotype considered to be homogeneous.

In the case of PBGC-13, it is possible to calculate potential gain through selection based on the WAT progenies. However, since copra/nut has been measured per elementary plot and not individually, estimates are based solely upon the number of nuts. The nut production of the best two WAT progenies is 10.3% higher than average. A similar calculation per Polynesian progeny leads to a figure of 31.0%. The improvement expected from the selection of African parents remains comparatively low.

The West African Tall, which is remarkably homogeneous, is considered to be a low variability ecotype. In trial PBGC-13, the WATs are crossed with a very heterogeneous PYT tester, which masks the differences between progenies. In addition, the experimental layout is designed to detect more accurately the differences between Polynesian parents.

In trial PBGC-15, although genetic progress is substantial (19% for copra/tree), it is slightly less than that in the other trials and confirms the relative homegeneity of the WAT. However, out of the parents tested, twelve can be divided up into four full-sib families, obtained from parents selected phenotypically and then crossed with each other. This relationship may have artificially reduced the differences between lines.

On the other hand, the Polynesia Tall reveals high improvement potential, whether crossed with a dwarf ecotype or a tall ecotype.

2. Effectiveness of phenotypic selection

Phenotypic selection prior to testing

The parents chosen for the tests were selected beforehand according to their phenotypic characteristics; whilst this initial selection was effective, the improvement achieved needs to be greater than that revealed by the progeny test.

Table 3. Comparison of the best lines with the mean of the population for yield components

Trial number	Percentage progenies chosen	Gain based on different components (percentage)			
		C/T	BN	NN	C/N
PBGC 2.2	8.3 20.8	30 25	2 3	29 25	0 -1
PBGC 2.3	6.7 20.0	22 18	3 2	25 19	-4 -1
PBGC 13	8.3 20.8	28 23	5 -0	28 24	-1 -3
PBGC 15	6.7 20.0	19 12	-1 0	21 14	-2 -2
PBGC 17	6.7 20.0	30 20	8 6	33 18	-3 2
PBGC 20	6.7 20.0	26 20	2 0	27 24	-1 -4

NN : Number of nuts C/T Copra/Tree
BN : Bunch number C/N : Copra/Nut

PBGC 2.2 Nuts and bunches 9-12 years, copra/nut 8-11 years
PBGC 2.3 Nuts and bunches 9-12 years, copra/nut 8-11 years
PBGC 13 Nuts and bunches 8-10 years, copra/nut 6-9 years
PBGC 15 Nuts and bunches 4-8 years, copra/nut 5-8 years
PBGC 17 Nuts and bunches 4-9 years, copra/nut 5-8 years
PBGC 20 Nuts and bunches 4-7 years, copra/nut 5-7 years

In trial PBGC-15, the control makes it possible to estimate the genetic gain due to this initial phenotypic selection. The control, which is made up of MYD x WAT hybrids obtained through assisted pollination, is 7.3% inferior to the average of fifteen MYD x WAT progenies. Improvement of 7.3% was therefore achieved through phenotypic selection within the population, then 19.0% through the progeny test. Whilst comparatively small, the role played by phenotypic selection still remains not inconsiderable.

Effectiveness of additional phenotypic selection

It would be interesting to find out what the results would be if phenotypic selection had been carried out on the parents with the best performance, rather than testing progenies.

The production characteristics of the pollenizers make it possible to simulate further phenotypic selection within the sample of parents chosen for the test. Table 2 enables a comparison to be made between the progress obtained through progeny tests with that which would have been obtained through further phenotypic selection based on yields.

For high selection pressure levels, mean effectiveness for the second phenotypic choice is low compared to that in progeny tests: around 9% improvement as opposed to 26%. Low result repeatability makes it dangerous to apply phenotypic selection only, whilst it enables a gain of 25% to be made in certain cases, in other cases the progeny of the highest yielding parent is inferior to the mean of the trial. Nonetheless, these results need to be placed in context. First of all, phenotypic evaluation is not always very accurate; given their intensive use in improvement programmes, the trees undergo hand pollination before their characteristics are well known. Such hand pollination leads to the uncontrolled disruption of production and can modify parent classification. Even if later assessment excludes crossing periods, bias still remains. Nonetheless, the alternative consists in accepting this bias or abandoning all phenotypic assessment; simulation therefore retains its practical experimental value.

In addition, the parents used in the progeny tests have undergone prior selection; we do not test the effectiveness of phenotypic selection throughout a population, but merely within a sample made up of the best trees in this population. Sampling introduces bias by artificially reducing phenotypic variability.

This example shows, however, that stringent selection based on parental characteristics can in no way replace the progeny test. The best strategy consists in selecting good parents within the ecotypes, then testing each of them individually.

3. Distribution of genetic progress depending on yield components

It is possible to compare selected progenies with the mean for certain yield components: number of bunches and nuts, copra/nut. Table 3 shows that the progress attained with respect to yield can basically be explained through the increase in nut number or, more precisely, the number of nuts per bunch; the copra/nut of the best progenies has not been improved and the number of bunches is only slightly improved.

As could be expected with an allogamous plant (tall ecotypes), whose improvement is only recent, considerable genetic progress proves to be feasible. Between-ecotype variability enables yield improvements of around 30% to be obtained within one generation.

Whilst phenotypic selection based on yield is effective, it proves to be clearly less productive than the progeny test method. Other elements, which will be coverd in a pending publication, suggest that this state of affairs results from low yield heritability, in the strict sense of the term, rather than from possible effects of specific combining ability. For coconut, the differences relative to performance in hybridization would seem to come mainly from additive effects.

From a genetic point of view, nut number proves to be a predominant yield component. This confirms the observations made on crosses between ecotypes (Meunier *et al.*, 1984). The strong negative correlation between copra/nut and nut number explains why there is no apparent improvement as far as copra/nut is concerned.

Implications for seed production: a new generation of improved seeds

The considerable genetic progress made leads to direct applications at seed production level; the method enables rapid extension of experimental results.

Seed production is ensured through the selfing of the parents chosen for individual aptitude tests. These selfs, which play a mainly multiplicative role, are carried out early enough for them to start bearing at the moment the results of the hybrid comparative trials are accurately known.

Thus, approximately 100 seedlings, obtained by selfing for each of the parents tested, have been planted in "multiplication trials". They will provide the pollen required for seed production. No selection is planned on these selfs, so as to guarantee that the reproductions conform to the initial cross.

To a certain extent, as with all progeny tests, this method makes it possible to choose genetic gain in accordance with selection intensity. Thus, for seed production, very intensive selection will provide maximum progress; if the quantity of pollen is not a limiting factor, seeds will be produced from the selfs of the the best parent. On the other hand, continuation of the improvement programme, which requires that variability be maintained, will involve lower selection intensities.

The advantage of this method is that seeds will be produced in already existing mother-tree seed gardens; only the pollen changes from one cycle to the next. *This technique makes it possible to produce improved seeds while valorizing the investment already made* (Wuidart and Rognon, 1981)

CONCLUSION

Over the next few years, individual combining ability tests will provide planting material which is 20 to 30% superior to current widely available hybrids. This improvement will cost less, because the seed gardens required for seed production exist already. Utilization of these "second generation" seeds will develop enormously over the next decade.

From a methodological point of view, results show that stringent selection based on parental characteristics can in no way replace the progeny test. The best strategy consists in selecting good parents within ecotypes, then testing each of them individually. In addition, this method also brings out hybrid combinations which are tolerant to certain diseases; it is in this way that genetic control of the parasites *Drechslera* (*Helminthosporium* leafspot) and *Phytophthora heveae* (premature nut-fall) can now be envisaged in Cote d'Ivoire (Franqueville *et al.*, 1988).

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INBREEDING DEPRESSION IN COCONUT (*COCOS NUCIFERA* L.)

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Abstract: The complexity in the genetic behaviour of coconut is due to its essential nature of cross fertilization. It is therefore possible that inbreeding depression can occur in coconut. With the objective of finding out whether inbreeding depression exists in coconut, breeding programmes were taken up as early as 1924 to evolve inbred lines and also to find out whether hybrid vigour is met with within the crosses between such progenies. Eighteen West Coast Tall palms of the Coconut Research Station, Kasaragod were selfed in the years 1924 to 1926. The first and second generation progenies were planted at Pilicode during 1926 and 1961 respectively.

The studies made on the first and second generation selfed progenies revealed that selfed progenies were inferior to their grand parents and sibs. Hybrid vigour was met with when crossing was done between the progenies of the same parent and it clearly indicated inbreeding depression in coconut by selfing.

INTRODUCTION

In coconut, two distinct types are seen - the talls and the dwarfs. Talls tend to be mainly outbred while dwarfs are usually inbred. The dwarfness is attributed to a single gene of heterozygous penetrance so that heterozygotes are more or less semi-tall. Due to the essentially outbreeding nature of the talls heterosis has been abundantly demonstrated in a wide range of crosses involving local strains or ecotypes as early as 1920 in India. Attempts for improvement of the crop through tissue culture techniques could not succeed so far for production on a commercial scale. The improvement is therefore, likely to depend on systematic identification of parental lines of good combining ability using pollination techniques so far developed. But in coconut, the problem of crop improvement by development of parental lines is a very difficult and prolonged task. Because of the extensive cross pollination, there is wide variation in all the palm characters and in the strict sense there is no variety in coconut. Evolution of purelines in coconut is a time consuming process. However, attempts have already been made in Kerala as early as 1924 to evolve purelines in the most commonly cultivated West Coast Tall variety by selfing. It was observed that by selfing, yield is reduced in the progenies due to inbreeding depression. This paper attempts to elucidate the phenomenon of inbreeding depression in coconut.

MATERIALS AND METHODS

The material for the study consisted of palms from two series of experiments conducted in the Agricultural Research Station, Pilicode from 1924 to 1985. During the years 1924, 1925 and 1926 selfing was done in eighteen West Coast Tall palms of the Coconut Research Station, Kasaragod. The progenies (S_1) obtained were planted at the Agricultural Research Station, Pilicode in the years 1926, 1927 and 1928.

Selfing was done in the progenies (S_1) of six known parents to produce the second generation selfs (S_2). In the same year crossing was done between progenies (S_1) of the same parents to produce sibs. The experiment was con-

Table 1. Yield performance (nuts/palm/year) of grand parents, selfs and sibmated progenies

Mother palms	Family groups				
	1/109	1/174	VI/4	1/129	VIII/127
1 Grand parents (mean of 10 years, 1920-29)	125.90 (100)	117.20 (100)	105.90 (100)	104.60 (100)	117.50 (100)
2 First generation selfs (S_1) (mean of 10 years, 1950-59)	48.43 (38.47)	59.57 (50.83)	48.65 (45.94)	48.57 (46.43)	46.98 (39.98)
3 Second generation selfs (S_2) (mean of 10 years, 1976-85)	34.84 (27.67)	49.91 (42.59)	39.96 (37.73)	44.60 (42.64)	39.85 (33.91)
4 First generation sibs (mean of 10 years, 1976-85)	45.39 (36.05)	81.13 (69.22)	55.00 (51.94)	57.53 (45.00)	55.95 (47.62)

Values in parentheses are in percentage

ducted in a typically laterite soil under rainfed condition in split plot design with four replications in compact family blocks. Six groups of progenies were allotted to six main plots and each main plot had two rows of five seedlings, each row forming a sub-plot. Around the experimental field, border rows were also provided with WCT palms. Data were recorded on the growth habits of the seedlings and production of nuts. The yield data of the grand parents were also collected for comparison. For comparing the yield between grand parents and progenies, only five family groups were considered since information on one family group was lacking but all the six family groups were included for comparision of second generation selfs and sibs.

RESULTS AND DISCUSSION

The data gathered on the production of nuts of the grand parents, first generation selfs, second generation selfs and the sib-mated progenies are presented in Table 1.

It is evident from the above data that there exists clear inbreeding depression in the materials studied. The higher nut yield obtained in the sibs of the progenies of the first generation selfs is a clear indication of the phenomenon of heterosis in a cross-bred crop like coconut. Except one family (1/109), all others have given increased yield as compared to the first generation selfs. However, all the sibs have given significantly higher yield over the second generation selfs.

The 't' values (Table 2) clearly indicate that the differences between the first generation and second generation selfs and the grand parents are highly

Table 2. Analysis of yield data of S_1, S_2 and sibs by paired 't' test

	S_1	S_2	Sibs	Parents
S_1	..	5.46**	1.06	14.76**
S_2			4.72**	13.25**
Sibs				7.34**

** Significant at 1% level
S_1 first generation selfs
S_2 second generation selfs

Table 3. Mean yield of nuts per palm per year (mean of 10 years, 1976-85)

	Family Groups						
Mother palms	1/109	1/109 (coloured orange)	1/174	VI/4	1/129	VIII/127	Mean
Second generation selfs (S_2)	34.84	53.11	49.91	39.96	44.60	39.85	43.75
Sibs	45.39	47.04	81.13	55.01	57.53	55.95	57.00
Mean	40.11	50.08	65.52	47.48	51.07	47.90	50.36

CD (0.05) for families 11.60; for sibs 11.67; for F.S. means 14.16

significant. However, the difference between the first generation selfs and sibs is not found to be significant. The data also show that the difference between the parents and their offsprings whether they are self pollinated or sib-mated is highly significant.

Inbreeding in coconut was studied by Liyanage (1969) on some characters like endosperm weight, embryo weight, leaf production and flowering period. It was reported that inbreeding depression existed in these characters as compared to the open pollinated progenies and the intensity varied among families. He also found that the endosperm weight and embryo weight were related to the breeding values of the grand parents. The result obtained in the present study for the number of nuts is in agreement with the above findings.

Cytological consequence of inbreeding depression was studied by Nambiar *et al.* (1970) in a few distinct exotic varieties of coconut at Kasaragod. Inbred and open pollinated progenies of Laccadives, Andaman, Philippines, New Guinea and Cochin China varieties and dwarf varieties of indigenous and Malayan origin were screened for meiotic behaviour. The open pollinated varieties showed more chromosomal aberrations and higher percentage of pollen sterility than the self pollinated dwarf varieties. It is suggested that inbreeding depression in Cochin China and lack of that phenomenon in Laccadive varieties are due to the difference in the intensity of inbreeding, the latter generally being less susceptible to inbreeding. Similar studies in the present material may help in revealing the cytological behaviour of the selfing and sibbing series.

Table 3 gives an effective comparison of the statistical difference in yield of the second generation selfs and crosses involving the progenies of the same parents.

It is evident that families differ significantly in their behaviour in inbreeding depression and sib mates are superior to selfs. This signifies that inbred lines could be utilized for exploiting heterosis in coconut on a large scale. It is well known that inbreeding increases homozygosity of genetic factors and heterosis is more marked in naturally cross fertilized plants especially when inbred lines are crossed. Harland (1957) while agreeing that by analogy with other out-bred species, selfing of tall coconut palms would be expected to reduce vigour, thought it at least possible that inbred lines can be developed which could be used for the production of hybrids for higher productivity. It is therefore, suggested that further research should be pursued by selfing the progenies in the successive generations with reference to inbreeding depression.

ACKNOWLEDGEMENT

The authors are thankful to the early research workefs of the Coconut Research Station at Kasaragod, Nileswar and Pilicode who have laid out the trial and taken the observations and also to the Kerala Agricultural University for permitting to peruse the records. They also gratefully acknowledge the Director, CPCRI, Kasaragod for supplying the yield data of the grand parent palms involved in the study.

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PHENOTYPIC STABILITY OF COCONUT (*COCOS NUCIFERA* L.) CULTIVARS FOR ANNUAL YIELD OF NUTS

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Abstract: Phenotypic stability for annual yield of nuts of 32 coconut cultivars grown at the Regional Agricultural Research Station, Pilicode was analysed by non-parametric procedures using 20 years yield data from 1965 to 1984. Two non-parametric measures of phenotypic stability, viz., mean of the absolute rank differences of the cultivar over the environments and variance among the ranks over the environments, were used for the analysis. There were significant differences in the stability of the cultivars. West Coast Tall, Laccadive Ordinary, Java, Fiji, Philippines Ordinary, Andaman Ordinary and Godavari were found to be the stable cultivars. Cochin China, SS Green, Laccadive Small etc. were found to be highly unstable cultivars.

Since some cultivars showed a biennial (alternate) bearing tendency, the analysis was conducted using the cumulative yield of two years also. In this case, cultivars like Cochin China, SS Green, Andaman Giant, Kappadam, Basanda etc. were found to be stable. They were not stable in annual yield due to their biennial bearing tendency. The cultivars recommended by the Kerala Agricultural University like West Coast Tall, Laccadive Ordinary, Andaman Ordinary, Philippines and Java were stable for annual yield whereas Kappadam and Cochin China were stable for the cumulative yield of two succeeding years only.

INTRODUCTION

Stability in yield is of utmost importance in the breeding programme of any crop. Though a large number of cultivars of coconut have been evaluated for years, an attempt to study the genotype x environment interaction and to identify phenotypically stable cultivars for their annual yield is lacking. The common parametric methods in use for the purpose viz., Finley and Wilkinson (1963), Eberhart and Russell (1966) etc. cannot be employed in the case of a perennial crop like coconut as the observations on different years of the same tree cannot be thought of as independent. Certain recently reported non-parametric procedures for the study of genotype x environment interaction can be appropriately employed in this situation. In this paper, an attempt is made to identify the phenotypically stable cultivars of coconut with respect to annual yield of nuts using non-parametric measures.

MATERIALS AND METHODS

Annual yield of 32 coconut cultivars grown at the Regional Agricultural Research Station, Pilicode were used for the study. The stability was estimated using 20 years yield data from 1965 to 1984 employing non-parametric procedures suggested by Nassar and Huhn (1987). Average yields of four palms per cultivar were used for the analysis.

Two non-parametric measures of phenotypic stability viz., mean of the absolute rank differences of the cultivar over the environments and variance among the ranks over the environments were used in the analysis. They were estimated as follows.

For each of the N environments all the K genotypes were ranked from 1 to K, the lowest value being awarded a rank of 1. Let rij denotes rank of the ith genotype in the jth environment. Two measures of stability for the ith genotype were obtained as:

$$Si^{(1)} = 2 \sum_{j=1}^{N-1} \sum_{j'=j+1}^{N} /rij-rij'/ \, / \, [N\ (N-1)]$$

and

$$Si^{(2)} = \sum_{j=1}^{N} (rij-\bar{r}i.j)^2 \, / \, (N-1),$$

$$\text{when } \bar{r}i. = \sum_{j=1}^{N} rij/N$$

Each of these estimates of stability parameters was tested for statistical significance using the following χ^2 test. $Zi^{(m)} = (Si^{(m)} \quad E\ [(Si^{(m)})]^2 / \text{var}\ (Si^{(m)})$, m = 1, 2 follows χ^2 with 1 degree of freedom. Var $Si^{(1)}$ was taken from Table 1 of Nassar and Huhn (1987).

$$E\ (Si^{(1)}) = (K^2 - 1) / (3K),$$

$$E\ (Si^{(2)}) = (K^2 - 1) / 12,$$

$$\text{var } Si^{(2)} = \frac{m4}{N} - \left[\frac{N-3}{N(N-1)} (E[Si^{(2)}])^2\right],$$

where $m4 = E(y-\mu)^4 = E(y^4) - 4\mu E(y^3) + 6\mu^2 E\ [Y^2] - 3\mu^4$
with $\mu = E(y)$ and $y = Si^{(2)}$,
$E(y^4) = (K+1)\ (2K+1)\ (3K^2 + 3K - 1) / 30,$
$E(y^3) = K(K+1)^2 /4,$
$E(y^2) = (K+1)\ (2K+1)/6$ and
$\mu = (K+1)/2$

An overall test for stability of genotypes was also carried out using test as

$$S^{(m)} = \sum_{i=1}^{K} Zi^{(m)}, \ m = 1, 2 \text{ follows}$$

the χ^2 distribution with K degrees of freedom

The parameters of stability were estimated using 20 years data (20 environments) and also using the cumulative yield of two consecutive years (10 environments) in order to iron out the effect of alternate (biennial) bearing habit.

RESULTS AND DISCUSSION

The parameters of stability estimated using 20 environments and 10 environments and the overall mean yield of nuts/palm are presented in Table 1. It was seen that the cultivars differed significantly with respect to their stability as evidenced by the highly significant values of $S^{(1)}$ and $S^{(2)}$ under both situations. It may be noted that the $S^{(1)}$ and $S^{(2)}$ values were highly significant in both cases indicating wide variability among the cultivars as regards stability of performance was concerned, either by considering yields of individual years or yields of two consecutive years. On inspecting Table 1, it may be noted that cultivars like Java, Philippines, Andaman Ordinary, Fiji, Godavari, Bengal, Laccadive Ordinary, West Coast Tall etc. are stable with respect to the annual yield (20 environments) of nuts as their $S^{(1)}$ and $S^{(2)}$ values were very low (nearing zero). The cultivars like Cochin China, SS Green, Laccadive Small, New Guinea etc. were among the highly unstable. This is clearly evidenced from the rank of each cultivar for their annual yield (Table 2). The drastic difference in rank in almost all the alternate years (alternate bearing) has been the main factor affecting the stability of Cochin China, SS Green, Laccadive Small and New Guinea. When compared to the stable cultivars the difference in ranks of each succeeding year was very high.

In the second system (set) of analysis where the cumulative yields of two consecutive years were taken as a

Table 1. Stability parameters for 32 coconut cultivars

Sl. No.	Name of cultivar	20 environments		10 environments		Mean yield of 20 years
		S1	S2	S1	S2	
1	New Guinea	5.376	6.706	0.029	0.0004	71
2	Cochin China	8.199	11.494	0.387	0.578	64
3	Java	0.450	0.480	0.153	0.991	66
4	SS Apricot	5.645	4.120	3.205	2.676	39
5	SS Green	23.911	71.841	0.153	0.319	55
6	Fiji	0.125	0.761	4.295	3.368	58
7	Philippines	0.119	0.210	1.202	1.190	71
8	Ceylon	2.714	0.613	4.840	7.195	70
9	Andaman Ordinary	0.00002	0.270	1.066	0.809	63
10	Andaman Dwarf	1.580	1.716	0.174	0.136	38
11	Andaman Giant	7.410	5.693	0.034	0.037	71
12	Laccadive Small	13.853	23.977	7.785	11.111	110
13	Kappadam	9.960	7.365	1.868	1.471	58
14	Bombay	8.342	5.633	3.931	2.926	68
15	Nalrosapuram	0.398	0.473	2.119	1.660	61
16	Gudiathum	0.384	0.394	1.937	1.998	65
17	Chingalpet	1.584	1.763	0.602	0.559	53
18	Selam	2.532	2.353	0.015	0.0005	54
19	Pollachi	4.464	3.233	0.001	0.053	51
20	Omallur	7.714	5.611	0.069	0.075	56
21	Kaithathali	4.814	6.333	1.937	1.961	71
22	Kodiripadu	4.347	3.633	10.833	5.559	68
23	Indupali	1.276	1.324	0.842	1.022	67
24	Godavari	0.934	0.663	0.506	0.353	71
25	Bengal	0.247	0.185	0.020	0.021	62
26	Mysore	4.008	3.330	0.143	0.262	65
27	Basanda	9.631	13.387	1.937	1.840	86
28	Banisa Hybrid	1.278	0.988	1.973	2.529	84
29	Baboor	0.410	0.553	0.207	0.038	75
30	Gangabondam	6.524	11.598	9.283	14.582	54
31	West Coast Tall	0.964	0.991	0.040	0.186	66
32	Laccadive Ordinary	0.751	0.839	0.196	0.062	79
	$S^{(1)} = \Sigma Z^{(1)} =$	136.970		61.763		
	$S^{(2)} = \Sigma Z^{(2)} =$		197.338		64.349	

$\chi^2(32, 0.05) = 46.194$ $\chi^2(20, 0.05) = 31.410$ $\chi^2(10, 0.05) = 18.307$

Table 2. Rank of some selected coconut cultivars for their annual yield of nuts (20 environment)

	Years																			
	1965	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84
Java	4	26	5	30	27	6	28	25	13	26	10	29	4	22	17	21	4	27	6	16
Philippines Ordinary	2	13	18	17	6	11	25	7	19	8	26	25	7	31	8	28	25	16	26	22
Andaman Ordinary	22	6	12	19	7	25	19	10	3	30	21	7	26	10	23	20	2	30	16	28
Fiji	9	11	7	2	2	22	14	9	9	13	13	27	8	30	12	29	13	31	19	30
Godavari	16	29	8	25	5	29	3	32	4	29	18	3	13	19	2	22	22	9	21	11
Bengal	8	8	10	24	8	28	5	26	8	31	9	8	27	7	25	25	20	18	22	18
WCT	12	23	18	26	26	21	12	22	15	7	25	6	21	5	26	12	8	29	5	25
Lacc. Ordinary	1	22	4	21	11	20	11	13	11	27	14	23	9	27	7	17	24	21	23	31
Cochin China	31	5	31	5	32	3	31	1	29	2	22	22	18	20	14	19	29	2	30	1
SS Green	7	32	1	32	1	31	1	30	1	32	1	32	1	32	1	32	1	32	1	32
Lacc. Small	29	30	2	31	3	1	32	2	32	22	2	32	2	28	16	1	18	1	13	4
New Guinea	18	3	21	2	30	5	30	4	30	1	28	18	16	26	28	3	32	10	28	8

Table 3. Rank of some selected coconut cultivars for their cumulative yield of nuts of two years (10 environments)

	Years									
	1965-66	1967-68	1969-70	1971-72	1973-74	1975-76	1977-78	1979-80	1981-82	1983-84
Java	6	8	32	31	18	16	7	24	10	12
Philippines Ordinary	2	10	6	27	20	29	9	7	26	29
Andaman Ordinary	26	11	8	22	1	22	30	25	1	16
Fiji	10	14	7	16	17	21	16	23	22	26
Godavari	23	12	9	5	6	25	22	2	28	27
Bengal	9	13	11	6	9	10	32	28	24	23
WCT	13	19	30	12	15	26	23	27	9	4
Lacc. Ordinary	15	7	2	13	21	23	26	4	25	28
Cochin China	18	25	24	29	22	3	4	1	18	24
SS Green	29	15	28	21	14	4	6	12	21	19
Lacc. Small	31	1	3	32	32	2	1	20	20	15
New Guinea	8	5	17	30	23	14	5	19	30	14

single environment, many of the unstable cultivars for annual yield were found to be stable. Cultivars like New Guinea, Cochin China, SS Green, Andaman Giant, Kappadam, Selam, Pollachi, Omallur, Mysore, Basanda etc. became stable for their cumulative yield of two years since their $S^{(1)}$ and $S^{(2)}$ values were nearing zero. Their stability is again clear from their annual ranks for nut yield as given in Table 3. Laccadive Small and Gangabondam were highly unstable under both systems of analysis.

This type of stability analysis should be coupled with analysis for yield also, in order to identify high yielding stable cultivars. The total yield of nuts (for 20 years) of the 32 cultivars was analysed in a completely randomised design. The cultivars did not vary significantly for their total yield. This was because of the large genetic variability among the palms of the same cultivar. The study however, revealed that the cultivars recommended by the Kerala Agricultural University like West Coast Tall, Laccadive Ordinary, Andaman Ordinary, Philippines and Java were stable for annual yield of nuts, whereas Kappadam and Cochin China were stable for the cumulative yield of two consecutive years.

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POLYMORPHISM OF COCONUT LEAF POLYPHENOLS

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Abstract: The study of coconut leaf polyphenols seems to show that the dwarfs in Africa were introduced from the Far East (GYD, EGD) and from the Pacific (CRD). In addition, the Green Dwarfs appear to be grouped together on various representations and would therefore all appear to be related.

Analysis reveals three groups which fit into geographical zones: Pacific, Far East and Africa. The variable and intermediate characteristics of coconuts in the Indian Ocean confirm that their dissemination followed a path extending through the Far East, India and Africa. Ecotypes presenting very variable morphologies appear in the same zone, such as the VTT with a large number of small nuts and the RTT with a small number of large nuts; this confirms that ecotypes with distinct morphological characteristics can prove to be genetically close.

Analysis of polyphenols by high performance liquid chromatography is an effective technique, which confirms hypotheses put forward about the dissemination of coconut. Nonetheless, this study needs to be gone into in greater depth with finer statistical analysis and should be extended to other ecotypes.

INTRODUCTION

There are numerous coconut ecotypes whose diversity cannot be perceived by traditional enzyme electrophoresis techniques. This led to the search for new genetic variability evaluation methods, including high performance liquid chromatography of leaf polyphenols. It was initially used in plant chemotaxonomy for systematics and phylogeny studies and is also used to measure genetic variability within a species. In this context, this paper describes the preliminary results of a study designed to characterize intraspecific diversity in coconut by analysing 16 phenolic compounds.

MATERIALS AND METHODS

The study concentrated on 32 coconut ecotypes belonging to the Port-Bouet collection (Marc Delorme Coconut Station, Cote d'Ivoire), taking 5 or 6 individuals per ecotype i.e., 171 individuals in all. Table 1 gives the list of ecotypes along with their origins.

Each individual is characterized by a chromatogrpahic profile based on the analysis of 16 leaf polyphenols. The heights of the 16 corresponding peaks form the basic data. They are converted into percentages by dividing the height of each peak by the sum of the heights of the 16 peaks. This makes it possible to disregard the total quantity of phenols per individual, which would vary substantially depending on the sample's environment. Different statistical analyses were carried out using these standardized data. They are (1) main components analysis (MCA) for all the individuals, (2) MCA for each ecotype, (3) dwarf-tall discriminant analysis (DA) of all leaf phenolic compounds for all the individuals and (4) DA per ecotype for all the individuals.

RESULTS AND DISCUSSION

The analyses bring out genetic variability for polyphenol composition between ecotypes and, within certain limits, within ecotypes.

Table 1. List of ecotypes studied

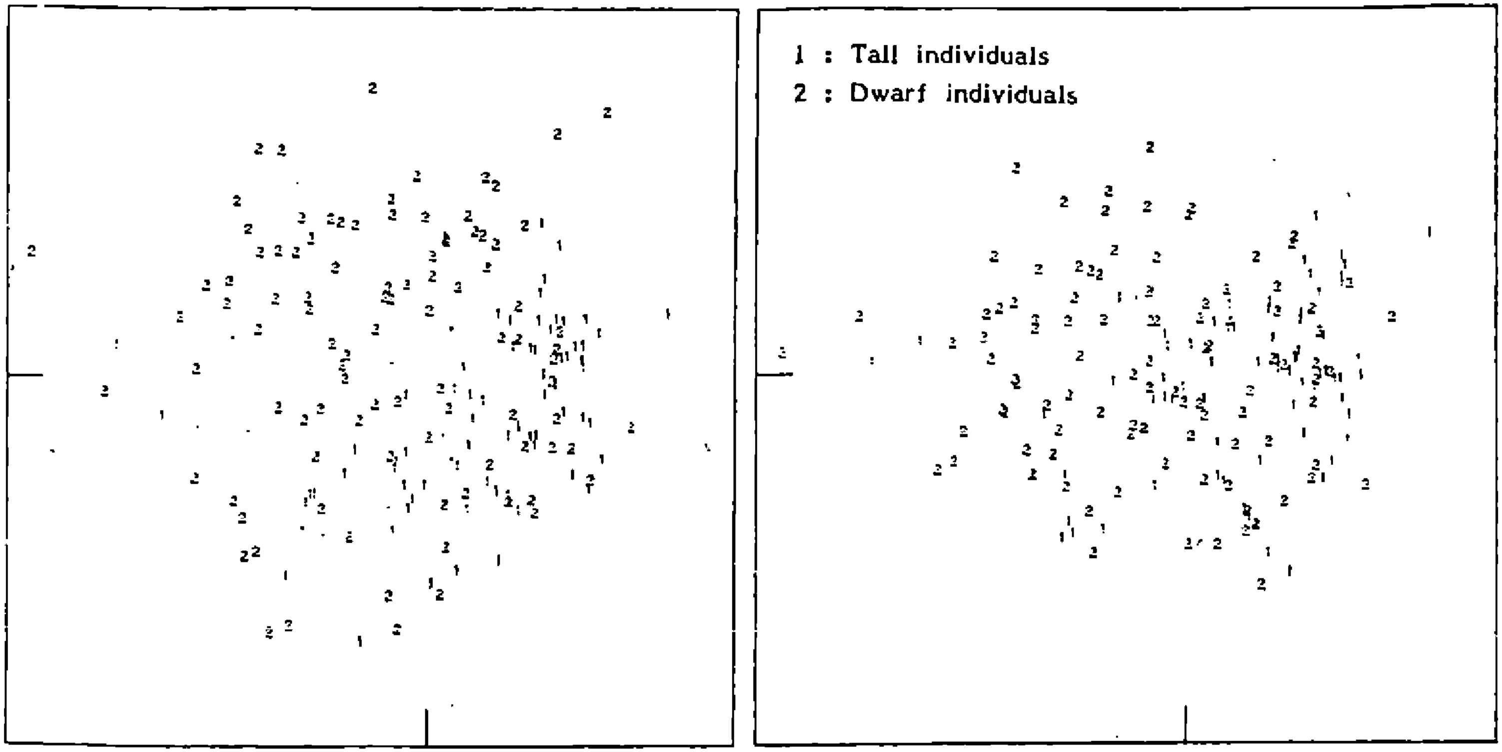
NO.	SIGN	TYPE	ORIGIN	GEOGRAPHICAL GROUP	n
1	NJM	Dwarf	Malaysia	Far East	6
2	GOA	Tall	Ouidah, Benin	Africa	6
3	GND2	Tall	Andaman, India	Indian Ocean	5
4	GML	Tall	Malaysia	Far East	5
5	GVT	Tall	Vanuatu	Pacific	5
6	GPY2	Tall	Rangiroa, Polynesia	Pacific	6
7	GCO	Tall	Comores	Indian Ocean	5
8	GTG	Tall	Tonga	Pacific	5
9	GND8	Tall	Laccadive Ordinary, India	Indian Ocean	5
10	GCB7	Tall	Ream, Cambodge	Far East	5
11	GND7	Tall	Laccadive Micro, India	Indian Ocean	5
12	GMZ	Tall	Mozambique	Africa	5
13	GOA	Tall	Cote d'Ivoire (Akabo)	Africa	5
14	GCA	Tall	Cameroun	Africa	5
15	NVE	Dwarf	Equatorial Guinea	Africa	5
16	GRT	Tall	Rotuma, Fiji Islands	Pacific	5
17	GTN	Tall	Tagnanan, Philippines	Far East	5
18	NVPTac	Dwarf	Tacunan, Philippines	Far East	6
19	NNL	Dwarf	Fiji Islands (Niu Leka)	Pacific	6
20	GRL	Tall	Rennell, Solomon	Pacific	5
21	NJG	Dwarf	Ghana (Origin Malaysia)	Africa (origin Far East)	6
22	NRM	Dwarf	Malaysia	Far East	6
23	NVT	Dwarf	Thailand	Far east	6
24	NBN	Dwarf	New Guinea	Pacific	5
25	GOA	Tall	Cote d'Ivoire, P. 052	Africa	5
26	GPYl	Tall	Tahiti, Polynesia	Pacific	5
27	NRY	Dwarf	Polynesia	Pacific	5
28	NVPCat	Dwarf	Catigan, Philippines	Far East	5
29	NVPPil	Dwarf	Pilipog, Philippines	"	6
30	NRC	Dwarf	Cameroun (origin Pacific)	Africa (origin Pacific)	5
31	GPA	Tall	Panama	America	6
32	NVS	Dwarf	Sri Lanka	Indian Ocean	6

n : Number of tested palms

1. Within-ecotype variability

Although the method basically aims at characterizing variability between ecotypes, it also makes it possible to bring out a few results relative to "within-ecotype" variability, subject to certain reservations dictated by the existence of different sources of error; in fact, at individual level, it is not possible to dissociate genetic variability from random variability; in addition, the small number of individuals tested per ecotype means that the accuracy of "within-ecotype" variability estimates is limited.

Generally speaking, within-ecotype variability is much wider in talls than in dwarfs, as suggested by their respective



(Plan 1, 2) (Plan 1, 3)

Fig 1. Standardized analysis of principal components for all the individuals

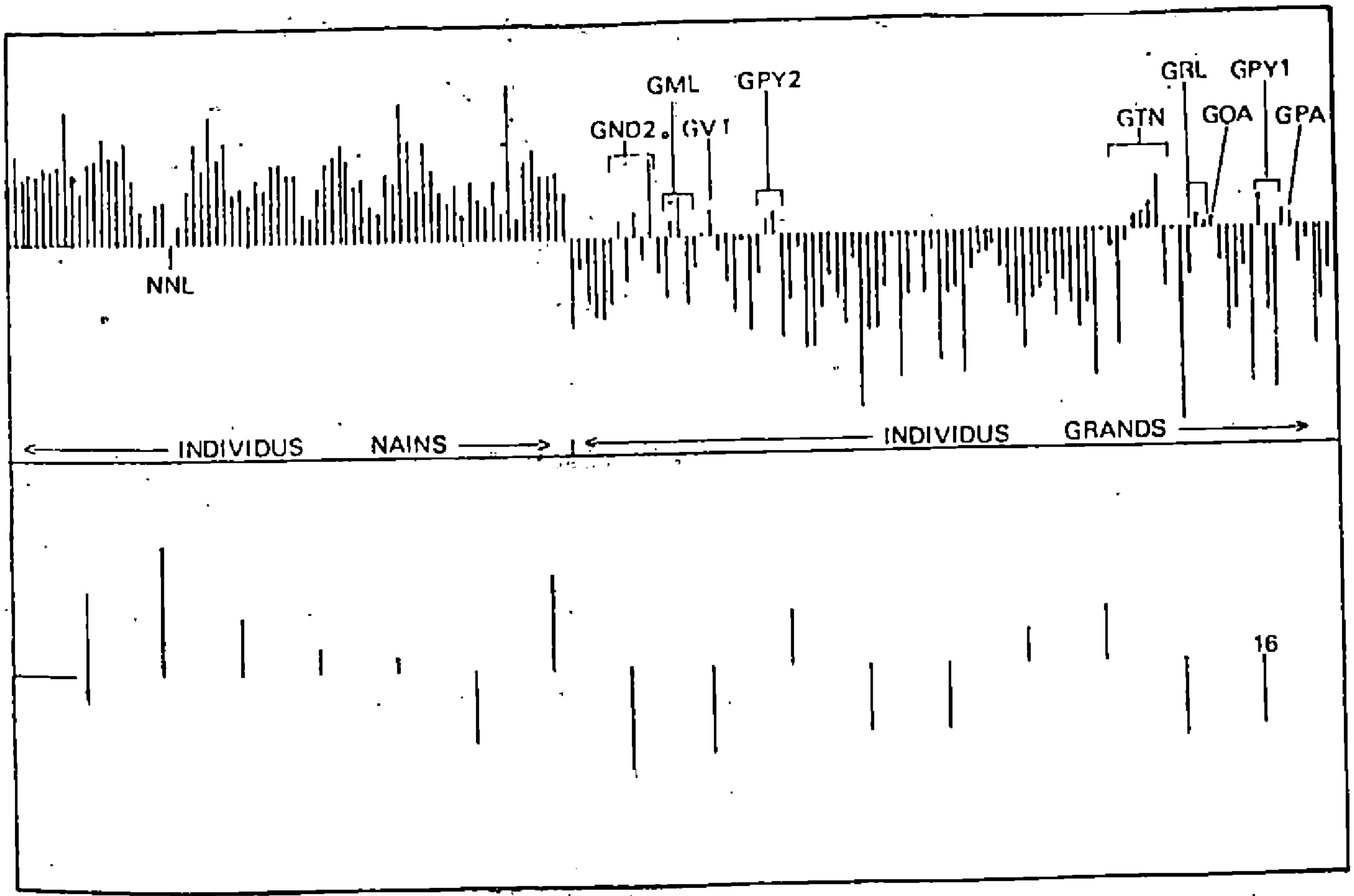


Fig 2. Discriminant analysis of all the individuals according to dwarf or tall criteria

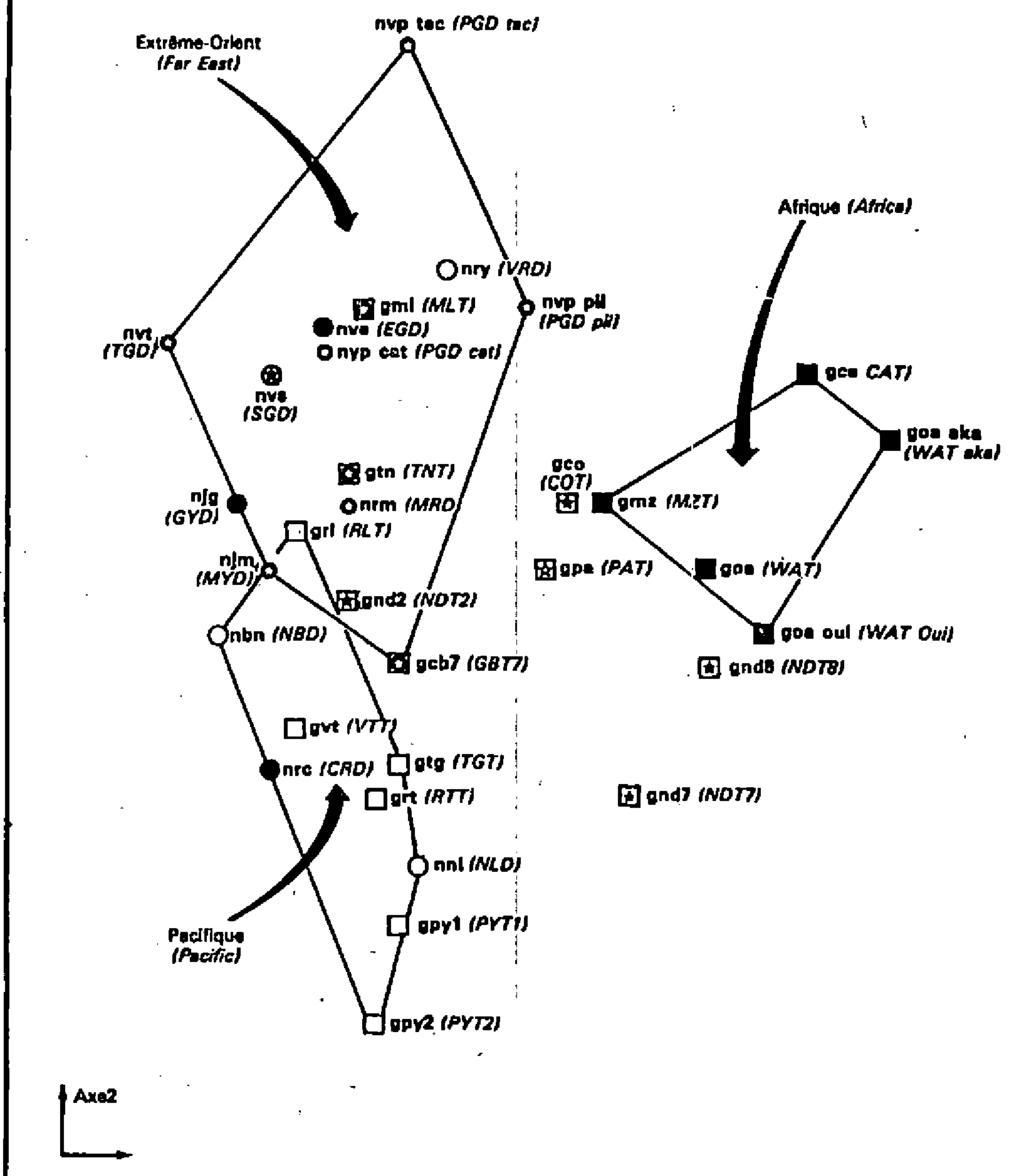


Fig 3. Discriminant analysis of all the individuals according to "ecotype" criteria

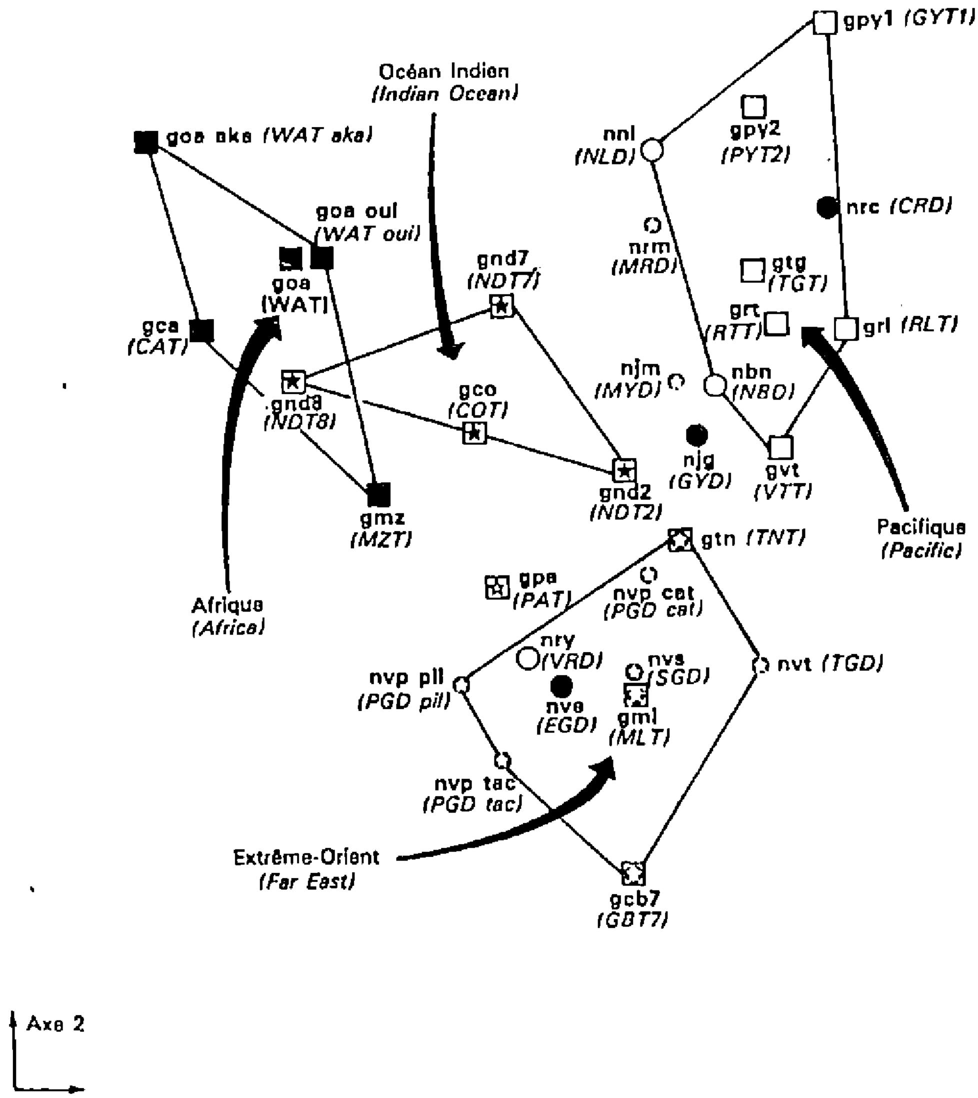


Fig 4. Discriminant analysis of all the individuals based on geographic origin

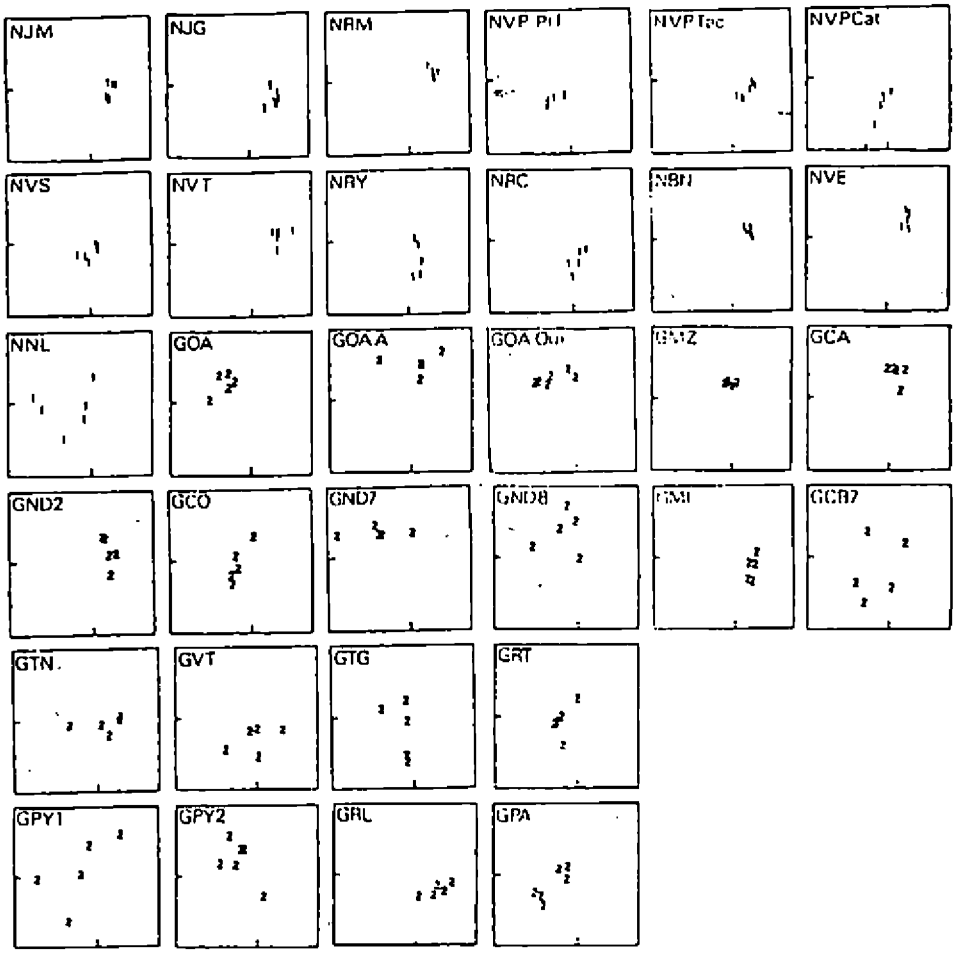


Fig 5. Analysis of leaf polyphenols. Analysis of the standardized principal components of all the individuals. Representation according to ecotype - plan 1, 2

reproduction methods (allogamy and autogamy). The Niu Leka Dwarf (NLD), the only allogamous dwarf studied, acts like a tall in this respect.

The NBD (New-Guinea) and the MRD (Malaysia) figure among the least variable dwarf ecotypes. The EGD (Equatorial Guinea) proves to be less polymorphic than the other Green Dwarfs. The MZT (Mozambique) is distinct among the talls because of its homogeneity, which seems to be greater than that of the different WAT (West Africa) ecotypes, and also goes against phenotypic observations.

2. Between-ecotype variability

a) *Dwarf-tall opposition*

Whether considering MCA or DA, the separation between dwarf and tall ecotypes is not visible *a priori*. It only becomes evident if the characteristics of the individuals or of the ecotypes are added to the figures. Hence on MCA plan 1.2 the tall individuals are distributed throughout the cloud whereas the dwarfs are located in the semi-circle situated approximately underneath the bisecting line, apart from three individuals of the NLD ecotype.

On plan 1.2 of the DA per ecotype almost all the dwarfs fall in the left-hand half. Although the distribution is not dichotomous, there exists a large area (centre centre-right) which contains tall ecotypes only which originate from Africa or the Indian Ocean. In accordance with historical data, this suggests that dwarfism did not originate from these regions.

The fact that variability is not split into two separate groups, "Dwarfs" and "Talls", seems to indicate that the appearance of dwarfism, on the species' historical scale, is a relatively recent phenomenon.

The discriminant analysis carried out on all the leaf polyphenols reveals a distinct separation between dwarf and tall ecotypes. Only 19 of the 171 individuals stand out through their atypical behaviour: a NLD individual behaves like a tall; certain tall individuals from various ecotypes behave like dwarfs: NDT2, MLT, PYT2, TNT, RLT, PYT1, WAT, PAT. This diversity makes it difficult to reach a conclusion as to the origin of dwarfism. As far as the NLD is concerned, it does not seem very likely that it is the ancestor of all the dwarfs; it is the only allogamous dwarf in the Port-Bouet collection and also has numerous morphological peculiarities.

b) *Geographical distribution*

The five groups used for classifying the Port-Bouet collection will be used here: Pacific, Far East, Indian Ocean, Africa and America (this latter group is only represented here by a single ecotype).

The representation provided by discriminant analysis displays three distinct groups corresponding to the Pacific, the Far East and Africa. A few of the exceptions observed can be explained. The Yellow Dwarfs from Ghana and Malaysia are near to one another which confirms the idea that the GYD was introduced into Africa from Malaysia under the British Empire.

Out of the Pacific ecotypes, the Cameroun Red Dwarf is found in isolation; here again, this tallies with hypotheses formulated according to historical data; this dwarf, which originates from the Caroline Islands, would appear to have been introduced by the Germans last century. However, the CRD appears surrounded by African ecotypes. Subject to certain reservations, this could be interpreted as introgression of the dwarf by African ecotypes. The CRD differs considerably from the other two Red Dwarfs.

The Green Dwarfs appear to be grouped together and therefore related: SGD (Sri Lanka), TGD (Thailand), PGD (Philippines), EGD (Equatorial Guinea). It is known that this latter dwarf, which has recently been planted in Africa, came from Brazil; it was no doubt introduced into Brazil before that from the Far East. Another representation, obtained from the heights of the peaks for two phenolic compounds typical of dwarfs (raw data), shows two groups of dwarfs: the Green Dwarfs and the Polynesia Red Dwarf are on one side and the rest of the dwarfs are on the other.

The eccentric position of the Polynesia Red Dwarf compared to the other Pacific ecotypes still requires interpretation; likewise with the Rennell Tall (RLT) ecotype which is surrounded by dwarfs of Malayan origin. On plan 3.4 the RLT is apart from all the other ecotypes.

The Indian Ocean ecotypes are divided up between the African and Far Eastern groups. This intermediate position can be explained geographically. The Comoro archipelago, whilst in the Indian Ocean, is still closer to Mozambique than to India, which explains why the COT and the MZT are close together. On the other hand, the Andaman Islands, from which the NDT2 originates, are relatively close to Thailand, the gateway to the Far East. The variable and intermediate characteristics of coconuts in the Indian Ocean suggests that dissemination followed a path extending through the Far East, India and Africa.

CONCLUSION

An analysis of coconut leaf polyphenols makes it possible to bring out a certain number of results:

* There is variability between ecotypes and, to various degrees, within each ecotype. The image of variability obtained through discriminant analysis tallies with hypotheses put forward on coconut dissemination. It reveals three groups fitting into geographical zones: Pacific, Far East and Africa. The variable and intermediate characteristics of coconuts in the Indian Ocean confirm that dissemination followed a path extending through the Far East, India and Africa. Ecotypes revealing very variable morphologies appear in the same zone, such as the VTT with a large number of small nuts and the RTT with a small number of large nuts; this confirms that ecotypes with distinct morphological characteristics can prove to be genetically close.
* Certain representations confirm historical data: the dwarfs in Africa would seem to have been introduced from the Far East (GYD, EGD) and the Pacific (CRD).
* The Green Dwarfs appear to be grouped together in various figures and would therefore appear to be related.

High performance liquid chromatography of leaf polyphenols therefore turns out to be a tool well adapted to evaluation of genetic variability in coconut palms and seems to be more effective, on this plant, than enzyme electrophoresis techniques.

Nonetheless, this study needs to be gone into in greater depth, by carrying out finer statistical analysis of available data. It should also be extended to other ecotypes, especially all those introduced into Cote d'Ivoire.

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EXPLOITING HETEROSIS IN COCONUT PALMS

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Abstract: Hybrid vigour was estimated in juvenile coconut palms through two separate experiments. Importance of exotic and indigenous coconut as parents in producing hybrids to achieve early germination and increased number of leaves per unit time was brought out by the first experiment. Intermediate values of seedling height with increased leaves in the hybrid indicate the potentiality for more leaves per unit height. Dwarfs as female had significant effect on early germination. Second experiment indicated the importance of dominant gene (sca) effects for early germination and additive gene effects (gca) for seedling girth, height and breadth of laminate leaf. Additive and dominant gene actions were true for increased number of leaves in the seedling.

INTRODUCTION

Hybrid vigour in coconut has been reported by a number of workers. However, the long pre-flowering period, separate male and female phases in the same monoecious inflorescence, poor setting, long development period for the nut, short dormancy, perennial growth habit, reduced multiplication value and the non-practicable breeding methodologies otherwise easily followed in annuals, have made recombination breeding most cumbersome in this palm.

Identifying juvenile characters correlated with nut and copra yield would be an advantageous approach for selecting parents. Satyabalan and Mathew (1976) reported high association values for girth at collar and number of leaves in the juveniles with yield. Fremond and Burnin (1976) reported higher number of leaves produced during the first two years as an indication to identify palms that would bear early. Nampoothiri *et.al.* (1975) found collar girth and leaves in the seedlings to be positively correlated with yield. Louis (1981) observed high heritability and high genetic advance for number of leaves, spathes, female flowers, and nuts produced per year and suggested selection based on these characters. But whether the dwarf or the tall variety of palm is to be utilised as female remains to be decided.

MATERIALS AND METHODS

Pollen collected from few selected Dwarf Green palms was dusted on to ten genotypes consisting of seven exotic, one indigenous and two tall x dwarf green hybrids (Table 1). In another experiment, four elite palms were pollinated with two selected pollinators as testers (Table 3). Hybrid nuts collected were sown in the nursery along with the selected nuts and the seedlings raised in a completely randomised design, adopting normal agronomic practices. Observations on the duration for germination, girth at collar, height, number of leaves and breadth of the fifth leaf were recorded during the ninth month of growth. The data were analysed for hybrid vigour and combining ability.

RESULTS AND DISCUSSION

Experiment I

The analysis of variance (Table 1) indicated highly significant differences for all the characters among the parents

Table 1. Hybrid vigour for juvenile characters in 9 month old coconut seedlings

Hybrid/parents	Duration for germinations (days)	Girth at collar (cm)	Height of the seedlings (m)	No. of leaves in 9 months	Breadth of 5th leaf (cm)
AO 1824 x 1920 DG	97.7*	14.57	1.60	8.00	22.90
AO 1826 x 1920 DG	102.1*	12.50	1.52	6.13	18.50
Ph 1866 x 1920 DG	103.1*	14.33	1.64	8.38	20.10*
Siam 1780 x 1920 DG	106.8	14.38	1.77	7.00	25.50*
CC 1788 x 1920 DG	120.3	13.75*	1.18	6.00	18.00
ECT 806 x 1920 DG	113.4	14.63	1.39	7.40	20.40
DG 1920 x 806 ECT	100.2	14.80	1.71	7.80	20.20
LS 1808 x 1920 DG	117.6**	11.50	1.53	6.13	18.50
DG 1920 x 1808 LS	100.0*	11.50	1.56	6.40	20.50
LO 1797 x 1920 DG	124.3	12.00	1.51	6.33	17.60
DG 1920 x 1797 LO	103.5*	14.38	1.39	6.25	17.50
(T x D) 1746 x 1920 DG	103.1*	15.63	1.53	6.50	23.40*
(T x D) 1767 x 1920 DG	82.3*	14.38	1.18	7.00	17.70
DG 1920	97.5	13.75	1.68	7.00	21.00
ECT 806	125.0	9.00	1.51	7.50	22.00
AO 1824	122.0	14.00	1.40	6.50	19.50
AO 1826	125.3	13.33	1.23	6.00	13.50
LS 1808	145.5	10.00	1.10	6.30	22.00
T x D 1746	135.0	13.33	1.22	5.60	21.30
PL 1866	130.3	14.67	1.25	7.00	27.00
T x D 1767	107.8	14.40	1.72	6.70	22.70
Siam 1780	121.3	14.33	1.21	6.80	15.30
LO 1797	128.0	11.33	1.19	6.70	20.33
CO 1788	129.0	15.00	1.40	6.70	20.00
F value	*	*	**	**	**
CD (0.05)	20.266	3.078	0.401	1.522	4.656

Note: Heterosis expressed over better parent
* Significant at 5% level ** Significant at 1% level

Table 2. Heterosis for juvenile characters (expressed as % over better parent)

Hybrids	Duration for germination over tall parent	Girth at collar	Height of seedlings	No. of leaves in 9 months	Width of the leaf
AO 1824 x 1920 DG	-24.48*	8.5	-5.0	12.5	0.3
AO 1826 x 1920 DG	-22.54*	20.0	-9.8	-14.8	-13.5
Ph x DG	-26.21*	7.7	-2.4	16.5	-35.0
Siam x DG	-14.15	0.4	6.7	0.0	17.6*
CC x DG	-7.50	11.1	42.4**	-16.7	-11.1
ECT x DG	-10.61	-11.1	-20.9	5.4	-2.9
DG x ECT	-25.00	5.4	1.8	10.3	-3.9
LS x DG	-23.73*	-15.9	-7.7**	-9.7	-10.0
DG x LS	-46.00*	-17.1	-8.4	-7.7	-15.8
LO x DG	3.25	-5.6	-20.9*	0.0	-11.1
DG x LO	-24.27*	-21.2	-14.4	-10.6	-14.3
(T x D) x DG	-30.48*	0.0	-9.6	0.0	-28.2
(T x D) x DG	-31.06*	-4.8	-20.3	-7.7	8.7*

* Significant at 5% level ** Significant at 1% level

Table 3. Hybrid vigour (expressed as % over better parent) in 9 months old coconut seedlings

Hybrids	Duration for germi-ation	Girth of collar	Height	No.of leaves	Breadth of the laminate leaf
ECT x Ayiramkachi (Ay)	8.5	-22.7	-27.3	-24.1	-16.7
San Blas x Ay	-3.6	1.7	0.0	0.0	-2.6
Lac. Micro x Ay	-25.2*	-15.0*	-62.5*	26.7*	-39.3*
Gangabondam x Ay	-15.4*	-0.8	-18.2	-10.7	-2.4
ECT x Local Tall	-26.0*	9.2	7.7	-1.9	7.7
San Blas x Local Tall	-13.5	9.8*	23.5*	21.1 *	-1.7
Lac. Micro x Local Tall	-3.6*	26.0	-85.7	-10.1	0.0
Gangabondam x Local Tall	-12.9	-7.1	-18.8	16.0	17.8

*Significant at 5% level

Table 4. Mean performance of F_1 hybrids and parents

Parent/hybrid	Days for germi-nation	Girth at collar (cm)	Height (m)	Number of leaves	Breadth of 5th leaf (cm)
ECT x Ayiramkachi	128.4	10.6	1.09	5.4	17.4
San Blas x Ayiramkachi	105.8	11.8	1.27	6.0	19.0
Lac. Micro x Ayiramkachi	115.0	10.0	0.75	7.5	14.0
Gangabondam x Ayiramkachi	114.4	12.0	1.13	6.2	20.4
ECT x Local Tall	103.9	11.9	1.25	5.4	20.9
San Blas x Local Tall	115.4	13.3	1.67	7.6	22.9
Lac. Micro x Local Tall	126.5	8.5	0.68	5.0	22.5
Gangabondam x Local Tall	116.0	11.3	1.08	6.5	26.5
ECT	117.5	13.0	1.39	6.7	20.3
San Blas	108.9	12.0	1.25	6.0	19.5
Lac. Micro	144.0	11.5	1.31	5.5	19.5
Gangabondam	132.0	12.1	10.14	5.6	20.9
Ayiramkachi	109.0	10.5	0.78	5.5	19.0
ECT	131.0	10.5	1.13	5.5	22.5
F value	**	NS	**	**	NS
SE	9.06	1.43	0.19	0.75	2.50
CD (0.05)	18.28	2.90	0.38	1.51	5.05

** Significant at 1% level

and hybrids. Hybrid vigour record is presented in Table 2. The duration for germination among the parents and hybrids ranged from 97 to 145 and 82 to 124 days respectively. Duration was reduced in all the single cross hybrids involving tall parent palms of Andaman Ordinary, Philippines, Laccadive Ordinary and Laccadive Small. The same was also true in the reciprocal crosses. Hybrids involving East Coast Tall did not have any reduction in the duration for germination in the direct and reciprocal crosses. Laccadive Ordinary however, registered significant reduction for the germination period in the reciprocal cross.

Hybrids from the three way cross also recorded reduction in germination period. In all the eight three-way cross hybrids the duration for germination

Table 5. Combining ability in juvenile characters

Genotypes	Days for germination	Girth of collar	Height of seedling	Number of leaves	Breadth of laminate leaf
a. *Gca effects*					
Lines					
ECT (878)	0.44	0.068	0.056	-0.80*	-1.3
San Blas (4277)	-5.06	1.368*	0.356*	0.60*	0.5
Lac. Micro (2847)	5.07	-1.906*	-0.404*	0.05	-2.2*
Gangabondam (2844)	-0.46	0.468	-0.008	0.15	3.0*
Testers					
Ayiramkachi (2869)	0.24	-0.056	-0.051	0.08	-2.75*
ECT (808)	-0.24	0.056	0.051	-0.08	2.75
SE (gca)	3.20	0.50	0.067	0.26	0.88
b. *Sca effects*					
ECT x Ay (878 x 2869)	12.86*	-0.57	-0.03	-0.88	1.00
ECT x ECT (878 x 808)	-5.04	0.67	-0.14	-0.88	0.80
San Blas x Ay (4277 x 2869)	-5.99	0.89	0.09	1.18*	-1.50
San Blas x ECT (4277 x 808)	-1.04	0.43	0.07	-0.23	-0.30
Lac Micro x Ay (2847 x 2869)	-12.86*	0.57	0.03	0.87	-1.00
Lac Micro x ECT (2847 x 808)	5.04	0.67	0.14	0.88	-0.80
GB x Ay (2844 x 2869)	5.99	-0.89	-0.09	-1.18*	1.50
GB x ECT (2844 x 808)	1.04	-0.43	-0.08	0.23	0.30
SE (sca)	6.40	1.02	0.13	0.53	1.77

Figures in parentheses are the serial numbers of the palms
* Significant at 5% level

tended towards the dwarf parent involved.

Girth of the seedlings at collar among the parents and hybrids ranged from 9.00 - 14.67 cm and 12.50 to 15.65 cm respectively and the differences among the parents were significant. However, the hybrids from the single and three way crosses failed to exhibit any significant differences.

Height of the seedlings significantly varied among the parents and hybrids. Hybrids between Cochin China x Dwarf Green, Laccadive Small x Dwarf Green, and Laccadive Ordinary x Dwarf Green recorded significant reduction from their respective better parents. The hybrids obtained from the reciprocal crosses failed to exhibit significant differences. Hybrids of other combinations failed to exhibit any significant reduction or increase for height of the seedling. The number of leaves significantly differed in the parents and hybrids. However, none of the hybrids registered any significant increase or decrease over their respective better parents. Hybrids of Philippines (San Ramon) x Dwarf Green recorded the highest value for the number of leaves. A general reduction for the number of leaves was observed in the hybrids during this period.

Breadth of the 5th leaf registered significant differences among parents and hybrids. However, the increase was significant over the better parents, only in two single cross hybrids and one three way cross hybrid viz., Philippines (San Ramon) x Dwarf Green, Siam Tall x Dwarf Green and Local Tall x Dwarf Green x Dwarf Green.

In general, two hybrids viz., Philippines (San Ramon) x Dwarf Green and (Local Tall x Dwarf Green) x Dwarf Green showed hybrid vigour for period of germination and breadth of the 5th leaf, while the hybrid, Laccadive Small x Dwarf Green recorded heterosis both for reduced duration and reduced height, over their better parents.

Experiment II

The F_1 hybrids of the four lines tested against the two testers viz., Ayiramkachi, a prolific bearer and Local Tall, a steady yielder with desirable morphology showed significant hybrid vigour for the four seedling characters viz., duration for germination, height, number of leaves and breadth of leaves (Table 3). All the four hybrids recorded hybrid vigour over the better parents.

Duration for germination was significantly reduced over their better parents in the crosses involving Gangabondam x Ayiramkachi, East Coast Tall x Local Tall and Laccadive Micro x Local Tall.

Girth at collar exhibited no significant differences among the parents and hybrids. The height of the hybrid seedlings in the cross combinations viz., Laccadive Micro x Ayiramkachi and San Blas x Local Tall recorded significant but negative values over their better parents.

The hybrid vigour was positive and significant for the number of leaves in the cross combinations viz., Laccadive Micro x Ayiramkachi, San Blas x Local Tall. None of the combinations registered increase over their better parents for the breadth of the laminate leaf. Hybrid of Laccadive Micro x Ayiramkachi, however, recorded significant reduction for the character over its better parent.

Combining ability

a. *General combining ability (gca)*

Neither the parents nor the testers revealed gca for the duration for germination. Parent San Blas, recorded positive significant values for gca for three characters viz., girth at collar, height and number of leaves. Parent Laccadive Micro showed significant but negative values for gca only for girth at collar, height and breadth of the laminate leaf. Among the testers Ayiramkachi recorded gca for only one character viz., breadth of the leaf.

b. *Specific combining ability (sca)*

Specific combining ability for duration for germination could be recorded only in two combinations viz., East Coast Tall x Ayiramkachi and Laccadive Micro x Ayiramkachi. Sca was not found important for girth at collar, height, and breadth of the embryonic leaf. However, combinations San Blas x Ayiramkachi and Gangabondam x East Coast Tall recorded specific combining ability for the number of leaves produced per unit time. Tester Ayiramkachi is found combining with more number of characters through specific combining ability.

The first experiment has brought out the importance of involving exotic and indigenous types as parents for hybrid vigour towards early germination and increased leaves per unit time. Dwarfs as female had a significant effect on the early germination of the nut. Intermediary values of height with increased leaves in the hybrid indicate the production of more leaves per unit height. In the adult palm, it would be a desirable trait, towards yield.

The second experiment has brought out the importance of dominant gene (sca) effects for early germination and both additive (gca) and dominant gene (sca) effects for seedling girth, height and breadth of the laminate leaf.

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CHARACTERIZATION OF COCONUT CULTIVARS

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Abstract: The coconut germplasm collection at the Central Plantation Crops Research Institute consists of 62 exotic and 35 indigenous collection at the World Coconut Germplasm Centre, Sipighat, Andaman. This is the largest collection available anywhere in the world, comprising representative samples from geographically divergent population. Basically there are only two distinct varieties in coconut the tall and the dwarf. While the talls were exentsively cultivated, the dwarfs were grown only as an ornamental type till recently when their value as parents in the hybrid production was established, for the purpose of preparing the descriptor. The identity of the individual introduction is maintained and it is considered as a separate accession because of the lack of reliable classification criteria. A suitable descriptor for coconut is still not available and hence even experienced coconut breeders find it difficult to identify the cultivars. Since most of the phenotypic characters useful in the identification of the cultivar are polygenic, a clear-cut demarcation is rather difficult in the identification. A model descriptor developed by this institute was taken as a basic document in the preparation of the descriptor by the Coconut Breeders' Consultation Group of the IBPGR. This descriptor is being used in this paper for characterizing 18 genotypes of coconut comprising 14 talls and 4 dwarfs. Eruit component analysis as well as other measurable phenotypic characters have been used in developing this descriptor for the characterization.

INTRODUCTION

Cocos nucifera L. is a monotypic species of tropical distribution. Because of its highly outcrossing nature several types widely differing from each other exist. At the same time some of the types do not differ much between each other. At the Central Plantation Crops Research Institute, Kasaragod, the germplasm bank has a collection of 62 exotic and 35 indigenous accessions. At the World Coconut Germplasm Centre (WCGC) in Andamans 24 exotic collections and 6 indigenous accessions are at present grown. Probably this is one of the largest collections available anywhere in the world. The identity of each accession is maintained and is considered as a separate entry due to lack of reliable classification criteria through which the duplicates can be identified. Basically in coconut there are only two varieties. They are the tall and the dwarf. In both these varieties there are a number of cultivars/types existing because of the variation in size, colour, quantity of copra, oil content etc. Even with all these it is difficult to identify these cultivars because of the lack of detailed descriptor and the confusion is still persisting. A few examples to suggest are described hereunder. The Laccadive Dwarf and the Kenthali of Karnataka look similar to Chowghat Orange Dwarf. Similarly the Laccadive Green Dwarf resembles to a very great extent the Chowghat Green Dwarf. Laccadive Ordinary (Chandrakalpa) and the West Coast Tall in most of the characters resemble each other except in oil content. Hence a detailed descriptor is essential so that these cultivars can be identified and utilized in the breeding programmes effectively.

The first systematic classification of coconut varieties and forms was attempted by Narayana and John (1949). Later Gangolly *et al.* (1957) reviewed the literature on the varietal classification. The coconut cultivars available in Sri Lanka have been classified by Liyanage (1958). The criteria used in the above classification were based on plant habit and geographical source. The third classification was attempted by Fremond *et al.* (1966) on the basis of floral biology. Harris (1978) in his paper on evolution, dissemination and classification had laid emphasis on fruit components, especially husk weight and meat/copra weight. Rao and Pillai (1982) also attempted to classify a few accessions based on the fruit components. One of the common criteria used in all these classification was on the nut characters. For the purpose of classification it is necessary to use data that are commonly available. It is also necessary to use parameters that can be assessed simply and accurately which may not be required to be repeatedly collected.

Characterization and the development of a descriptor for coconut is apparent from the above references. Even today there is a lot of confusion even among experienced coconut breeders in classifying certain cultivars/types. The term *semitall* is being used in cases where it has been proved beyond doubt that they are typical dwarfs. The classical example is Gangabondam. This is a typical dwarf cultivar. *Typica, Nana, Javanica, Gigantia, Ramona* etc. are some of the terms used to describe certain types of cultivars. Instead of giving a clear picture this has created more confusion among workers. Hence it was felt that a detailed descriptor may be developed so that these ambiguity is avoided and these materials are properly documented and evaluated. With this objective the Central Plantation Crops Research Institute developed two sets of descriptors one for the collection of germplasm during survey and expedition which is also called the passport data and another for the evaluation. This was discussed in detail by the Breeders' Consultative Group on Coconut of IBPGR in 1978 and approved. This descriptor was used in the present study to characterize some of the coconut germplasm available at the CPCRI, Kasaragod.

MATERIALS AND METHODS

The coconut descriptor developed by the CPCRI and approved by the Consultative Committee of the International Board for Plant Genetic Resources in their meeting held in January 1978 was used in this study to record the observations on coconut cultivars used in the present study. The characters listed formed into five major heads namely, stem characters, leaf characters, inflorescence characters, breeding behaviour and fruit components. A total of 41 characters were studied in 18 cultivars. The study was undertaken on palms which were over 20 years of age. The morphological characters were recorded from 10 palms. For the characters of nuts, 24 nuts from six palms, harvested during the summer months were studied.

The nuts were stored till the husk was dry and then studied for the nut characters. The sampling procedure adopted was as suggested by Coconut Breeders' Consultative Committee of FAO (Anon, 1978). The present study was confined to 18 cultivars in four distinct groups viz., exotic talls, exotic dwarfs, indigenous talls and indigenous dwarfs. There were 7 exotic talls, 2 exotic dwarfs, 7 indigenous talls and 2 indigenous dwarfs. In characterizing these cultivars five major group of characters were taken into consideration. They were stem characters including age at flowering, leaf characters, inflorescence characters, breeding behaviour, nut characters and its ratios. The characters were grouped into two sets, those that could be measured (quantitative characters) and those which were recorded as visual observations (qualitative).

Table 1. Stem characters

Sl. No.	Name of cultivar	Age at flowering (months)	Presence/ absence bole on surface planting	Girth of stem at 1 m height (cm)	No. of leaves in 1 m stem
1	Andaman Ranguchan (AR)	122	Present	96	20
2	Benaulim (Ben)	102	Present	88	18
3	Borneo (Bor)	104	Present	94	21
4	Ceylon Tall (CT)	114	Present	95	18
5	Chowghat Green Dwarf (CGD)	41	Absent	58	56
6	Chowghat Orange Dwarf (COD)	42	Absent	60	45
7	Jamaica Tall (JT)	86	Present	88	27
8	Laccadive Micro (LM)	98	Present	83	24
9	Laccadive Ordinary (LO)	64	Present	79	32
10	Malayan Green Dwarf (MGD)	74	Absent	74	33
11	Malayan Yellow Dwarf (MYD)	44	Absent	63	46
12	Nadora Tall (NT)	120	Present	96	17
13	Nicobar Tall (NiT)	138	Present	93	19
14	Philippines Lono (PL)	121	Present	91	29
15	San Ramon (SR)	95	Present	91	24
16	St. Vincent (St.V)	118	Present	81	15
17	Zanzibar Tall (ZT)	85	Present	91	18
18	West Coast Tall (WCT)	98	Present	79	15

Table 2. Leaf characters

Sl. No.	Cultivar	No. of leaves in the crown	Length of petiole (cm)	Length of leaf-let bearing area (cm)	No. of leaf-lets in a leaf	Length of a leaflet (cm)	Breadth of a leaflet (cm)
1	2	3	4	5	6	7	8
1	AR	33	145	464	232	125	6
2	Ben	32	144	435	244	129	6
3	Bor	41	132	442	218	126	6
4	CT	36	131	435	236	129	6
5	CGD	28	99	306	196	102	5
6	COD	22	96	346	180	101	5
7	JT	32	132	429	218	116	5
8	LM	30	128	414	224	121	6
9	LO	28	94	325	210	103	5
10	MGD	31	131	374	200	112	6
11	MYD	31	110	326	180	105	5
12	NT	30	138	462	244	124	6
13	NiT	28	125	414	242	121	6
14	PL	33	117	436	234	125	6
15	SR	40	126	422	210	121	6
16	St.V	26	126	439	238	113	6
17	ZT	24	148	454	226	134	5
18	WCT	36	137	421	244	122	6

Table 3. Inflorescence characters and breeding behaviour

	Cultivar	No. of inflore-scence in a year	Lenght of inflore-scence (cm)	Mean No. of female flower per inf.	Setting %	Length of peduncle (cm)	Length of spikelet (cm)	No. of spike-lets in an inflo-rescence	Duration of male phase	Duration of female phase	Overla-pping of phase within	Overla-pping between inflore-scence	Pollina-tion Self/cross	Interspadix
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	AR	10	114	23	25	65	46	43	18	3	0	0	Cross	Interspadix
2	Ben	10	102	23	36	59	37	43	19	4	0	2	Cross	-do-
3	Bor	11	127	26	27	53	44	43	21	4	0	2	Cross	-do-
4	CT	9	124	27	24	56	42	43	19	5	0	2	Cross	-do-
5	CGD	9	60	17	38	33	31	33	16	5	4	0	Self	Nil
6	COD	9	67	20	30	35	32	35	18	5	4	0	Self	Nil
7	JT	9	132	20	33	54	45	42	20	4	0	4	Cross	Interspadix
8	LM	10	83	38	40	49	42	39	20	5	0	4	Cross	-do-
9	LO	12	70	24	40	36	36	35	19	4	0	3	Cross	-do-
10	MGD	8	102	26	34	44	35	46	14	4	3	4	Self	-do-
11	MYD	10	81	23	36	43	31	40	18	4	4	0	Self	Nil
12	NT	8	108	22	33	62	45	41	19	4	0	0	Cross	Nil
13	NiT	7	89	17	26	52	41	39	18	3	0	0	Cross	Nil
14	PL	12	116	27	22	49	62	38	20	5	0	5	Cross	Interspadix
15	SR	12	127	21	22	54	54	39	20	4	0	4	Cross	-do-
16	St.V	9	120	21	15	51	44	37	20	5	0	4	Cross	-do-
17	ZT	8	109	38	17	61	49	42	19	4	0	0	Cross	Nil
18	WCT	12	105	19	35	58	40	38	19	4	0	0	Cross	Nil

Table 4. Nut characters and ratios

	Cultivar	Weight of fruit (g)	Weight of husk (g)	% of husk in fruit	Weight of nut (g)	% of nut to fruit	Weight of meat (g)	% of meat to fruit	Weight of shell (g)	% of shell to nut	Taste of tender nut water	Taste of tender kernel	Shape of fruit
	1	2	3	4	5	6	7	8	9	10	11	12	13
1	AR	1204	447	37.2	757	62.8	367	30.4	210	17.4	Good	Good	Oblong
2	Ben	799	227	28.5	572	71.5	253	31.6	144	18.0	Good	Average	Oblong
3	Bor	1450	463	32.0	987	68.0	444	30.6	249	17.1		Poor	Round/oblong
4	CT	1092	444	40.7	668	59.3	328	30.0	176	16.1	Average	Average	Oblong
5	CGD	453	263	48.1	190	41.9	71	15.6	41	9.0	Average	Average	Oblong with constriction at base
6	COD	634	255	40.3	379	59.7	194	30.5	112	17.6	Good	Good	Round
7	JT	920	290	31.6	630	78.4	304	33.0	185	20.1	Average	Average	Round
8	LM	562	280	49.9	282	50.1	156	27.7	81	14.4	Poor	Poor	Oblong/round
9	LO	1120	782	69.9	338	30.1	174	15.5	115	10.2	Average	Poor	Oblong
10	MGD	905	436	48.2	469	51.8	213	23.5	106	11.7	Average	Average	Oblong
11	MYD	724	328	45.5	396	54.6	183	25.2	131	18.0	Average	Average	Oblong/round
12	NT	862	326	37.9	536	62.1	300	34.8	117	13.5	Poor	Average	Oblong
13	NiT	1117	406	36.4	711	63.6	358	32.0	178	15.9	Average	Average	Oblong
14	PL	1509	714	47.4	795	52.6	338	22.3	206	13.6	Average	Good	Round
15	SR	1996	607	30.5	1389	69.5	591	29.6	293	14.6	Poor	Poor	Oblong/round
16	St.V	1128	625	55.5	503	44.5	245	21.7	147	13.0	Poor	Poor	Oblong
17	ZT	1250	436	34.9	814	65.1	400	32.0	185	14.8	Poor	Average	Oblong
18	WCT	1196	630	52.7	566	47.3	283	37.7	168	14.0	Average	Average	Oblong/round

RESULTS AND DISCUSSION

Presence or absence of bole is a distinct character which can be utilized in identifying a dwarf variety from a tall population. But this character alone cannot be taken as a key character for identification of talls and dwarfs. A set of characters together is taken for identification of talls and dwarfs. One of the important characters which distinguishes tall and dwarfs is the precocity in flowering seen in dwarfs. In exotic as well as in indigenous dwarfs the time taken for flowering is considerably low as compared to the talls (Table 1). The variation observed in Malayan Green Dwarf clearly indicates that this particular cultivar is not a typical dwarf. When the Malayan Yellow Dwarf has taken 44 months to flower the MGD has taken 74 months. Both the CGD and COD have taken around three and half years only for flowering. Hence it is safe to conclude that Malayan Green Dwarf is a semitall cultivar, a term which was used by some earlier workers. Another important character useful in characterizing the cultivar is the stem girth. A clear difference can be observed between the talls and the dwarfs. Here also the MGD shows an intermediate value. Most of the talls have a value above 75 cm. The typical dwarfs had lower values. The number of leaves produced by the palm in a length of 1 m is an important character useful in the characterization. It can be seen from Table 1 that between cultivars this character varies. In dwarfs the number of leaves produced in 1 m stem will be very high when compared with the tall. When around 45 leaf scars are counted in dwarfs this varies from 15 to 32 in talls. In this character, MGD comes close to talls only.

Considerable variation exists in the number of leaves available in different cultivars. However, a clear demarcation could not be observed in this trait even though CGD had the lowest value of twenty two. But four other characters i.e., length of petiole, length of leaflet bearing area, number of leaflets on the leaf and the breadth of leaflets have shown marked differences between talls and dwarfs (Table 2). The leaflet breadth is low in dwarfs while most of the talls had greater values including MGD. The number of inflorescences produced by the different cultivars shows variation among them. In coconut a tree generally produces 12 leaves in a year and from every leaf axil one inflorescence emerges. In effect in a year 12 inflorescences are produced and 12 bunches are harvested. The inflorescence is initiated in the leaf axil of every leaf, but in a few cultivars during certain seasons, these inflorescences get aborted (Pillai *et al.*, 1972). In dwarfs it is seen that under west coast conditions a few inflorescences get aborted during winter season. In a few tall cultivars also this phenomenon exists (Table 3). Cultivars like Nicobar Tall, Nadora Tall, Zanzibar Tall, St. Vincent and Ceylon Tall produce less number of inflorescences in a year. In dwarfs the inflorescences are smaller when compared with talls. However, variation does exist in the length of inflorescences in talls also. Nicobar Tall has a shorter inflorescence of 89 cm length, while Jamaica Tall has a long inflorescence of 132 cm. The number of female flowers produced in an inflorescence greatly depends upon the manurial status of the soil. Much variation could not be seen for this particular trait. Lakshadweep cultivars possess higher setting percentage when compared with other cultivars. St. Vincent and Zanzibar Tall recorded the lowest setting percentage. The length of the inflorescence stalk generally known as peduncle, is a useful trait in the characterization. In the typical dwarf types they are very short. However, in some talls like Laccadive Ordinary the peduncle is short. Short peduncle always helps the bunches to rest on the leaf which will avoid the buckling of bunches. The length of spikelet in the inflorescence is also useful to some extent in the identification of cultivars. The data recorded have shown that dwarfs have shorter spikelets compared to talls. Malayan Green Dwarf gave values close to the talls. Duration of male phase, overlapping of male and female phase in the same inflorescence and interspadix pollination are some of the important characters helpful in the characterization. Different cultivars behave differently with regard to its breeding behaviour (Table 3). While the Malayan Green Dwarf had the shortest male phase it had overlapping of the phases within the inflorescence as well as between the inflorescences resulting in self-pollination as well as interspadix pollination. Malayan Yellow Dwarf and Chowghat Orange Dwarf had the highest percentage of self-pollination. However, it was observed that a few female flowers in the inflorescence get pollinated with pollen from other sources. All the talls are cross-pollinated, however, in many cases interspadix pollination was observed during certain seasons of the year. This trait is useful in the identification of cultivars. The most useful traits in the characterization of the cultivars are the nut characters and their ratios between the different components of the nut. The shape of the nut is also useful in identification. In some cultivars special features will also be present as seen in CGD where a constriction is seen developing at maturity at the base of the nut. The shape of the nut is generally coming in one of the three groups i.e., oblong, round or elliptical. Normally the shape of nut does not vary within a cultivar. If at all there is variation it is due to the heterozygous condition of the tree. The variation is generally noticed only in talls where cross-pollination prevails. Other important characters that are less influenced by the environment are the ratios of the nut to fruit, meat to fruit, shell to fruit and husk to fruit. These characters are helpful in characterization. Tastes of tender nut water and tender kernel are also two useful characters even though they are qualitative in nature. Even the flavour of the water can be used in identification of certain cultivars like *Klapawangi* of Malaya. The presence of sugars and amino acids present in the tender coconut water is also a diagnostic tool in characterization.

The materials studied under the present investigation can be classified into Indian, Sri Lankan, Indian Ocean, Malaysian, Philippine, NC American and African groups based on its location of collection. Percentage of husk in the fruit was considered as one of the important characters in distinguishing the groups 'Niu Vai' and 'Niu Kafa' suggested by Harris (1978). However, for further characterization, additional characters have to be considered. In the paper on practical identification of coconut varieties, Harris (1981) has utilized a few characters like nature of palm, fruit analysis, breeding behaviour etc. In the present study the naturally evolved types like West Coast Tall, Laccadive Ordinary, Laccadive Micro, Chowghat Green Dwarf, Chowghat Orange Dwarf, Ceylon Tall, St. Vincent Tall, Malayan Green Dwarf and Malayan Yellow Dwarf have shown higher percentage of husk while the introgressed forms like San Ramon, Zanzibar Tall, Jamaica Tall, Borneo, Benaulim etc. have lesser percentage of husk. The present study confirms the earlier studies of Rao and Pillai (1982) where a broad classification of a few cultivars had been made based on the fruit components.

The study reveals that a number of

characters are available both qualitative and quantitative with which it is possible to identify the different genotypes of coconut. A detailed descriptor based on these characters will help to a great extent in eliminating the present confusion existing in the identification of coconut genotypes. This will also help in discarding duplicate accessions from the original collection. A world-wide attempt by coconut breeders may be essential to characterise all the germplasm available today. An earnest attempt has been made by the authors towards this line of work which will be useful for research workers for identifying various genotypes to a greater extent.

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GENETIC LOAD IN COCONUT PALM

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Abstract: The floral morphology of coconut helps to maintain the concealed genetic variability. The mechanism involved in delaying the process of fixation of deleterious genes is of importance. The delayed fixing of these genes indicate chromosomal inversion, and linked nature of these genes with positive and negative pleotropic effects. Some of these genes under homozygosity as measured by progeny row test exhibit lethal effects of different nature and grade. These include sterile embroys, inviables and sub-vitals with lesser effects. Frequencies involving recessive lethals observed on the seednuts are striking.

The pattern of segregation indicates mono, di and multi-hybrid segregations. Genetic polymorphism is found common both in the selected as well as non-selected palms. A few chlorophyll deficient seedlings like viridis were observed. The viridis and xantha types were not observed in the dwarf and tall nuts from the various centres and in specific crosses. However, only one parental tree recorded xantha progeny. The albinos were completely absent in the entire seedlings under observation. Failure of germination due to aborted embryo was noticed. While tall palms which had one generation of selection showed reduced rate of abortion, dwarf types recorded a high rate. In hybrids, the rate of aborted/sterile embryos varied with the male parent involved. The rate of premature death after germination was more in dwarfs and low in the hybrids.

Though selection continuously removes the deleterious mutant genes in the population linkage, inversion and continuous mutation are assumed for building up and maintaining heterozygosity within this limited genetic load in coconut.

INTRODUCTION

Coconut (*Cocos nucifera* L.) is a monotypic species with no close relatives. The crop has undergone considerable domestication. Genetic variation through spontaneous mutation and the inherent special floral morphology of the palm fit for cross pollination help conceal recessive genes and maintain variability. The mechanism involved in delaying the fixation of the deleterious recessive genes in the coconut population is of great significance. Natural and conscious selections for yield and other desirable genes through generations have led to the elimination of most undesirable genes fixed.

Some of these undesirable genes are floating and remain unfixed in populations of the tall and dwarf varieties. This may be due to the fact that most of them are recessive and remain closely linked or stuck in the inverted segments of chromosomes. These genes may have positive and negative pleiotropic effects. These genes when fixed exhibit lethal effects of different grades. They include those causing abortion of the embryos, inviables that die during development and growth, and sub-vitals which cause lesser lethal effects.

Reduced rate of multiplication and the long generation period in the palm provide less opportunity to estimate the genetic load for the various lethal genes. Sophisticated techniques to study the lethal genes would involve assaying the specific enzymes, RNAs and amino acids in the intact palm. The simple technique of studying genetic load is by measuring the relative viabilities (fitness) of heterozygous and homozygous individuals for the respective wild genes through progeny row test. Literature to this effect is rather limited.

Nevertheless, preliminary observations in the healthy coconut nurseries of variety tall and dwarf have indicated that on an average 10% of the nuts failed to germinate while a small percentage (0.04%) of the sprouts died without symptoms of any pests or diseases. Besides these, random segregation for weak and lanky seedlings and those with chlorophyll deficiencies of different order could also be observed. This was common both in the prepotent and low yielding mother palms. However, the type and percentage of segregants differed among these palms. This prompted to observe the frequency of these deleterious genes causing lethal, and semi-lethal effects in the natural populations based on one or two generations of conscious selection.

MATERIALS AND METHODS

The material consisted of mature seednuts of tall and dwarf varieties from known coconut tracts in Coimbatore and Dharmapuri districts of Tamil Nadu, hybrid seedlings of Tall x Dwarf Green parentage and specific parent trees and their hybrids from the coconut nursery, Tamil Nadu Agricultural University, Coimbatore. Specific dwarfs observed were Chowghat Dwarf Orange, Chowghat Dwarf Green and Dwarf Green. Besides these, a set of 300 nuts from the Local Dwarf Yellow and 250 nuts from Lakshadweep Tall also formed material for the study.

Normal package of practices were adopted in raising the seedlings. Germination of the nuts was assessed at the sixth month of planting. The lethal and semi-lethal characters were scored by recording the dead sprouts, seedlings with weak and poor development and chlorophyll deficiencies during the course of one year.

Homozygous lethals which showed inviability (90-100%) were termed as lethals, those with 50-90% inviability were termed as semi- lethals, and those with lesser deleterious effects with weak and lanky look and those with chlorophyll deficiencies were named as sub-vitals. Seedlings with chlorophyll deficiencies were classified as (1) albino (pure yellow, lacking chlorophyll), (2) xantha (brownish green) and (3) viridis (brownish yellow).

Ungerminated nuts were confirmed by the presence of aborted embryos and the dead sprouts through their drying of the entire foliage without any symptom of pests or diseases. The lethals, semi-lethals and sub-vitals were worked out in percentage and expressed in fraction.

RESULTS AND DISCUSSION

Experiment I

Tall variety collected from five distinct coconut centres, representing random and one or two generations of conscious or directed selections for high yield and three types of dwarf with one generation selection and hybrid nuts of Tall x Dwarf Green were subjected to the progeny row trial (Table 1). Seednuts which failed to germinate due to aborterd embryos were observed in all palms, irrespective of tall, dwarf or hybrids. Centres of selection had no impact on the embryo abortion observed. Selection in relation to the number of generation had a corresponding reducing effect on the rate of embryo abortion.

Table 1. Frequency of lethals, semi-lethals and sub-vitals in tall, dwarf and hybrid nuts

Name of the centre	Nuts sown	Ungerminated		Dead sprouts		Xantha		Viridis		Weak seedling	
		No.	Frequency	No.	Frequency	No.	Frequency	No.	Frequency	No.	Frequency
Tall											
Chettipalayam	5400	828	0.1533	66	0.0122	-	-	7	0.0013	61	0.0113
Razakkapalayam	6300	195	0.0309	62	0.0098	-	-	3	0.0048	43	0.0068
Coconut nursery	3600	204	0.0567	72	0.0200	-	-	1	0.0003	26	0.0072
Millets Station (MBS)	450	14	0.0345	7	0.0172	-	-	2	0.0044	6	0.0133
Lakshadweep Tall	250	28	0.1120	4	0.0160	7	0.0280	2	0.0080	7	0.0280
	16000	1269	0.0793	301	0.0188	7	0.0280	15	0.0093	143	0.0893
Dwarf											
Dwarf Green	98	35	0.3571	7	0.0714	-	-	-	-	6	0.0612
Dwarf Orange	192	43	0.2239	7	0.0364	-	-	-	-	9	0.0469
Dwarf Yellow	351	103	0.2934	15	0.0427	-	-	-	-	12	0.0342
	641	181	0.2837	29	0.0452	-	-	-	-	27	0.0421
Hybrid											
VHC-1	650	200	0.3076	17	0.0261	-	-	-	-	38	0.0585

Table 2. Frequency of lethals, semi-lethals and sub-vitals in tall, dwarfs and T x D hybrids

Tree/ T x D	No. of nuts	Ungerminated		Dead sprouts		Weak seedling	
		No.	Frequency	No.	Frequency	No.	Frequency
T21	41	4	0.0976	1	0.0244	2	0.0488
T21 x DG 60	17	4	0.2353	2	0.1176	2	0.1176
T21 x DG 50	18	2	0.1111	3	0.1667	2	0.1111
T21 x DG 18	27	4	0.1481	1	0.0370	2	0.0741
T23	61	4	0.0656	5	0.0819	5	0.0819
T23 x DG 60	14	1	0.0714	2	0.1429	3	0.2143
T23 x DG 50	21	-	-	1	0.0476	2	0.0952
T23 x DG 18	13	-	-	-	-	2	0.3330
T84	24	3	0.1364	1	0.1666	3	0.1364
T84 x DG 60	18	-	-	-	-	-	-
T84 x DG 50	12	1	0.0833	2	0.1667	-	-
T84 x DG 18	11	1	0.0909	-	-	-	-
T25	22	2	0.0909	2	0.1176	0	0.1176
T25 x DG 60	31	1	0.0323	3	0.0968	1	0.0323
T25 x DG 50	26	3	0.1154	2	0.0769	2	0.0769
T25 x DG 18	20	1	0.0500	2	0.1000	-	-

Viridis and albino were absent

Table 3. Frequency of lethals, semi-lethals and sub-vitals in tall and twin palms

Parents	No. of nuts sown	Ungerminated		Dead sprouts	
		No.	Frequency	No.	Frequency
T 167	56	13	0.2321	2	0.0357
T 169	16	3	0.1875	1	0.0625
T 21	47	6	0.1276	3	0.0627
T 23	61	4	0.0656	11	0.1803
T 84	24	3	0.1256	4	0.1667
T 25	22	2	0.0909	4	0.1818
T 112A	8	2	0.2500	2	0.2500
T 142	15	3	0.2000	-	0.0984
T 67	13	1	0.0769	-	-
T 65	14	5	0.3571	-	-
T 64	16	5	0.3125	-	-
T 98A	15	4	0.2667	1	0.0667
T 98B	10	5	0.5000	-	-
T 100A	6	2	0.3333	-	-
T 100B	7	-	0.0000	-	-
T 81A	9	1	0.1111	-	-
T 81B	10	6	0.6000	-	-

Table 4. Frequency of lethals, semi-lethals and sub-vitals in dwarf palms

Parents	No. of nuts sown	Ungerminated		Dead sprouts	
		No.	Frequency	No.	Frequency
CDG	40	20	0.4000	1	0.0250
CDO	40	12	0.3000	2	0.0500
DG 27	14	4	0.2852	-	-
	94	36	0.0383	3	0.0319

Table 5. Frequency of lethals, semi-lethals and sub-vitals in TxD hybrid nursery (n = 10,000)

Ungerminated		Dead sprouts		Weak seedlings		Xantha	
Number	Frequency	Number	Frequency	Number	Frequency	Number	Frequency
1205	0.1205	485	0.0485	2226	0.2226	1	0.0001

Centre (1) with one generation of random selection had the highest rate of abortion (0.1533). However, the dwarf types recorded higher rate of abortion irrespective of Orange, Yellow or Green. Existence of recessive genes with lethal effect under homozygosity or on fixation is assumed. These genes are concealed and maintained by tall, dwarf and hybrid palms, in heterozygosity.

The phenomenon of the premature death of the embryo at early development and growth resulting in dead sprouts without any symptom of pests or diseases was observed in all palms irrespective of variety, centre or generation of selection. Talls from the five different centres exhibited no marked reductions irrespective of the number of generations of directed selection (0.0188). However, it was very much reduced in centre (2). The rate of premature death was almost four-fold in dwarf (0.0452). Hybrids showed a rate almost double that of the talls (0.0261).

The delayed death observed after specific development and growth is only suggestive of the fact that yet another pair of alleles in homozygosity are involved with pleiotropic effects on the various developmental or growth activities. This gene is also carried in balanced lethal form and eliminated as and when it is fixed.

Chlorophyll deficiency was absent in dwarf and hybrid seedlings. Among the talls, however, two distinct types of segregants for leaf colour viz., xantha and viridis were clear. Xantha type of chlorophyll deficiency ranged from zero to 0.0280, while viridis from zero to 0.0093. Highest frequency of viridis was observed in centre (1). This is only suggestive of the fact that in dwarfs the gene controlling chlorophyll has not undergone any visible mutation . In hybrids, as it is obvious the recessive from the tall is carried in balanced lethal form. In talls perhaps more than one loci are involved in controlling the chlorophyll colour or that the gene block is locked closely in linkage with other growth factors or located in inverted chromosome segments. This is assumed based on the fact that segregation for chlorophyll deficiencies is observed even in palms selected for one or more generations.

There is marked variation in the rate of sub-vitals or weak seedlings in variety tall representing centres and generation of selection. The type of seedling also varied with grades of vigour. Centres (2) and (3) had the least frequencies for the sub-vitals. Dwarfs and hybrids registered almost 100% increase over talls. The sub-vitals often linger for life with no reproductive ability. This may be due to more than one pair of alleles in balanced lethalism having pleiotropism over many developmental and growth factors.

The very fact that the various types of segregants representing fixation of genes under different grades and rates are being carried by selected healthy and high yielding palms suggests that these genes when held in heterozygosity have positive and negative pleiotropic effects.

Experiment II

The frequencies of lethals, semi-lethals and sub-vitals were scored on four specific and high yielding palms of variety tall (T 21, T 23, T 84, T 25) and their hybrids in combination with dwarfs of three colour types (Table 2).

In parent palm T 84 abortion of embryo was the highest (0.1364). Among the hybrid combinations, the frequency of abortion was the highest wherever Dwarf Green 60 was used as pollen parent. The frequency ranged from 0.032 (T 25 x DG 60) to 0.2353 (T 21 x DG 60).

The dead sprout was highest (0.1667) in T 21 x DG 50 and lowest (0.0370) in T 21 x DG 18. Frequency of dead sprouts was, however, higher among the hybrids than the female parents observed. Semi-lethals like chlorophyll mutant were the least in the parents. Hybrids failed to reveal any type of chlorophyll deficiency (0.0164). The absence of chlorophyll deficiency in other parents may indicate either the absence of balanced lethalism or that the population scored is too small for the purpose. Hybrids exhibited no chlorophyll deficiency as dwarfs are assumed to carry the wild genes for chlorophyll which confirmed the assumption that in the hybrids the lethal effects are masked by the normal gene.

Among the parent palms, overall mean for the dead sprouts was 0.0608, while it ranged from 0.0488 (T 21) to 0.1364 (T 84). Among the hybrids, the values for dead sprout were the highest in combinations where DG 50 was involved as male. The frequency was the least in combinations involving DG 18 as male. Tall 84, however, failed to produce any dead sprouts with DG 60 or DG 18.

Though production of sub-vital (weak seedling) was observed in all the parent palms and hybrids, T 84 failed to produce sub-vitals in all the three combinations. This is suggestive of the fact that the gene for sub-vital trait is absent in T 84.

Chlorophyll deficiency was absent in the hybrids. However, parent palm T 23 recorded xantha type chlorophyll deficiency with 0.0164 frequency.

Experiment III

Lethals, semi-lethals and sub-vitals, were observed in tall palms of random selection from a large segregating population, twin palms with low, medium and high yield potential and a large number of hybrid nuts from tall palms of one generation selection (Table 3).

Chlorophyll deficiency of any kind or grade was absent in the entire population. The absence of segregation for chlorophyll deficiency among the normall tall and twins, may be that the balanced lethalism was absent in the materials observed. It is also possible that the population is too tiny for the purpose. The fact that segregation for abortion is absent in both the twinlets, is only indicative of that the particular twinlet claims its origin to the fraternal type. It is also possible that the twinlets developed from two different eyes of the nut.

The three dwarf types studied from Chowghat region of Kerala recorded very high frequency for embryo abortion (Table 4) ranging from 0.2852 to 0.4000. This only confirms the fact that balanced lethalism for this gene and the rate of fixation are high in dwarfs.

A large population of 10,000 hybrid nuts (Tall x Dwarf Green) observed indicated that abortion, premature death of young sprouts and weak seedlings are exhibited in hybrids also (Table 5). The frequency of chlorophyll mutant was extremely low (0.0001). The appearance of the chlorophyll deficiency, hitherto never observed in the hybrid.

Elimination of the deleterious gene by fixation in dwarfs, appears to be with a higher frequency. The abortion observed in almost all the materials with high rate, only tempts to suggest that lethality of this type is brought about by a single pair of recessive genes. The absence of 3:1 type of segregation may be due to the deviation brought about by tight linkage or inversion.

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SEASONAL VARIATION IN FLORAL CHARACTERS OF T x CDO COCONUT HYBRIDS

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Abstract: The floral characters of 69 WCT x CDO coconut hybrid trees maintained in the KADP farm of the Kerala Agricultural University, Vellanikkara were observed continuously for a period of one year from 15th October, 1985. These trees belonged to 14 parental combinations involving three male and 14 female parents. Observations were taken on the number of spadices, number of female flowers, number of buttons set and pollen fertility and viability in every standard week during the period of one year. Spadix production initiated in January and increased gradually reaching a peak in the middle of March. Thereafter, it decreased sharply and attained zero by the month of October. Female flower production also had a similar trend. Button setting exhibited a uniform trend for the whole year, ranging from 30 to 47 per cent except in the last week of June when it was only 1.8 per cent, possibly, due to the heavy rains prevailed during this period. A high setting percentage was observed during August, September and October due to the favourable weather. The pollen fertility and viability were very high throughout the year except in the months of April and May. The trends observed in respect of different characters were discussed in relation to the ambient weather factors.

INTRODUCTION

Weather is known to play a very important role in the growth and yield of any crop and coconut is not an exception. Hence a knowledge of the pattern of variation in the various economic parameters of the crop as a result of the influence of weather elements helps its good management. Performance of coconut in different months of the year due to ambient weather conditions has been reported by a few workers. However, attempts to unravel the intrinsic influence of weather on coconut hybrids are very rare. Marechal (1928) reported high female flower production in dwarf palms during November to March in Fiji. Patel (1938) reported very low spadix production during the period from October to January and high spadix production in March in West Coast Tall palms at Nileswar. Similarly, female flower (button) production was reported to be high during March to May and low during September to January. Bhaskaran and Leela (1983) observed that the coconut hybrids are highly sensitive to temperature and seasonal rains. They reported high button production in hot weather period and high button setting during north east monsoon for T x D hybrids. An attempt is made herein to find out the consequences of weather prevailing during seasons on the manifestation of the different floral characters in a set of WCT x CDO coconut hybrids maintained under rainfed conditions.

MATERIALS AND METHODS

Sixtynine WCT x CDO F_1 coconut hybrids belonging to 14 parental combinations involving three pollen parents and 14 distinct mother palms of WCT formed the material for this investigation. All these plants were selected from a trial on 'Fixing up selection criteria for hybrid varieties' using T x CDO and T x G populations which were planted in 1978 at the KADP farm of the College of Horticulture, Vellanikkara, Trichur and were in regular flowering at the time of experimentation. Observations on the various floral characters were made con-

Table 1. Distribution of floral characters by standard week

Week		No. of spadices opened	No. of female flowers	No. of spadices having female phase	No. of receptive female flowers	No. of buttons set	Percentage of buttons set	Fertility %	Viability %
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Oct. 15 to Dec. 31		-	-	-	-	-	-	-	-
Jan.	1-7	1	63	-	-	-	-	-	-
	8-14	1	18	-	-	-	-	98.76	85.26
	15-21	2	74	-	-	-	-	99.64	91.88
	22-28	2	155	2	81	0	0.00	95.34	87.06
Feb.	29-4	11	398	0	0	0	0.00	97.07	87.21
	5-11	13	530	2	74	4	5.41	96.49	89.62
	12-18	17	703	2	155	12	7.74	97.50	92.07
	19-25	18	548	12	447	46	10.29	97.23	88.87
Mar.	26-4	18	729	9	420	49	11.67	98.34	87.49
	5-11	10	341	17	779	86	11.04	97.74	79.35
	12-18	29	978	19	616	77	12.50	97.77	94.66
	19-25	19	485	13	644	60	9.32	96.54	84.07
	26-1	19	622	8	279	29	10.39	94.60	72.48
Aprl.	2-8	21	642	28	1042	125	12.00	60.50	0.00
	9-15	20	645	17	545	78	14.31	66.00	0.00
	16-22	16	437	18	559	70	12.52	66.10	0.00
	23-29	23	741	15	563	69	12.26	65.00	0.00
May	30-6	13	265	23	777	166	21.36	64.80	0.00
	7-13	12	225	9	305	45	14.75	64.50	0.00
	14-20	15	493	21	762	181	23.75	63.80	0.00
	21-27	20	507	8	198	74	37.37	80.90	0.00
Jun.	28-3	15	331	12	273	68	24.91	92.00	31.00
	4-10	7	168	14	499	107	21.44	97.90	80.00
	11-17	8	211	15	449	91	20.27		
	18-24	7	165	14	341	34	9.97		
Jul.	25-1	14	314	5	111	2	1.80		
	2-8	4	95	8	221	35	15.84	98.14	89.00
	9-15	7	182	6	140	18	12.86	98.10	88.50
	16-22	14	273	12	271	36	13.28	97.80	87.80
	23-29	10	216	3	80	14	17.50	98.20	90.50
Aug.	30-5	7	173	7	182	38	20.88	98.40	89.90
	6-12	13	285	12	260	49	18.85	97.30	85.90
	13-19	6	124	9	187	85	45.45	96.79	83.83
	20-26	7	177	7	173	52	30.06	97.10	85.50
Sep.	27-2	15	310	8	175	63	36.00	95.70	87.60
	3-9	9	199	12	260	98	37.69	97.40	88.00
	10-16	3	52	9	214	79	36.92	98.00	87.90
	17-23	9	196	14	291	114	39.18	98.20	88.60
	24-31	6	116	7	155	61	39.35	97.50	85.50
Oct.	1-7	-	-	4	78	37	47.44	97.9	84.10
	8-14	-	-	8	17	-	-	98.00	87.20

Fertility and viability of pollen could not be determined from 11th June to 1st July due to heavy rain tinuously for a period of one year from 15th October 1985. The study period of one year was divided into 52 standard weeks. Important floral characters were compiled and tabulated for each standard week. Three week moving averages were obtained to have a better understanding of the trend for production of spadices, female flower production, number and percentage of buttons set and fertility and viability of pollen. Fertility of pollen was studied by staining freshly collected pollen in 2% acetocarmine. Sucrose solution (25%) was used as medium for testing pollen viability. Meteorological data for the standard weeks were obtained from the Department of Agrometeorology, College of Horticulture.

RESULTS AND DISCUSSION

The number of spadices, female flowers produced, spadices in active female phase and the corresponding number and percentage of buttons set, pollen fertility and viability during the different standard weeks of the study period of one year are furnished in Table 1.

In the experimental palms, opening of spathes was almost absent from October to December during the course of the investigation. Spadix emergence was observed to commence by early January and it gradually increased reaching a peak in the middle of March with a total of 29 spadices in the population studied during the standard week from 12th to 18th March. Thereafter the production decreased slowly and attained zero by the next October. This is in general agreement with the findings of Patel (1938) who observed that the number of bunches opened was maximum during the month of March at Nileshwar-1 and in April at Kasaragod. The number of bunches was very low from October to January at both the places. They reported a relatively high rate of abortion of spadices that were to open during the rainy months and this was attributed to the drought at the time of formation of bunches. Bhaskaran and Leela (1983) also obtained similar results in tall and dwarf varieties and reported that abortion of spadix occurred mostly during the south-west monsoon. Spadix abortion was the lowest during the period during October and November when hot weather prevailed in the present study.

Female flower production also showed a similar trend as spadix production. More of female flowers were produced during the months of February, March, April and May and a maximum of 978 was recorded in the experimental trees during the period from 12th to 18th of March whereas the minimum production was 18 recorded during 8th to 14th January (Table 1.). No spadix was produced in any of the selected palms from 15th October to 31st of December 1985. These observations are in agreement with those made by Patel (1938) and Bhaskaran and Leela (1983). According to the former, production of female flowers in the WCT variety was low from September to January and high during March to May at Kasaragod. The low production in September to January is probably due to the adverse effects of the weather conditions prevailing at the time of differentiation of the ovary and the perianth from the primordium of the female flower which takes place about six to seven months prior to the opening of the spathe. In other words, the first differentiation of the ovary in the spadices which are to open during February to June takes place in the rainy months. On the contrary, differentiation of the ovaries of the spadices that open during August to December when production of female flowers is generally low, takes place during the dry months of February to June (Menon and Pandalai, 1960). Bhaskaran and Leela (1983) also observed similar pattern for female flower production. They reported that 50 per cent of the annual female flower production was accounted for in hot weather period.

Setting of buttons in inflorescences having active female phase during the course of the investigations exhibited a uniform trend - the values ranged from 30 to 47 per cent except in the last week of June, when it was only 1.8 per cent which possibly could be due to the undesirable consequences of heavy rains (328 mm) experienced during this period which in turn affected normal pollination. High setting percentages observed during August, September and October must be due to the favourable climatic conditions especially the absence of moisture stress in the soil. A set of favourable factors like a temperature range between 22°C and 30°C, relative humidity which remained at about 90 in the FN and between 60 and 80% in the AN and a good temperature regime was prevailing during these months.

Pollen fertility appeared to be the least influenced by seasonal variations. It was above 90 per cent in all standard weeks except in the summer months of April and May during which season the fertility was between 60 and 70 per cent. The decrease in fertility could be due to the effect of a relatively high temperature that prevailed and/or due to greater moisture stress in the soil as reported by Stanley and Linsken (1974). Pollen viability also had the same trend keeping a level above 80 per cent for most of the study period, but was totally inviable in summer months. A moderately high level of button setting not withstanding low pollen fertility and total pollen inviability during the summer season is difficult to explain and needs further study. However, the possibility of pollination and fertilization during early hours of the day when the temperature was not too high to be detrimental to pollen germination, cannot be ruled out.

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YIELD COMPONENTS IN COCONUT PALMS

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Abstract: A study on the morphological and chemical components of yield in coconut palms was conducted at the College of Horticulture, Vellanikkara, in order to characterize different yield groups based on these components, with a view of utilizing the information for identification of potential yielders.

Twenty coconut palms each under low, medium and high yield groups (<40 nuts/palm/year, 40-80 nuts/palm/year and >80 nuts/palm/year respectively) were selected for the study. Observations on morphological characters, mineral nutrients and biochemical constituents were recorded and correlated with yield. There was significant positive correlation for the total number of leaves retained by the palm (0.693**) and length of leaves (0.675**) with yield. Among the mineral nutrients analysed nitrogen and potassium content in leaves had significant positive correlation with yield (0.417** and 0.614**). Significant positive correlation between total chlorophyll content and yield (0.631**), soluble sugars and yield (0.364**) could also be observed. The total phenolic constituents exhibited a negative correlation with yield (-0.553**). There was marked direct effect for leaf length, potassium content and chlorophyll content on yield. Yield prediction model using these characters with 74 per cent efficiency could be proposed.

INTRODUCTION

Crop improvement programme in perennial crops like coconut is a time consuming process. The long bearing period of the crop necessitates formulation of criteria for selecting promising material. The over all growth and vigour of the palms can be assessed from the morphological characters. Information on the causal mechanism at the cellular level will be of immense use in explaining the effects brought about by different plant characteristics. Biochemical parameters may also be utilized for identifying potential yielders, if definite relationship between the yield and such characters could be established.

Earlier studies conducted in coconut palms have revealed that the length of stem, number of leaves, length of leaves, number of leaflets and the number of flowers per bunch are correlated to yield (Satyabalan *et al.*, 1972, Abeywardena, 1976). Association between foliar nutrient status and yield has been reported by many workers (Indirakutty and Pandalai, 1968; Devi and Pandalai, 1968; Gopi and Jose, 1983). A fairly high degree of correlation between chlorophyll content of leaf and yield had also been reported (Mathew and Ramadasan, 1975). Identifying such plant characteristics which can provide reliable indication towards the yield potential of palms will be useful in breeding programmes. The study outlined here was conducted to characterize yield, based on morphological parameters, foliar nutrient status and biochemical constituents.

MATERIALS AND METHODS

Coconut palms cv. West Coast Tall, grown at the Agricultural Research Station, Mannuthy were selected based on their yield for 5 years and grouped into low yielders (<40 nuts/palm/year), medium yielders (40-80 nuts/palm/year), and high yielders (>80 nuts/palm/year). Twenty palms from each group were selected for the study.

Table 1. Biometric, mineral and organic constituents and their correlation with yield (Mean values from 20 palms under each group)

Particulars	Low yield group	Medium yield group	High yield group	Correlation coefficient (r)
No. of leaves	27.00	34.29	35.59	0.693**
Length of leaves (m)	4.49	5.27	5.26	0.675**
Length of petiole (m)	1.08	1.27	1.26	0.497**
No. of leaflets	208.80	237.50	237.65	-0.431**
Length of leaflets (cm)	87.16	93.65	88.77	0.094
Periodicity of leaf emergence (days)	32.39	28.40	28.29	0.499**
Girth at collar (cm)	66.15	77.25	75.90	0.508**
Total N in leaf (%)	1.65	1.78	1.96	0.417**
P in leaf (%)	0.187	0.199	0.202	0.192
K in leaf (%)	1.322	1.629	1.622	0.614**
Ca in leaf (%)	0.406	0.407	0.387	-0.017
Mg in leaf (%)	0.182	0.200	0.178	-0.042
Soluble sugar in leaf (%)	0.917	0.955	1.038	0.364**
Starch in leaf (%)	1.029	0.920	0.946	0.120
Total phenolic compounds in leaf (%)	2.850	1.923	1.926	-0.553**
Total chlorophyll (mg/g)	2.206	2.825	2.902	0.637**

** Significant at 1% level

Table 2. Partial regression coefficients for yield on selected characters

Characters	Regression coefficient βi	Standard deviation SE βi	t
Number of leaves	0.634	0.236	26.909**
Length of leaves	15.220	0.610	20.596**
Nitrogen content in leaf	11.798	0.794	2.964**
Potassium content in leaf	32.298	1.237	6.168**
Chlorophyll content in leaf	14.399	0.699	14.857**
Total phenolic constituents	-1.468	0.495	2.691**
Soluble sugars in leaf	6.432	1.043	24.258**
$R^2 = 0.736$			

** Significant at 1% level

Table 3. Direct and indirect effects of selected characters on yield

Characters	K	Chlor-ophyll	Total phenols	Soluble sugars	N	No. of leaves	Length of leaves	Total (r)
K	*0.289*	0.092	0.017	0.012	0.042	0.061	0.102	0.614
Chlorophyll	0.104	*0.254*	0.017	0.022	0.023	0.076	0.140	0.637
Total phenols	-0.155	-0.123	*0.036*	-0.015	-0.033	-0.072	-0.138	-0.553
Soluble sugars	0.055	0.088	0.009	*0.062*	0.025	0.094	0.095	0.364
N	0.082	0.039	0.002	0.010	*0.148*	0.039	0.090	0.416
No. of leaves	0.141	0.156	0.020	0.015	0.046	*0.124*	0.188	0.692
Length of leaves	0.097	0.117	0.016	0.019	0.044	0.077	*0.304*	0.674

Direct effects are denoted in italics

Observations on the total number of leaves retained by the palm, periodicity of leaf emergence, length of leaves, length of petiole, number of leaflets, length of leaflets and the collar girth were recorded. Samples collected from the 14th fully opened leaf were used for estimation of total nitrogen, phosphorus, potassium, calcium and magnesium content using standard methods. Solube sugars and starch present in the leaf samples were estimated by anthrone method. Total phenolic constituents were estimated as suggestd by AOAC (1970). Chlorophyll content was estimated in fresh leaf samples by recording differential absorptivity of extracts. Correlation coefficients were worked out between yield and the characters under study. Yield prediction model was formulated based on regression analysis.

RESULTS AND DISCUSSION

Among the morphological characters studied, the number of leaves retained by the palm, length of leaves, length of petiole, number of leaflets per leaf and the girth of stem at collar region had positive correlation with yield. The periodicity of leaf emergence, computed in terms of number of days elapsed between two successive leaf emergences, had a negative correlation with yield. Foliar nitrogen and potassium status showed positive correlation while phosphorus, calcium and magnesium contents did not indicate any definite relationship. The yield was significantly correlated to solube sugars present in leaves. Starch content in the samples did not show any definite relationship. The total phenolic constituents exhibited a negative correlation while chlorophyll content had a positive correlation with yield.

The number of leaves retained by the palm is considered to be a marker for growth and vigour of the palm. The total dry matter accumulation by the palm can mostly be manifested from the production of nuts and leaves, as the annual increment in length and girth of stem is only marginal. The number of leaves and dry matter accumulation are two mutually reciprocating characters one enhancing the other. The path coefficient analysis had indicated that the number of leaves contributes to the yield indirectly. The leaf length, chlorophyll and potassium levels are the most important paramaters through which the effect is manifested. The increase in photosynthetic area and synthesising capacity are reflected on yield.

The nitrogen and potassium status in leaves were found to bear significant positive correlation with yield. The nitrogen status is known to be associated with production of female flowers and rate of production of flower bunches. The higher level of nitrogen observed in medium and high yielding palms may be attributed to the difference in the ability of palms to absorb the nutrients from soil which results from genetically controlled factors. The path coefficient analysis indicates that the direct effect of nitrogen on yield is most pronounced. Foliar potassium levels in different yield groups were also found to bear significant positive correlation with yield. Coconut palm is considered to be a luxuriant feeder of potassium which has a prominent role on flower production and nut development. It is also important for the synthesis of chlorophyll. The marked direct effect of potassium on yield shows that this could be a major limiting factor in the low yielding palms. The status of other elements like phosphorus, calcium and and magnesium in leaves could not indicate any definite relation with yield.

The soluble sugar content in leaf samples had shown that it is significantly correlated with yield. Being the immediate product of photosynthesis, this may indicate that the high yielding palms had better synthesising capacity. The direct effect of solube sugars on yield was not marked. Being the primary product of synthetic process, it must undergo various metabolic changes before the over all effect is manifested on yield. Starch content in the leaf samples did not indicate any definite pattern of variation. The significant negative correlation observed between total phenolic constituents and yield may be considered as a marker for efficient partition of metabolites in high yielding palms. In the low yielding palms, a major portion of the products of synthesis is used for regulatory functions. The efficiency of photosynthetic process could be gauged from the chlorophyll content in the leaves. This is further stressed by the direct effect of chlorophyll on yields.

Based on the statistical analysis, yield prediction models could be formulated using the eleven characters which were positively correlated to yield. The coefficient of multiple determination (R^2) was 0.747 when eleven characters were used in the model as shown below:

$$y = -254.84 + 33.2\ K + 14.1\ C - 0.978\ P + 4.872\ S + 10.953\ N + 0.97\ LN + 14.643\ LL + 25.204\ LP + 0.0463\ LLN + 0.32\ f - 0.555\ G$$

(where K = potassium (%); C = chlorophyll (mg/g); P = phenols (%), S = soluble sugars (%), N = total nitrogen (%); LN = number of leaves; LL = length of leaves; LP = length of petiole; LLN = number of leaflets; f = periodicity of leaf emergence (days) and G = girth at collar).

Almost the same level of efficiency could be achieved when the seven apparently prominent characters were used (R^2 = 0.736). Thus, it could be concluded that the relative contribution of four characters i.e., petiole length, number of leaflets, periodicity of leaf emergence and girth at collar region, was only 1.1 per cent. Expected yield from the palm could be predicted using the model

$$y = -144.575 + 32.298\ K + 14.399\ C - 1.468\ P + 6.432\ S + 11.798\ N + 0.634\ LN + 15.22\ LL$$

The above model can be used for forecasting the expected yield with known values of the yield components.

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INFLUENCE OF SEEDNUT CHARACTERS ON SEEDLING VIGOUR IN COCONUT

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Abstract: Seednuts collected from ten super-mother palms and six sets of ordinary mother palms of WCT variety selected from five different locations of southern districts of Kerala were sown in replicated progeny trial. Mother palm, seednut and seedling characters were observed and their inter-correlations and correlations with seedling vigour index were worked out following standard methods. The number of leaves in mother palms showed positive correlation with number of bunches whereas number of nuts per bunch showed negative correlation with most of the important nut and seedling characters. The over all seedling vigour index is positively and significantly correlated to important seednut characters. All the growth parameters of seedling showed significant positive correlation with recovery of quality seedlings. These results justify the procedure of balancing the number and size of nuts in selecting mother palms to ensure the production of more number of quality seedlings than selecting purely on the basis of number of nuts per tree. From the study of linear relationship between seedling vigour index and seednut characters and the relative position of each mother tree under investigation about respective regression lines, it has been concluded that while selecting mother trees, more emphasis has to be given to weight of husked nut and meat.

INTRODUCTION

Coconut (*Cocos nucifera* L.) one of the nature's greatest gifts to man, is beset with many unique breeding problems. According to Nambiar and Nambiar (1970) and Satyabalan and Mathew (1976) the study of the relationship of early growth features of this crop, with adult performance would help us in identifying prepotent mother palms. As a part of the larger programme of identifying such prepotent palms through seedling progeny analysis, the present study aims at assessing the influence of seednut charcters on seedling vigour in coconut.

MATERIALS AND METHODS

In the present study seedling progeny analysis was conducted in super-mother palms of coconut with annual yield of not less than 300 nuts per tree. These were compared with control mother palms (average mother palms with annual yield of not less than 80 nuts per tree). Ten super-palms (Nos 1 to 10) were selected from five different locations in Trivandrum and Quilon districts of Kerala State. Five groups of control mother palms (Nos 11 to 15) each consisting of five trees representing a location from where a super-palm was selected were also included in the study. In addition to these five control groups a general control (No.16) comprising of random samples of 70 seednuts collected by the Department of Agriculture, Kerala State from the seed procurement belt in North Kerala (Badagara) was also included. Seednuts were collected separately from each super-palm and collected in bulk from each group of control mother palms. Thus there were altogether 16 lots of seednuts. Each lot comprised 60 to 70 seednuts after rejecting malformed and barren nuts.

Random samples of five nuts were drawn from each seed lot and subjected to fruit component analysis. The rest of the seednuts were sown in the nursery

Table 1. Coefficients of simple correlation between mother palm, seednut and seedling characters

Sl.No. of characters	r	Sl.No. of characters	r
1 x 2	0.535*	6 x 13	0.696*
1 x 8	0.668**	6 x 15	0.553*
3 x 9	-0.580**	6 x 16	0.758**
4 x 5	0.842**	9 x 10	0.770**
4 x 6	0.824**	9 x 11	0.830**
4 x 9	0.640**	9 x 12	0.774**
4 x 10	0.553*	9 x 13	0.767**
4 x 11	0.582*	9 x 16	0.938**
4 x 13	0.604*	10 x 11	0.862**
4 x 15	0.608*	10 x 12	0.840**
4 x 16	0.801**	10 x 13	0.899**
5 x 6	0.966**	10 x 14	0.620**
5 x 8	0.795**	10 x 16	0.801**
5 x 9	0.733**	11 x 12	0.936**
5 x 10	0.684**	11 x 13	0.960**
5 x 11	0.746**	11 x 14	0.626**
5 x 12	0.666**	11 x 16	0.860**
5 x 13	0.805**	12 x 13	0.944**
5 x 14	0.573*	12 x 14	0.544*
5 x 15	0.568*	12 x 16	0.739**
5 x 16	0.867**	13 x 14	0.669**
6 x 9	0.633**	13 x 16	0.829**
6 x 10	0.575*	14 x 15	0.572*
6 x 11	0.614*	14 x 16	0.612*
6 x 12	0.552*		

* Significant at 0.05 level; ** Significant at 0.01 level

The characters are 1. No. of leaves 2. No. of bunches 3. No. of nuts/bunch 4. Wt. of unhusked nut 5. Wt. of husked nut 6. Wt. of meat 7. Thickness of meat 8. Diameter of eye 9. Germination % 10. Height of seedling 11. Girth at collar 12. No. of leaves (seedling) 13. Leaf area 14. Age at leaf splitting 15. % of quality seedlings to total seedlings 16. % of quality seedlings to total seednuts

in RBD with 16 treatments and three replications. There were 20 seedlings in each plot. Seednuts were sown in raised beds of 2.25 x 7.20 m giving a spacing of 45 x 45 cm. Nuts were vertically sown in furrows sprinkled with sand and 5% BHC dust.

Number of leaves, number of spadices, number of bunches and number of nuts per bunch were recorded for mother palms. The fruit component characters recorded for nuts were weight of unhusked nut, weight of husked nut, weight of meat and diameter of eye. Germination per cent at sixth month of sowing, seedling height, girth at collar, number of leaves, leaf area and age at leaf splitting were recorded for the seedlings. Correlations between mother palms, seednuts and seedling characters and between mother palm and seedling vigour index were worked out. Seedling vigour index was worked out based on index scoring method using mean and standard deviation of the six seedling characters. Simple linear regression equations were developed between seednut characters and seedling vigour index which were found to have positive and significant correlation.

RESULTS AND DISCUSSION

The number of bunches per tree failed to show significant correlation with any other characters studied except number of leaves per tree (Table 1). The increase in number of leaves usually show corresponding increase in bunch number also (Menon and Pandalai, 1958). Number of nuts per bunch showed negative correlation with weight of unhusked nut, husked nut, meat, germination, growth of seedlings and recovery of quality seedlings from total number of nuts sown.

Weight of unhusked nut showed significant positive correlation with weight of husked nut, meat, germination of nut, seedling height, girth at collar, leaf area and percentage recovery of quality seedlings from total number of seedlings as well as seednut sown.

Weight of husked nut exhibited very high positive correlation with weight of meat, diameter of eye, germination of nut, seedling height, girth at collar, number of leaves, leaf area, age at leaf splitting and percentage recovery of quality seedlings from total number of seedlings and seednuts. Weight of meat also showed similar correlation with all seedling characters and recovery of quality seedlings.

Meat thickness and eye diameter failed to show significant correlation with any seedling characters. Seednut germination showed significant positive correlation with seedling height, girth at collar, number of leaves, leaf area and percentage recovery of quality seedlings from total number of seednuts sown.

Seedling height, girth at collar and number of leaves showed significant positive correlation with each other and with leaf area, age at leaf splitting and quality seedling recovery percentage. Positive correlations were obtained between height and girth at collar of seedlings by Pankajakshan and George (1961). Ramadasan *et al.* (1980) also obtained significant positive correlations among seedling height, girth at collar, number of leaves and leaf area.

Leaf area and age at leaf splitting showed significant positive correlations with each other and with recovery percentage of quality seedlings.

Simple intercorrelations between mother palm and seednut character with seedling vigour index are presented in Table 2. The results show that seedling vigour index is significantly and positively correlated with weight of unhusked nut, husked nut and meat. The significant positive correlations of seednut characters with seedling characters indicate the importance of seednut charcters in selecting mother palms.

Table 2. Correlation coefficients (r) between mother palm and seednut characters with seedling vigour index

Character	Seedling vigour index
Mother palm characters	
Number of leaves	0.2543
Number of bunches	0.4404
Number of nuts per bunch	0.1614
Seednut characters	
Weight of unhusked nut	0.5110*
Weight of husked nut	0.5728*
Weight of meat	0.5475*
Thickness of meat	-0.0285
Diameter of eye	-0.0972

* Significant at 5 per cent level

This is further established by the significant positive correlation of these characters with seedling vigour index.

All the growth parameters of the seedlings showed significant positive correlation with recovery of quality seedlings which is the measure of prepotency. The seedling growth characters recorded higher correlation with seednut-to-quality seedling recovery percentage, thereby showing the reliability of this measure of prepotency. A similar response has been obtained between weight measurements on seednut and percentage of quality seedlings to total number of seednuts sown.

The correlation studies between mother palm and seednut characters with seedling vigour index (Table 2) show that selection of mother palms based on seednut character is a viable suggestion. These results suggest that, if selection of mother trees for higher weight of unhusked nut, husked nut and meat is practised, more vigorous seedlings can be obtained. Kannan and Nambiar (1979) observed that high and medium vigorous seedlings of high yielding palms equalled in their adult performance. The present study also justifies such a procedure of balancing the number and size of nuts in selecting mother palms to ensure the production of more number of quality (vigorous) seedlings than selecting purely on the basis of number of nuts. A selection procedure for mother palms tailored in this direction will help the plant breeder to identify prepotent palms with better efficiency.

The simple linear regression equations between seedling vigour index (Y) and three seednut characters viz., weight of unhusked nut (X_1), weight of husked nut (X_2) and weight of meat (X_3) with attached standard errors are $Y = 4.7585 + 0.0020\ X_1\ (0.0020 \pm 0.0009)$; $Y = 4.9008 + 0.0032\ X_2\ (0.0032 \pm 0.0012)$; $Y = 5.1731 + 0.0041\ X_3\ (0.0041 \pm 0.0017)$.

It can be seen that the mother palm T_4 is superior to the rest, by virtue of its isolated and elevated position above the respective regression lines. Observing super-palm T_4 alone, seedling vigour index is more related to weight of husked nut and meat. Hence it is derived that T_4 which produces seednuts with the highest weight of unhusked nut, husked nut and meat is sure to produce seedlings with highest vigour index as well. This conclusion proves that while selecting mother trees, more emphasis can be given to these three criteria and the average vigour index of seedlings produced from such trees can be predicted using these regression equations.

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HERITABILITY AND CORRELATIONS IN WEST COAST TALL COCONUT PALMS

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Abstract: Seednuts collected from ten super-mother palms and six sets of ordinary mother palms of West Coast Tall variety of coconut from southern districts of Kerala were sown in replicated progeny trial and seednut and seedling characters were observed. The heritability and coheritability (broad sense) of seednut and seedling characters and genotypic, phenotypic and environmental correlations between seedling character pairs were worked out following standard methods. Extremely high heritability estimate for weight of unhusked nut, husked nut and meat were obtained. Heritability estimates were medium to high for all the seedling characters. The coheritability for any two of these characters was also high. Highly significant positive genotypic correlations were obtained for most of the seedling character pairs, indicating predominance of additive gene action for the expression of those characters.

In a programme of breeding for improvement of the yield potential of a crop, information on the heritability and inter-relationship of yield and its component characters is of immense value. Liyanage and Sakai (1960) worked out the heritability and genetic correlations amongst four characters namely flowering period, yield of nuts, yield of copra and weight of husked nut in coconut. They found higher genetic progress in yield of copra and nuts compared to weight of husked nut and flowereing period. Sakai (1960) pointed out that values of heritability and the extent of genetic correlations differ with changes in environmental conditions. Only limited studies in this line were undertaken in West Coast Tall coconut. As part of the larger programme of identifying prepotent palms through seedling progeny analysis, the present study is aimed at assessing heritability and coheritability (broad sense) of seednut and seedling characters and genotypic, phenotypic and environmental correlations between seedling character pairs in selected WCT coconut palms.

The materials for the study consisted of 10 super-palms (palms yielding not less than 300 nuts per tree per year) selected from five different locations in Trivandrum and Quilon districts of Kerala. Five groups of control mother palms (palms yielding not less than 80 nuts per tree per year) each consisting of five trees representing a location from where a super-palm was selected, were also included in the study. In addition to these control groups, a general control comprising of random sample of 70 seednuts collected from the seed procurement belt in North Kerala (Badagara) was also included. Each seed lot comprised of 60-70 seednuts after rejecting malformed and barren nuts. Random samples of five nuts were drawn from each seed lot and subjected to fruit component analysis. The rest of the seednuts were sown in the nursery in 16 x 3 RBD with seednuts sown in raised beds of 2.25 x 7.20 m giving a spacing of 45 x 45 cm. Nuts were vertically sown in furrows sprinkled with sand and 5% BHC dust. The heritability (broad sense) estimates were computed for the analysis of variance table following the method of Henson *et al.* (1956). The coheritability and genotypic, phenotypic and environmental correlations between seedling characters were worked out from the respective ANOVA and ANCOVA tables following the methods of Al-jibouri *et al.* (1958) and Singh and Choudhari (1979).

Table 1. Heritability (in broad sense) of seednut characters

Seednut character	Heritability (%)
Weight of unhusked nut	92.50
Weight of husked nut	94.39
Weight of meat	90.32
Thickness of meat	34.15
Diameter of eye	74.53

Heritability estimates of weight of unhusked nut, husked nut, and meat were extremely high (Table 1). Similar results with reference to weight of husked nut and meat were obtained by Lakshmanachar (1959) and Liyanage and Sakai (1960). Diameter of eye also exhibited high heritability whereas thickness of meat registered a low heritability estimate. The high heritability values for most of these quantitative seednut characters indicate additive gene action in their expression. This result indirectly suggests the worthiness of selecting mother palms on the basis of these seednut characters.

Heritability estimates were medium to high for all the seedling characters. The coheritability estimates for any two of these characters were also high (Table 2). This indicates that the effect of environment is comparatively less on these characters and that selection for these characters will yield genetically superior and genuinely vigorous seedlings. The coheritability estimates are useful in predicting heritability of any character when selection is being practised for some other related character. Thus when coconut seedlings are selected on the basis of germination, the seedlings in the next generation will also show better height, girth, number of leaves, leaf area and age at leaf splitting.

Genotypic correlation was higher than phenotypic correlation for all characters (Table 3). Likewise, in all cases except one phenotypic correlation stood above environmental correlation. Only the environmental correlation coefficient of seedling height and number of leaves did exceed the corresponding phenotypic correlation coefficient. The age of leaf splitting registered a comparatively lower genotypic, phenotypic and environmental correlation with other characters.

High genotypic correlation between the seedling characters indicate the predominance of additive gene action governing the expression of these characters (Allard, 1960). The present results justify this conclusion by virtue of the presence of highly significant positive genotypic correlation between most of the seedling characters.

Table 2. Heritability and coheritability of seedling characters

Seedling character		Heritability	Coheritability				
			1	2	3	4	5
1	Germination	69.12	84.39	90.76	93.10	88.15	84.16
2	Height of seedling	62.62	–	73.29	75.84	72.16	66.39
3	Girth at collar	76.16	–	–	73.92	79.19	81.12
4	Number of leaves	65.23	–	–	–	79.15	81.38
5	Leaf area	76.24	–	–	–	–	70.89
6	Age at leaf splitting	63.25	–	–	–	–	–

Table 3. Genotypic (G), phenotypic (P) and environmental (E) correlation between seedling characters

Seedling character		2	3	4	5	6
1 Germination %	G	0.8732**	0.8758**	0.8799**	0.8082**	0.4304
	P	0.6807**	0.7002**	0.6347**	0.6656**	0.4325
	E	0.3128	0.2386	0.1253	0.2913	0.1855
2 Height of seedling	G		0.8948**	0.5648**	0.9286**	0.4067
	P		0.8441**	0.3042	0.8861**	0.3855
	E		0.7577**	0.5655**	0.8306**	0.4396
3 Girth at collar	G			0.7624**	0.9766**	0.5775*
	P			0.7269**	0.9403**	0.5285*
	E			0.6584**	0.8219**	0.3149
4 No. of leaves	G				0.9955**	0.5268*
	P					0.8869**
	E					0.6435**
5 Leaf area	G					0.5514*
	P					0.5460*
	E					0.5379*
6 Age at leaf splitting	G					-
	P					-
	E					-

* Significant at 0.05 level; ** Significant at 0.01 level

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COMPARING KOMADAN COCONUT TYPE WITH WEST COAST TALL

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Abstract: Komadan, a local coconut ecotype popular in parts of Pathanamthitta district of Kerala is compared with West Coast Tall (WCT) cultivar through estimation of mean and variance of mother palm, seednut and seedling characters. Forty Komadan palms available in the Instructional Farm, College of Agriculture, Vellayani, Trivandrum and fifty WCT palms of the same age group and belonging to the highest yield range available in the Coconut Research Station, Balaramapuram were used for the study. Ten seednuts collected from each palm were used for raising seedling progenies.

Of the seven mother palm characters studied Komadan palms were found superior in all characters except difference in nut yield between peak and lean harvests compared to WCT. In seednut characters, there was no difference between the two types. The Komadan type further exhibited superior seedling vigour in terms of number of days taken for sprout, height, collar girth and mean number of split leaves. The results indicate that Komadan is a superior coconut ecotype deserving further research attention.

'Komadan' is a local coconut type popular in the Central Travancore area of Kerala. The evolutionary status of Komadan type is still shrouded in mystery. A preliminary observation done on the available Komadan mother palms in the Instructional Farm, College of Agriculture, Vellayani, Trivandrum has indicated their superiority over ordinary West Coast Tall mother palms available there (Gopimony, 1982). This study also indicated the overlapping nature of male and female phase suggesting a self-pollinated breeding system in this coconut type. Local enquiries made at the centre of origin of Komadan revealed a curious process of shrewd selection for yield-linked phenotypic characters like bronze colour and oblong shape of nuts, vigour of seedlings as indicated by early arborial germination of seednuts, larger number of leaves, collar girth and height, bronze colour of leaf stalk etc., conducted for many generations by 'Komattu Tharavadu' of Thiruvalla leading to the development of the present Komadan type there. The present study was undertaken to verify this hypothesis of genetic superiority of Komadan over West Coast Tall.

Forty Komadan mother palms (25 years old) available at the Instructional Farm, College of Agriculture, Vellayani and 50 WCT mother palms of similar age and yield range available at the Coconut Research Station, Balaramapuram were used for the study. Seednuts collected from each of the above palms during the summer months of 1981 were used for seednut and seedling studies. Four hundred seednuts from Komadan and 500 from WCT were used for taking observations on seednut characters whereas 371 Komadan seedlings and 404 WCT seedlings were used for observing seedling characters.

The mean and standard deviations of seven mother palm characters in Komadan and WCT types and their corresponding 't' values for comparison of means are given in Table 1. Komadan mother palms were found significantly superior in girth of stem, number of fronds, number of bunches per palm,

Table 1. Mean data on mother palm characters in WCT and Komadan coconut types

Characters	West Coast Tall		Komadan		t-value
	Mean of 50 palms	SD	Mean of 40 palms	SD	
Girth of stem (cm)	77.1	8.63	75.0	6.45	6.05**
Number of fronds	28.6	2.87	32.0	5.68	11.25**
Number of bunches	13.6	2.89	17.0	3.27	3.85**
Number of female flowers per bunch	25.1	6.99	30.0	11.44	2.41*
Percentage of fruit set	32.1	10.60	39.5	10.02	19.47**
Annual nut yield	83.1	30.88	126.0	43.29	81.87**
Difference in nut yield between peak and lean harvests	22.6	12.86	23.0	10.11	1.08

* Significant at 0.05 level, ** Significant at 0.01 level

Table 2. Mean data on seednut and seedling characters in WCT and Komadan coconut types

Characters	West Coast Tall			Komadan			t-value
	Mean	Population size	SD	Mean	Population size	SD	
Fresh weight of seednut (kg)	1.37	500	0.32	1.41	400	0.31	0.80
Volume of seednut (l)	2.55	500	0.72	2.64	400	0.77	1.45
No. of days for sprouting	210.33	404	35.62	165.72	400	32.70	18.60**
Height of one year seedling (cm)	88.34	404	33.60	137.32	371	46.14	20.41**
Collar girth (cm)	10.02	404	1.58	12.92	371	2.40	19.33**
No. of split leaves in one year old seedling	0.29	404	0.61	1.11	371	1.14	12.05**

** Significant at 0.01 level

number of female flowers per spadix, percentage of fruit set and annual nut yield per palm. The mean annual nut yield of Komadan palm (126.0) was found to be more than that of WCT (83.1). The difference in nut yield between peak and lean harvests was found to be insignificant indicating homogeneity for this character in the two types.

The mean and standard deviations of two seednut characters and four seedling characters are given in Table 2. In seednut characters the two coconut types did not show any significant difference. But in the four seedling characters the Komadan type showed significant superiority over West Coast Tall.

Even though family-wise progeny analysis among the different mother palms of the two coconut types has not been attempted here the mean values of the total seedling progenies obtained from the two types clearly indicated the superior vigour of Komadan compared to West Coast Tall. Harland (1957) advocated seedling progeny performance for identifying superior coconut genotypes for nut yield. Ninan and Pankajakshan (1961) found that some high yielders showed markedly superior progeny performance than others. Liyanage (1967) reported a positive and significant correlation between number of leaves produced by the seedlings and the yield of copra at maturity. He felt that selecting seedlings on the basis of high leaf number was a quick method of isolating palms of high breeding value. When the results obtained from the present study are critically examined in the light of the above reports, the Komadan type as available at the Instructional Farm, College of Agriculture, Vellayani can be considered as a genetically superior ecotype compared to the best West Coast Tall genotypes available at the Coconut Research Station, Balaramapuram. Komadan deserves further research attention.

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EVALUATION OF CERTAIN COCONUT (*COCOS NUCIFERA* L.) HYBRIDS UNDER RAINFED CONDITIONS

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Abstract: Studies were conducted from 1973 to 1987 at the Regional Agricultural Research Station, Pilicode, on the performance of fifteen hybrids along with West Coast Tall as check variety. The study was conducted in laterite soil under rainfed conditions. All the T x D hybrids were superior to West Coast Tall in respect of all the economic characters studied. Among the hybrids, West Coast Tall x Malayan Dwarf Yellow and West Coast Tall x Chowghat Dwarf Green were superior in respect of leaf, nut and copra production. Maximum out-turn of copra per palm per annum was also recorded by these two hybrids.

Among the hybrids large number of variations were observed in almost all the characters studied. There was significant difference in mean number of cumulative leaf and nut production of the hybrids. T x D hybrids were found to perform better than D x T hybrids in mean number of nuts and leaf production.

Coconut hybrids have been reported to bear earlier and yield more number of nuts and higher copra than local cultivar, West Coast Tall. However, considerable variations occur in the progenies involving different parental combinations (Rajamony *et al.*, 1983). Among the six cultivars crossed with Gangabondam as pollen parent hybrid of Laccadive Ordinary was the best combination (Kannan and Nambiar, 1974). In laterite soil of Kasaragod under rainfed conditions, Chowghat Dwarf Orange x WCT was superior in yield of nuts and copra compared to WCT x CDO or WCT x Gangabondam (Satyabalan, 1982). The present study was taken up to find out the best hybrid combination in respect of economic characters under rainfed conditions.

Fifteen coconut hybrids of both T x D and D x T involving different talls and dwarfs of exotic as well as indigenous origin with WCT as a check, were planted at the Regional Agricultural Research Station, Pilicode during 1973. Planting was done in single palm plots with five replications in laterite soil, under rainfed conditions. Cultural and manurial practices were done as per the package of practice recommendations of the Kerala Agricultural University. Observations on 14 plant and nut characters were recorded. The percentage of oil in the copra of each nut was estimated by cold percolation method of Bhandari (1974).

Observations recorded on the various nut characters of the different hybrids showed wide variations (Table 1). Among the characters studied polar diameter of the nut and thickness of kernel varied significantly at 1% level. The maximum value of polar diameter was observed in Fiji x Gangabondam hybrid followed by WCT x Gangabondam (23.4 cm and 23.2 cm respectively). WCT x Malayan Dwarf Yellow recorded the lowest value, 18.9 cm. There was no significant difference among the hybrids in equatorial diameter of the nut. The value ranged from 17.7 cm in WCT x Strait Settlement to 15.4 cm in LO x CDO.

Cochin China x CDO recorded maximum value in weight of husked nut followed by Fiji x CDO (851.0 g and 813.9 g respectively). The hybrid WCT x MDY recorded the minimum value of

Table 1. Nut characters of different hybrid combinations of coconut

Hybrid/cultivar	Polar diameter (cm)	Equatorial diameter (cm)	Weight of nut (g)	Weight of husked nut (g)	Weight of opened nut (g)	Weight of shell (g)	Thickness of meat (cm)
WCT x CDO	20.2	16.2	980	649.3	452.8	154.2	1.36
CC x CDO	19.7	17.6	1262	851.0	623.3	176.3	1.30
AO x CDO	19.7	16.3	1154	757.8	571.9	175.8	1.19
LO x CDO	19.9	15.4	923	575.4	448.9	141.3	1.23
Fiji x CDO	20.5	17.3	1203	813.9	586.9	185.7	1.29
Fiji x GB	23.4	15.9	974	602.3	465.5	140.7	1.29
WCT x MDY	18.9	16.4	815	520.5	401.6	106.7	1.31
WCT x TBL	20.7	16.8	1216	637.0	571.4	164.6	1.32
WCT x SS	21.8	17.7	1092	693.7	514.9	155.9	1.30
WCT x CDG	21.0	16.6	1064	600.8	509.6	133.8	1.35
WCT	22.1	16.9	928	615.7	481.9	145.4	1.32
CDO x WCT	19.5	16.5	1109	777.5	564.3	167.0	1.25
CDO x LO	19.0	15.5	868	576.8	426.8	141.2	1.13
GB x LO	23.1	16.6	1088	622.4	462.5	145.7	1.17
WCT x LD	19.1	16.4	1026	655.7	490.6	158.4	1.19
WCT x GB	23.2	16.2	1084	595.9	470.5	139.6	1.31
F value	**	NS	NS	NS	*	NS	**
CD (0.05)	2.4	-	-	-	25.7	-	0.12

* Significant at 5% level, ** Significant at 1% level

520.5 g. In weight of opened nut the ranking was almost the same as for weight of husked nut and the differences were significant at 5% level. With regard to shell weight, Fiji x CDO with 185.7 g ranked first followed by Cochin China x CDO with 175.0 g. The lowest shell weight was recorded by the hybrid WCT x MDY (106.3 g). The nut characters presented in Table 1 indicated the medium performance of WCT cultivar which is the major cultivated type in Kerala, for almost all characters studied.

Mean growth and yield performance of different hybrids and WCT presented in Table 2 clearly show the superiority of T x D hybrids over the reciprocal cross and WCT. Among the T x D hybrids, WCT x MDY, WCT x CDG and WCT x CDO recorded maximum cumulative yield of nuts with 624.4, 614.5 and 504 nuts respectively. These three hybrids are on par and significantly differ from other hybrids. Based on the mean copra yield recorded up to 1987, WCT x MDY ranked first with 129.19 kg followed by WCT x CDG (126.04 kg), WCT x CDO (97.35 kg) and Fiji x CDO (93.16 kg). In the case of oil content maximum recovery of 67.11 per cent was from WCT x Gangabondam followed by WCT x MDY with 66.33 and WCT x CDO with 65.31 per cent.

Studies made so far on the performance of the 15 hybrids show that the two hybrids WCT x MDY and WCT x

Table 2. Mean growth and yield characters of different hybrids recorded during 1987

Hybrid/cultivar	Number of leaves			No. of nuts produced		Copra content (g)	Oil content (%)	Mean copra yield up to 1987 (kg)
	On the crown	Produced in 1987	Till date	In 1987	Till date			
WCT x CDO	32.4	13.6	159.4	131.6	504.0	193.2	65.31	97.35
CC x CDO	29.4	13.6	153.8	97.2	304.0	218.9	63.26	66.55
AO x CDO	29.4	12.6	156.6	109.2	361.4	184.1	61.44	66.54
LO x CDO	28.4	12.2	149.8	114.0	345.8	168.9	63.00	58.41
Fiji x CDO	29.0	12.2	159.0	114.8	420.6	221.5	62.82	93.16
Fiji x GB	29.0	13.8	158.2	81.4	285.5	186.2	64.15	53.21
WCT x MDY	31.4	12.8	156.8	177.2	624.4	206.9	66.33	129.19
WCT x TBL	29.2	12.4	157.6	121.0	387.2	211.3	62.21	81.80
WCT x SS	30.6	13.8	162.2	113.0	430.0	191.7	64.91	82.42
WCT x CDG	30.5	13.0	161.7	171.0	614.5	205.1	64.94	126.04
WCT	30.8	14.0	147.6	56.6	195.6	192.3	65.08	37.61
CDO x WCT	28.6	12.6	150.6	108.0	301.6	214.8	61.37	64.79
CDO x LO	26.2	11.0	144.6	52.2	198.6	167.5	63.53	33.26
GB x LO	29.4	12.8	155.4	104.0	357.2	173.5	62.28	61.97
WCT x LD	28.2	12.0	150.0	114.0	424.2	191.2	63.67	81.09
WCT x GB	35.2	14.6	162.8	78.6	362.0	179.6	67.11	65.03
CD (0.05)	3.86	NS	NS	46.88	169.70	NS	NS	

CDG are superior in respect of the production of nuts and copra followed by WCT x CDO and Fiji x CDO. Based on this study the four hybrids were selected for multilocational trial at five different research stations under the Kerala Agricultural University.

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Table 2. Distribution of seedlings based on vigour

Family	F_1 progeny No.	Mean* yield of nut	Total seedlings	Vigorous seedlings (%)	Medium seedlings (%)	Poor seedlings (%)
VIII/23	109	88.82	79	45.56	32.92	21.52
	112	94.82	64	57.82	34.37	7.81
	113	72.27	46	54.36	34.78	10.86
	114	72.73	42	69.06	23.80	7.14
	115	98.73	63	55.33	28.57	15.88
Mean				55.10	31.30	13.60
1/58	165	56.82	33	48.48	39.40	12.12
	167	71.09	50	58.00	30.00	12.00
	168	45.91	32	34.38	46.87	18.75
	169	70.18	54	35.18	50.00	14.82
	174	29.82	31	16.12	58.06	25.80
Mean				40.00	44.00	16.00
1/109	141	55.09	42	14.28	38.09	47.63
	142	76.64	52	42.30	46.15	11.55
	144	77.55	76	27.64	46.05	26.31
	146	66.27	35	57.14	42.86	-
	148	29.50	8	25.00	50.00	25.00
Mean				33.33	44.14	22.53
VIII/158	153	38.18	25	12.00	56.00	32.00
	155	71.18	16	31.25	50.00	18.75
	156	53.73	18	22.22	66.66	11.12
	159	72.81	30	53.34	36.66	10.00
	160	31.91	12	25.00	50.00	25.00
Mean				30.70	50.49	18.81
I/76	126	44.73	35	28.57	28.57	42.86
	128	62.36	24	20.84	54.16	25.00
	129	65.45	34	32.36	55.88	11.76
	135	83.55	54	55.56	29.62	14.82
	136	99.36	47	12.76	44.68	42.56
Mean				31.95	40.73	27.32
VIII/143	41	82.91	59	44.09	35.62	20.29
	49	87.36	76	35.52	44.73	19.75
	50	98.73	42	38.09	40.47	21.53
	52	36.27	33	21.22	39.39	39.39
	99	47.55	27	51.85	37.04	11.11
Mean				37.98	40.08	21.94

* Mean over ten years

nificant variation between families and between progenies of the same family. Total number of leaves produced also showed significant difference.

The seedlings obtained from each progeny were grouped into vigorous, medium and poor based on the collar girth, height and total number of leaves produced one year after sowing and the data on the percentage of seedlings coming under each group are presented in Table 2. Out of five progenies in each family the number of progenies which produced more than 50 per cent vigorous seedlings was four in VIII/23 and one each in the rest of the families.

The results revealed that the hybrid palms varied significantly in respect of production of vigorous seedlings irrespective of their yield. Though some of the high yielding palms produced more number of vigorous seedlings some others produced more number of poor seedlings. The same is the case with poor yielding palms. For instance, progeny number 136 which gave a mean annual yield of 99.36 nuts produced only 12.76 per cent vigorous seedlings, while progeny number 99 with an annual yield of 47.55 nuts produced as high as 51.85 per cent vigorous seedlings. It could be reasonably assumed from the results that while the high yielding palms could transmit their high yielding traits to their progenies in controlled pollination, the hybrids under open pollination need not necessarily transmit the same traits to their offsprings. If the seedling characters could be taken as criteria for their future performance, the capacity of the hybrid palms for production of high yielding progenies under open pollination would likely to be independent of the yield of hybrid palms. This is an indication of the highly heterozygous nature of the hybrids. The results are in conformity with the findings of Nambiar (1971) and Kannan (1976).

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CORRELATION AMONG FLORAL AND YIELD CHARACTERISTICS IN COCONUT, VARIETY DWARF GREEN

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Abstract: Correlation coefficients were worked out between floral and yield traits in coconut variety Dwarf Green. The nut yield was found to be significantly and positively correlated with number of spadices and duration of female phase whereas number of leaves produced and length of spadix exhibited significant positive correlation with number of spadices. It is therefore suggested that number of spadices and duration of female phase should be considered as selection criteria for nut yield improvement in coconut variety Dwarf Green.

Coconut (*Cocos nucifera* L.) is a highly cross pollinated crop, showing great variation in its yield potential. Possibly desirable variations can be utilized for better yield, which may be achieved through hybridization as well as selection. In recent years, there has been a good progress in coconut improvement by exploiting the genetic potential of T x D and D x T hybrids. A knowledge of the associations among floral characters, vegetative characters and yield of nuts is a prerequisite for any selection programme (Satyabalan *et al.* 1969). A study was, therefore, initiated on coconut variety Dwarf Green to estimate the extent of correlations between different quantitative characters and yield.

The experiment was conducted at the Plantation Crops Research Station, Gujarat Agricultural University, Mahuva. Thirty palms of the Dwarf Green cultivar of coconut were randomly selected out of 192 palms during 1984-85. All these palms had uniform growth and age (10 years). Detailed observations were recorded on 19 floral characters, vegetative characters and yield of individual palms. These characters were: number of leaves produced, interval between successive leaves produced, number of spadices produced, interval between successive spadices produced, number of open spadices, days to opening of spadix, i.e., interval between emergence to opening of spadix, interval between leaf and spadix produced, length of spadix, duration of female phase, duration of male phase, number of female flowers, number of female flowers having spikelets, number of female flowers per spadix, total fruit drop, fruit setting percentage, number of spikelets per spadix, length of spikelets, number of spikelets bearing female flowers and number of nuts per palm. Correlation coefficients were worked out between floral/vegetative and yield characters.

The nut yield was found to be significantly and positively correlated with number of spadix produced (0.400**), and duration of female phase (0.363*). However, a significant negative correlation (-0.498**) was apparent between yield and interval between leaf and spadix produced. The number of spadices exhibited a significant positive correlation with number of leaves produced (0.503**) and length of spadix (0.476**) while it had significant negative correlation with interval between spadix produced (-0.776**). The number of leaves produced showed significant negative correlation with total periodical

Table 1. Mean number of days for sprouting, collar girth, height and number of leaves produced by one year old F_2 progenies of T x D

Family	F_1 progeny No.	Mean number of days for sprouting	Collar girth (cm)	Height (cm)	Total leaves
1	2	3	4	5	6
VIII/23	109	121.07	8.64	92.00	5.58
	112	110.79	9.61	109.59	6.14
	113	107.65	9.51	109.53	6.02
	114	105.28	10.10	114.25	6.43
	115	103.43	9.19	99.39	6.06
Mean		109.64	9.41	104.95	6.03
1/58	165	89.67	9.26	95.25	5.42
	167	97.33	9.60	101.00	5.72
	168	105.62	9.08	87.00	5.40
	169	102.93	9.18	89.74	5.83
	174	108.50	8.87	99.75	5.13
Mean		100.80	9.20	94.55	5.50
1/109	141	107.34	7.54	73.88	5.19
	142	109.89	9.16	96.54	5.86
	144	110.21	8.58	86.98	5.56
	146	105.48	9.62	104.57	5.80
	148	126.11	8.76	82.53	5.75
Mean		111.81	8.73	88.90	5.63
VIII/158	153	100.44	8.01	77.54	4.96
	155	95.82	9.74	92.21	5.56
	156	100.05	8.71	86.72	5.06
	159	89.79	10.12	96.83	5.73
	160	96.07	8.28	87.54	5.50
Mean		96.43	8.97	88.17	5.36
1/76	126	112.51	8.27	75.85	5.44
	128	112.99	7.94	78.84	5.84
	129	101.58	9.28	94.30	5.74
	135	102.65	9.74	109.51	6.29
	136	111.92	7.75	71.71	5.09
Mean		108.33	8.60	86.06	5.68
VIII/143	41	120.73	8.65	90.38	5.58
	49	109.66	8.95	92.54	5.54
	50	109.26	8.68	95.39	5.60
	52	124.57	8.13	80.33	5.42
	99	106.56	9.76	91.90	5.81
Mean		114.16	8.83	90.11	5.59
CD (0.05)		-	0.931	13.24	0.414
SEm ±		1.68	0.15	1.85	0.055

Table 2. Distribution of seedlings based on vigour

Family	F1 progeny No.	Mean* yield of nut	Total seedlings	Vigorous seedlings (%)	Medium seedlings (%)	Poor seedlings (%)
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	159	72.81	30	53.34	36.66	10.00
	160	31.91	12	25.00	50.00	25.00
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	99	47.55	27	51.85	37.04	11.11
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* Mean over ten years

nificant variation between families and between progenies of the same family. Total number of leaves produced also showed significant difference.

The seedlings obtained from each progeny were grouped into vigorous, medium and poor based on the collar girth, height and total number of leaves produced one year after sowing and the data on the percentage of seedlings coming under each group are presented in Table 2. Out of five progenies in each family the number of progenies which produced more than 50 per cent vigorous seedlings was four in VIII/23 and one each in the rest of the families.

The results revealed that the hybrid palms varied significantly in respect of fruit drop (-0.470**). Number of female flowers per spadix had significant positive correlation with length of spadix (0.641**) number of open spadices (0.586**) and spikelet bearing female flowers (0.770**). Number of open spadices showed a significant positive association with fruit set (0.546**). Number of spikelets had a significant positive correlation with mean length of spikelets (0.538**). Rest of the associations between different pairs of traits were statistically not significant.

The study, therefore, revealed that number of spadix and duration of female phase were important yield components in coconut variety Dwarf Green while number of leaves produced and length of spadix had significant positive association with yield component i.e., number of spadix. Therefore, these characters should be considered as selection criteria for yield improvement in coconut variety Dwarf Green.

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IBPGR'S PAST AND FUTURE ACTIVITIES IN COCONUT GERMPLASM CONSERVATION

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Abstract: The recently changed mandate of the International Board for Plant Genetic Resources (IBPGR) is briefly mentioned as well as its new strategy. As part of these new developments, the field programme is discussed including the establishment of the new field offices in Asia and Latin America. The past achievements of IBPGR in the field of coconut germplasm collection, conservation, documentation, evaluation and training are listed.

IBPGR'S MANDATE AND STRATEGY

Recently the mandate of the International Board for Plant Genetic Resources has been extended and formulated as follows:

> *"To further the study, collection, preservation, documentation, evaluation and utilization of the genetic diversity of useful plants for the benefit of people throughout the world. IBPGR shall act as a catalyst both within and outside the CGIR system in stimulating the action needed to sustain a viable network of institutions for the conservation of genetic resources for these plants".*

In order to facilitate the execution of this new mandate the strategy of IBPGR has been defined and the various programmes were structured accordingly. In summary this new programme structure comprises:

Administrative Programme

1. Administration

2. Technical services
   - Technical and scientific committees
   - Information and editorial
   - Library

Field Programme

3. Global genetic resources network
   - Development activities
   - Base collections in genebanks
   - Data management

4. Germplasm acquisition
   - Monitoring of genetic erosion
   - Collection of endangered germplasm
   - Selective collection to fill diversity gaps
   - Facilitation of germplasm distribution

5. Germplasm characterization and evaluation
   - Data acquisition
   - Data analysis and application
   - Evaluation strategy

6. Training
   - Post-graduate courses
   - Specialized short technical courses
   - Individual training programmes
   - Intern fellowships

Research Programme

7. *In vitro* culture research
   - Collection and tissue culture technology
   - Disease indexing and therapy
   - Cryopreservation
   - Genetic stability
   - Pilot study for *in vitro* genebanks

8. Genetic diversity research
   - Species mapping
   - Ecogeographic studies
   - Biochemical methods
   - Wild relatives of priority crops

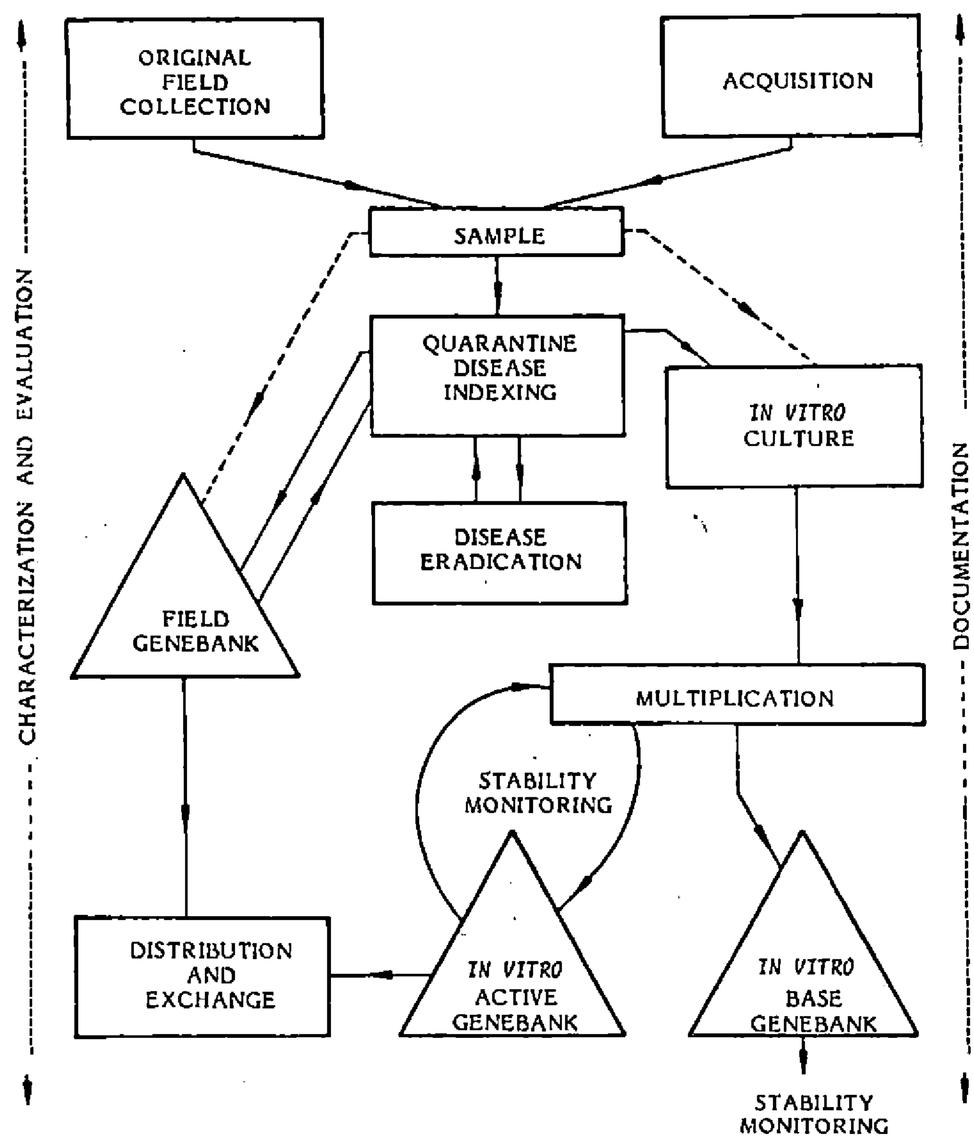

Fig 1. IBPGR coconut *in vitro* genèbank

9. Seed conservation research

Physiology of stored seed
Genetic stability
Dormancy
Regeneration and genetic integrity
Non-destructive disease indexing

ACHIEVEMENTS

Past achievements of IBPGR in the field of coconut germplasm collection, conservation, documentation, evaluation and training are:

* traditional field collection of 318 accessions in 10 different countries through the support or organization of five projects;
* research and development of *in vitro* field collecting methods; application of methods in collecting missions;
* downstreaming of these new developments into national programmes;
* development and publication of a descriptor list;
* assistance in the planning and realization of regional germplasm activities, i.e., South East Asian Working Group on Palms;
* support of germplasm exchange, which indirectly leads to the utilization of germplasm in local improvement programmes;
* consultancy to and on-the-job training personnel of national programmes.

FUTURE ACTIVITIES

After the structural changes in IBPGR's basic programme more attention will be paid to applicable research of basic conservation issues. In case of coconut, research activities include:

* further improvement of the conditions for the *in vitro* collecting techniques under prospecting conditions, i.e., direct culturing and solid endosperm cylinder method;
* promotion of a comprehensive *in vitro* conservation scheme for coconut as a model crop; however, further research on *in vitro* cloning techniques will be a condition (see Fig. 1).

The field programme, mainly through the established field offices, will further focus on the collection, conservation, evaluation and utilization of coconut germplasm. An important vehicle for an optimal coordination of such activities on a global and/or regional level will be the formation of a *coconut network* which should be headed by a Steering Committee. This network has to establish plans for a global network of active and base coconut collections; establish a comprehensive data base of global coconut germplasm collections; revise and publish a descriptor list including standards how to obtain the data; set priorities for collecting and coordinate the field work; identify further research activities on germplasm conservation and utilization; foster the germplasm flow between the potential users following standard quarantine rules and regulations; coordinate further evaluation of collected germplasm, especially for disease resistance; identify areas of research on genetic diversity and coordinate its implementation and define priority areas for further training of the staff of national programmes. IBPGR could assist such a crop network in the implementation of its plan of work in various ways, i.e.,

* support and coordinate meetings of Steering Committee;
* assist in the collection of

germplasm where deemed necessary;

* assist in the establishment of a global data base and publish directory;
* assist in the establishment of a network of base collections;
* assist in the safe exchange of germplasm through its regional seed handling units;
* publication of the revised descriptor list;
* conduct and/or assist in genetic diversity studies;
* offer training opportunities in those fields which lack adequately trained personnel.

Finally, IBPGR and its field offices regard it as one of their main objectives to advise and assist national plant genetic resource programmes in all matters related to germplasm conservation, documentation and evaluation/utilization, as well as, to assist in the building up of national capabilities.

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Technical Session 2

BREEDING FOR PEST, DISEASE AND ENVIRONMENTAL STRESS RESISTANCE

DETECTION OF *PHYTOPHTHORA HEVEAE* TOLERANCE CHARACTERS IN COCONUT IN COTE D'IVOIRE

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Abstract: *Phytophthora heveae* causes bud rot and nutfall in coconut, leading to either death of the coconut palm, or harvest losses which can exceed 30%. Damage can be reduced by injecting Fosetyl-A1 fungicide into the stem. The existence of *Phytophthora* resistance characters observed in a wide range of coconut varieties and hybrids in the field in Cote d'Ivoire suggests that coconut performance with respect to this parasite can be improved. The West African Tall proves sensitive to bud rot, but tolerant as regards nutfall; the Malayan Yellow Dwarf x West African Tall hybrid reacts in the opposite way. -Some hybrids are sensitive to both forms of disease expression, whilst others present good tolerance. Within the Malayan Yellow Dwarf x West African Tall hybrid (PB 121) there is considerable variability: some crosses are sensitive, others are highly tolerant. These studies show that a compromise can be found, both between the different hybrids and within the same hybrid to accommodate good tolerance to *Phytophthora* and improved production.

INTRODUCTION

Damage to coconut caused by various species of *Phytophthora* has been reported throughout the entire inter-tropical zone (Schierer, 1970; Graham, 1971; Joseph and Radha, 1975, Rodriguez, 1982 ; Quillec and Renard, 1984). The disease becomes apparent through two distinct symptoms: bud rot, which results in wilting and death of the tree, and immature nutfall, which sometimes results in losses exceeding 30%. Although these two symptoms are usually independent of each other, they can simultaneously affect the same tree (Quillec *et al.*, 1984).

The first cases of bud rot in Cote d' Ivoire were identified in 1977 on the local Tall. Nut-fall caused by *Phytophthora* was only detected in 1982 on PB 121 hybrid plantations (Malayan Yellow Dwarf x West African Tall). The role played by *Phytophthora heaveae* was demonstrated and chemical methods were tested to control the disease. These trials have made it possible to develop an effective chemical control technique which protects coconuts from heavy nut-fall for at least two years after treatment (Quillec *et al.*, 1984; Renard *et al.*, 1986).

In addition to this research, a programme to determine varieties which are genetically resistant to *Phytophthora* has been initiated: this article gives the first results obtained from this programme.

MATERIALS AND METHODS

1. Experimental design

The observations were carried out

on three different trials. The first two are tests comparing ecotypes and hybrids between ecotypes. The third is a genetic test aimed at improving the PB 121 hybrid.

TC-08

This trial is a performance test and was planted in 1979 and 1980 in the zone the most affected by bud rot in Cote d'Ivoire. The trial compares 21 ecotypes or hybrids between different ecotypes. The experimental design in complete blocks includes 20 replications of three trees each. Density is 143 trees/ha.

GC-11

This trial tests hybrids between ecotypes and was planted in 1974; it compares four Dwarf x Tall type combinations and a West African Tall (WAT) control. The experimental design in complete blocks includes six replications; each experimental plot is made up of five adjacent rows of five trees each, i.e., 25 trees. Planting density is 143 trees/ha.

GC-15

This trial, planted in 1978, compares the progeny from 15 WAT parents crossed with the Malayan Yellow Dwarf (MYD). The experimental design is 4 x 4 lattice; each experimental plot includes 12 coconuts planted in two adjacent rows of six trees each. Planting density is 160 trees/ha. The control is a PB 121 obtained through assisted pollination, such as those supplied to growers.

2. Observation methods

Observations were concentrated on the two disease symptoms: bud rot and immature nut-fall. The phytosanitary data dealing with bud rot were gathered on a monthly basis. As soon as the first symptoms appeared, the tree was classified as diseased. Nonetheless, these data were only considered valid after the terminal bud had been dissected, which provided confirmation of the role played by the disease in the death of the tree. Nuts were also counted monthly in trials GC-11 and GC-15 and every two months in trial TC-08. The parameters recorded were number of mature and healthy nuts (C1), number of immature aborted nuts without any visible symptoms of infestation by *Phytophthora* (C2) and number of immature aborted nuts infected with the disease (C3).

The percentage of nuts affected by the disease is estimated using the ratio C3/(C1+C3).

RESULTS AND DISCUSSION

1. Varietal tolerance

1.1 Bud rot

Table 1 gives the percentage of death due to bud rot at the end of December 1987 in trial TC-08. The "double-entry" presentation makes it possible to visualize the influence of the parents on tolerance to bud rot. The classification of different varieties depending on losses due to *Phytophthora* is given in Annex 1. Performance with respect to bud rot sensitivity varies considerably between ecotypes and hybrids. Certain varieties suffered no losses (MLT, MYD x MLT, MYD x PYT1), while others suffered losses of over 25% (EGD x WAT, MRD). The WAT proves to be sensitive and transfers high sensitivity to its progeny, particularly in crosses with dwarfs. The other tall ecotypes appear to be much more tolerant. The MYD seems tolerant, unlike the other dwarfs, and transfers this tolerance to hybrids. Hence, although the WAT is very sensitive, hybrid PB 121 (MYD x WAT) reveals a good level of tolerance to bud

Table 1. Percentage of dead trees due to bud rot per cross (trial TC-08)

	Parental ecotype							
	WAT	RLT	MLT	VTT	PYT1	MYD	MRD	CRD
WAT	16							
RLT	7							
MLT			0					
VTT			5	5				
PYT1								
MYD	3	2	0	3	0	5		
MRD	18	8			2		27	
CRD	17	3	5					12
EGD	25							

Table 2. Percentage of nut-fall due to *Phytophthora* per cross (trial TC-08)

	Parental ecotype							
	WAT	RLT	MLT	VTT	PYT1	MYD	MRD	CRD
WAT	6							
RLT	5							
MLT			3					
VTT			3	2				
PYT1								
MYD	13	8	3	3	3	4		
MRD	9	6			7		4	
CRD	19	7	7					1
EGD	22							

Table 3. Results of observations on nut-fall due to *Phytophthora* (Trial GC-11 from 1984 to 1987, annual mean)

Hybrids tested	Percentage of nuts affected by the disease	Number of ripe disease-free nuts
EGD x RLT	9.2	78.2
CRD x WAT	6.3	122.2
CRD x RLT	3.6	98.7
WAT control	3.6	62.8
MYD x RLT	3.3	113.4

rot. With the EGD x WAT hybrid, sensitivity is only expressed very late (Fig 1). In the other trials, mortality due to bud rot was rare and classification was therefore impossible.

1.2 Nut-fall

TC-08

Table 2 gives the percentage of nuts affected by the disease in trial TC-08 during the 1987 harvesting campaign, while Annex 2 gives all of the data

Table 4. Percentage of nut-fall due to *Phytophthora*

Line No.	Percentage of nut-fall					Classification	Mean number of nuts/tree/yr
	1984	1985	1986	1987	Mean		
2515	13.2	31.9	32.5	22.6	25.8	1	86.5
2527	8.0	20.8	20.0	12.1	16.6	2	97.4
2521	5.1	20.9	19.3	14.0	15.8	3	99.0
2517	4.7	16.0	15.7	14.3	13.9	4	94.7
2514	6.2	13.8	14.0	15.0	13.2	5	99.7
2520	2.8	17.6	13.4	13.1	12.9	6	90.2
2522	2.0	13.9	11.2	10.6	10.6	7	93.3
2516	5.5	16.2	12.4	6.8	10.5	8	106.9
2526	3.5	12.9	9.6	6.4	9.2	9	120.3
2519	5.1	10.2	10.1	8.4	9.2	9	101.5
2523	3.3	11.6	8.7	7.8	8.7	11	110.4
2524	2.7	15.7	7.0	5.9	8.4	12	94.4
2518	2.3	13.2	7.8	5.5	8.3	13	95.6
2513	4.9	9.6	6.3	4.2	6.5	14	103.3
2528	0.8	6.4	3.6	3.4	4.1	15	106.9
2525	0.2	7.3	2.8	1.2	3.2	16	114.2

recorded as well as the classification of treatments according to nut-fall sensitivity. The percentage of nuts affected by the disease varies considerably depending on the planting material. Certain hybrids and ecotypes are practically unaffected (CRD, VTT, MYD x PYT1, VTT x MLT, MYD x VTT, MYD x MLT, MLT), while others lose almost a fifth of their nuts (EGD x WAT, CRD x WAT). A positive correlation can be seen (r = 0.45**) between the two symptoms of the disease, bud rot and immature nut-fall. Nonetheless, certain types react differently to each symptom. The WAT, which is sensitive to bud rot, seems relatively tolerant to nut-fall, even though it transfers high sensitivity to hybrids (particularly to hybrids with dwarfs). The MRD, and to a lesser degree CRD, are sensitive to bud rot and tolerant to nut- fall. Classification of the different ecotypes and hybrids carried out in 1986 and 1987 proves to be relatively stable (Annex 2) and each tallies well with the other.

GC-11

Table 3 gives the results of observations on nut-fall due to *Phytophthora* and production over four consecutive campaigns (1984-1987), with details of the data given in Annex 3. Subsequent to arc sine transformation of the percentages(1), statistical analysis shows a significant effect of varieties on the percentage of nuts affected with *Phytophthora*. A Duncan test at 5% shows that the EGD x RLT hybrid stands out from the other hybrids. This confirms the sensitivity of green dwarf hybrids, which was already detected in trial TC-08. There is also a significant effect of varieties on nut production per tree and per year. It can be seen that

(1) The percentage of nuts affected corresponds to the percentage calculated from the mean over four years, and not from the mean annual percentage.

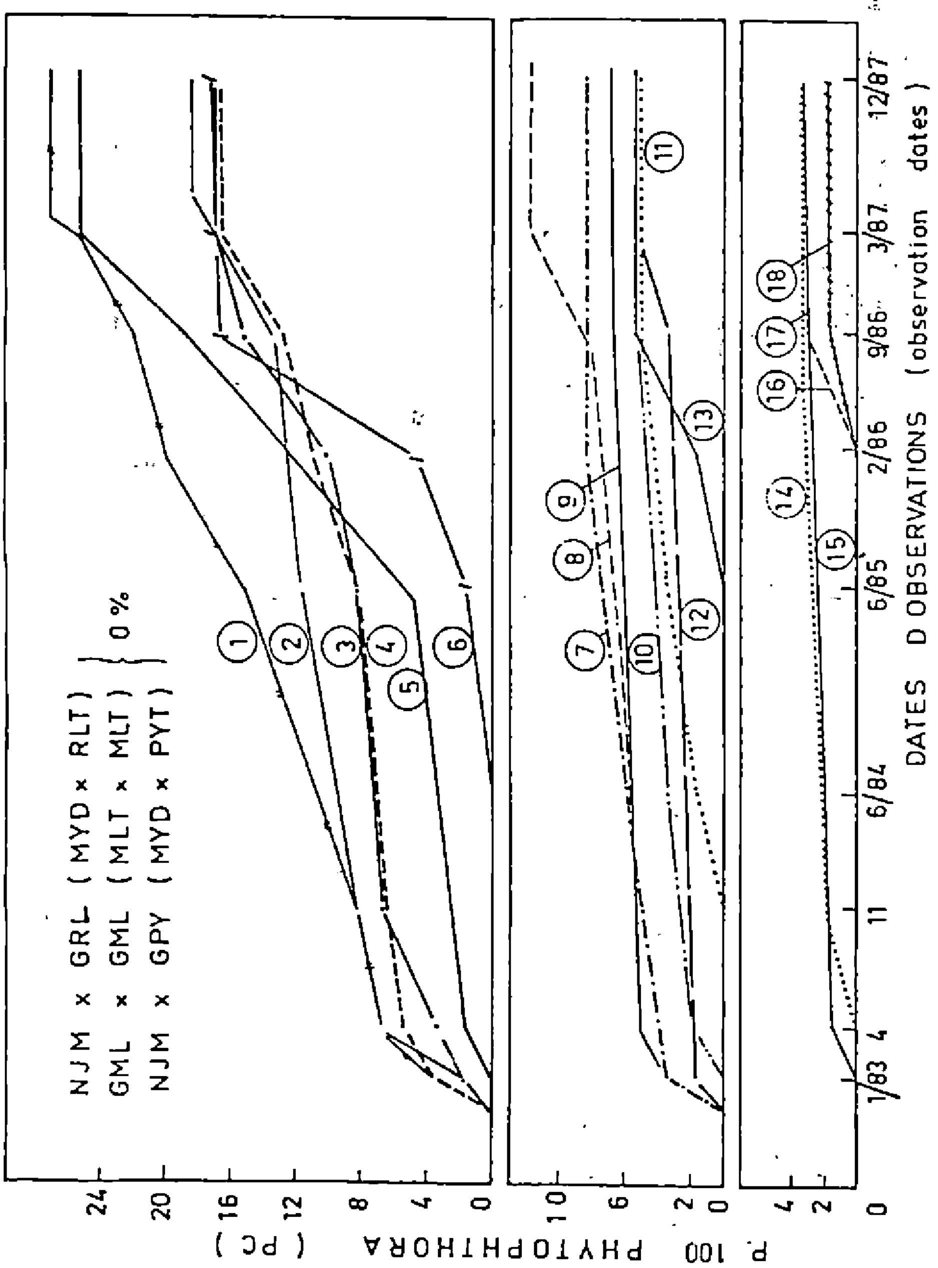

Fig 1. Evolution of bud rot due to *Phytophthora heveae* from 1983 to 1987

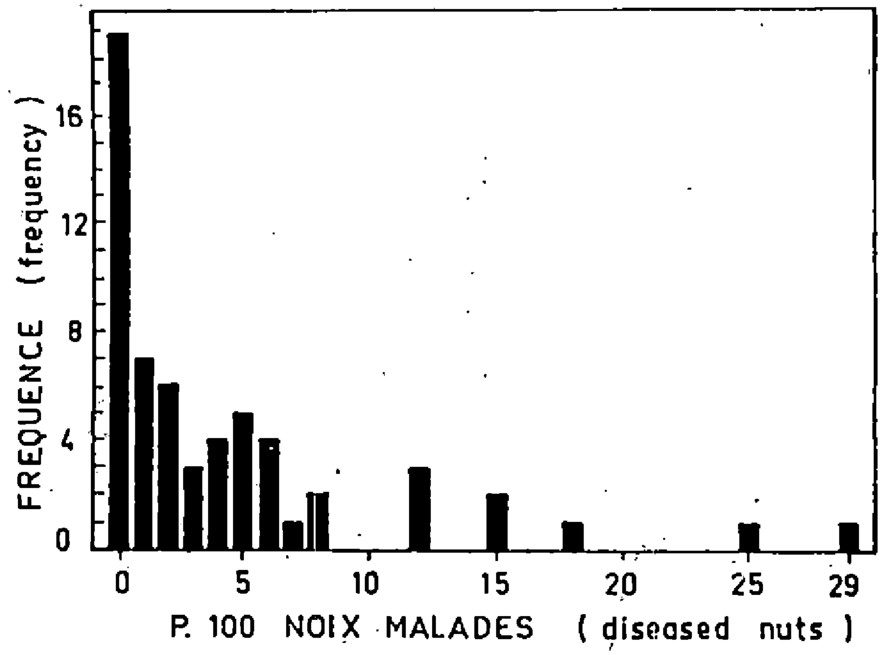

Fig 2a. Frequency histogram - Line PB 2528 - tolerant

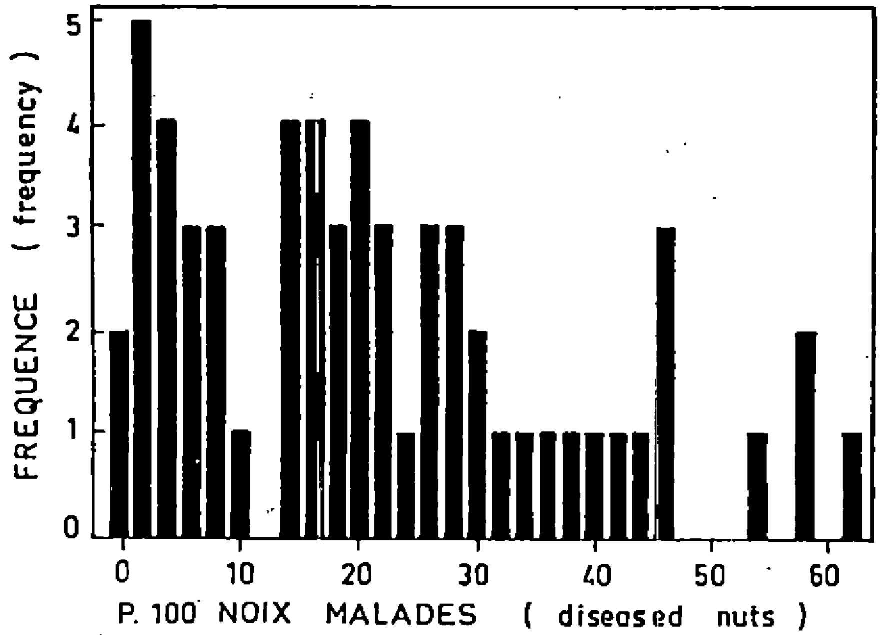

Fig 2b. Frequency histogram - Line PB 2515 - sensitive

Annex 1

Trial : TC-08 - Classification of planting material according to sensitivity to bud rot

Planting material	Number of trees planted	Number of living trees on 31-12-87	Mortality due to bud rot		
			Number of trees	%	Classi-fication
MRD	60	44	16	27	1
EGD x WAT	60	45	15	25	2
MRD x WAT	60	49	11	18	3
CRD x WAT	60	50	10	17	4
WAT - SAMO	110	92	18	16	5
WAT - PB	64	54	10	16	5
CRD	60	53	7	12	7
MRD x RLT	60	55	5	8	8
WAT x RLT	60	56	4	7	9
MYD	60	57	3	5	10
VTT x VTT	60	57	3	5	10
CRD x MLT	58	55	3	5	10
VTT x MLT	60	57	3	5	10
MYD x WAT (PB 121)	60	58	2	3	14
CRD x RLT	60	58	2	3	14
MYD x VTT	60	58	2	3	14
MYD x RLT	60	59	1	2	17
MRD x PYT1	60	59	1	2	17
MYD x MLT	63	63	0	0	19
MLT x MLT	56	56	0	0	19
MYD x PYT1	60	60	0	0	19

MYD = Malayan Yellow Dwarf
MRD = Malayan Red Dwarf
EGD = Equatorial Green Dwarf
CRD = Cameroun Red Dwarf
WAT = West African Tall
WAT PB = Port Bouet origin
WAT SAMO = Samo origin
RLT = Rennell Tall
VTT = Vanuatu Tall
MLT = Malayan Tall
PYT1 = Polynesian Tall

the CRD x WAT, which is relatively sensitive to nut-fall, remains the most productive in the trial.

2. Individual tolerance

Table 4 summarizes the results of observations on nut-fall due to *Phytophthora* in trial PBGC-15 from 1984 to 1987. The trial was analysed according to a lattice design,following arc sine transformation of the percentages. The 16 progenies were classified in decreasing order of sensitivity. The WAT is generally considered to be a very homogeneous ecotype. However, sensitivity to nut-fall varies considerably depending on the progeny tested: certain lost less than 5% of their nuts on average (PB-2525, PB-2528) while one progeny lost more than 25% (PB-2515).

With a view to determine the type of resistance detected in trial PBGC-15, a tree-by-tree comparison was carried out on sensitive and resistant lines. Fig 2 shows the distribution of individuals belonging to lines PB-2528 and PB-2515 according to their sensitivity to nut-fall. Sensitive and tolerant trees can be observed in each group, while only the proportions differ. Resistance therefore seems to be of the horizontal type. The Duncan test at 5% confirms the sensitivity of PB-2515 progeny and the tolerance of lines PB-2528 and PB-2525. These latter two lines also produce good yields, which indicates, therefore, that

Annex 2

Trial: TC-08 - Classification of planting material according to sensitivity to nut-fall

Planting material	Number of bearing trees	% of diseased nuts in 1987	Classification		Number of healthy nuts/tree
			1987	1986	
EGD x WAT	41	22	1	2	44.4
CRD x WAT	49	19	2	1	54.8
MYD x WAT	57	13	3	3	55.3
MRD x WAT	47	9	4	4	63.3
MYD x RLT	57	8	5	8	45.3
CRD x RLT	55	7	6	6	36.8
MRD x PYT1	53	7	6	11	45.3
CRD x MLT	49	7	6	6	52.0
WAT - SAMO	76	6	9	9	41.1
MRD x RLT	50	6	9	12	42.9
WAT - PB	52	5	11	4	38.2
WAT x RLT	58	5	11	12	48.4
MRD	32	4	13	16	60.1
MYD	41	4	13	14	51.8
MLT x MLT	46	3	15	10	26.0
MYD x MLT	62	3	15	14	42.0
MYD x VTT	53	3	15	17	56.3
VTT x MLT	53	3	15	20	39.8
MYD x PYT1	56	3	15	17	45.7
VTT x VTT	52	2	20	17	42.0
CRD	46	1	21	21	34.1

Annex 3

Trial: GC-11 - Percentage of nut-fall due to *Phytophthora* according to planting material

Planting material	1984	1985	1986	1987
WAT	0.6	3.9	4.9	4.3
CRD x WAT	1.2	9.1	6.7	8.2
EGD x RLT	1.3	10.6	7.9	15.2
CRD x RLT	0.7	4.3	3.5	5.5
MYD x RLT	0.7	3.1	3.8	5.6
Mean (%)*	1.1	6.3	5.6	7.7

* Mean percentage of nut-fall, all varieties combined

i.e., $\dfrac{\text{Total number of nuts with } \textit{Phytophthora} \text{ in the trial}}{\text{Total number of nuts with } \textit{Phytophthora} + \text{total number of healthy nuts}}$

it is possible to improve the PB-121 hybrid with respect to both production and tolerance to *Phytophthora* at the same time.

The tolerance of a plant to a disease is defined as its ability to support the presence of the parasite without suffering any great damage. The objective of the coconut improvement programme in Cote d'Ivoire is two-fold: plants are sought which are both resistant and productive. The WAT is used to create highly productive hybrids. Although it generally transfers its sensitivity to *Phytophthora*, it is possible to select WAT pollenizers which produce tolerant and productive hybrids. Control of the disease requires several research axes to be developed.

3. Development of inoculation tests

The development of inoculation tests at nut, bud and possibly seedling level would make it possible to compare, with a known inoculum and homogeneous infection pressure, the performance of various hybrids and ecotypes. The inoculation test for nuts could be carried out in the laboratory on nuts cut from the tree, so as to avoid contaminating healthy trees and to side-step certain environmental effects. Cross-checks carried out with isolates obtained from bud rot and diseased nuts would make it possible to compare pathogen strains and determine whether or not parasite specificity exists.

4. Host-pathogen relationships

This approach consists in studying the plant's defence strategies, which could intervene either before contamination (plant structure, morphology of natural openings, presence of toxic compounds, etc.) or after contamination (distribution of wounds, abscission of cells or diseased organs, neosynthesis of toxic compounds, etc.) Research into correlations between tolerance to the disease and the plant's morphophenological characteristics should make it possible to determine selection criteria for resistance to *Phytophthora*.

5. Epidemiology

The ways in which the disease develops in the field remain obscure. The effects of external factors such as wind, relative humidity, rain and insects have yet to be studied. Methods to preserve and transport the inoculum have to be found, so as to improve comparisons of ecotypes and hybrids in the field.

6. Genetic determinism of resistance

Traditionally, a distinction is made between two types of resistance to a given pathogen. Vertical resistance, which provides a high level of resistance, but is generally considered to be fragile, is specific to certain pathotypes and requires pathogen mutation. Its genetic determinism is oligogenic. Horizontal resistance, which is generally partial (tolerance), but because of its stability, it hinders the development of all the patho types. This resistance is determined by a large number of genes. The results of trial PBGC-15 seem to indicate that coconut resistance to *Phytophthora* is more than likely of this type. Nonetheless, the study of *Phytophthora* resistance heritability requires further work.

Existence of vertical resistance

Certain PB 121 trees from trial PBGC-15 appear to be completely free of attacks on nuts: artificial inoculation would make it possible to determine whether this results from an absence of contamination or total resistance to the disease. Another method consists in seeking oligogenic inheritance characteristics within progeny from individualized distribution peaks (sensitive - resistant). Each WAT parent tested in PBGC-15 was selfed and the selfs were planted in a multiplication trial at the rate of about 100 per parent. These selfs constitute privileged material for observing possible segregations.

Quantitative study of resistance

The good performance of to WAT parent with respect to the disease does

PHYSIOLOGICAL AND BIOCHEMICAL CRITERIA FOR BREEDING FOR DROUGHT TOLERANCE IN COCONUT

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Central Plantation Crops Research Institute, Kasaragod 670 124, India

Abstract: The ability of coconut genotypes to withstand drought conditions depends upon various physiological and biochemical factors which impart drought tolerance. Among these, the pattern of soil moisture depletion by the roots and transpirational loss of water through the leaf surface were found to be important. The accumulation of wax on the leaf surface and the stability of the activity of certain enzymes were found to have a bearing on stress tolerance. On the basis of the above criteria, coconut genotypes were ranked according to the degree of tolerance. The hybrids, WCT x WCT, LO x GB, LO x COD and WCT x COD ; the talls, WCT (selections) and Andaman Giant proved to be drought tolerant having a relatively high depletion of soil moisture by the roots, low transpirational loss from the leaf surface and the high content of cuticular wax, all desirable traits in the conservation of water by the tissues. The dwarfs, COD, MYD, GB and MOD; the tall cultivar, Laccadive Micro; and the hybrid, COD x WCT were characterized by an imbalance of water relations. Their low soil moisture depletion and higher rate of transpiration resulted in their susceptibility to drought; these genotypes also had low wax deposition. Further evidence was obtained through the determination of enzyme activities of glutamate oxalacetic transaminase (GOT) and acid phosphatase (APH), which showed distinct differences between the tolerant and susceptible genotypes. Thus, the much needed link between cellular processes and external manifestation of stress symptoms in coconut was established. The implications of these findings in the breeding programme for drought tolerance in coconut are discussed.

INTRODUCTION

The impact of drought on coconut yield is well documented in literature (Rao, 1986; Rajagopal *et al.*, 1986a; Liyanage, 1987). Unlike the annuals, the adverse effect of drought, caused either by low rainfall or delayed onset of monsoon or both at any given time, persists for the subsequent two or three years and this is explained on the basis of the relationship between the degree and intensity of dry spell and the ontogeny of coconut inflorescence (Rajagopal and Shivashankar, unpublished). The critical soil moisture level at which the coconut palm suffers from stress and the impact of weather variables on the development of stress in coconut have been reported (Rajagopal *et al.*, 1989a; Kasturibai *et al.*, 1988). Voleti *et al.*, (1989) have demonstrated the differential response of coconut genotypes to soil drought based on a study of different soil types.

The biochemical basis for drought tolerance in coconut has been reported (Shivashankar, 1988; Shivashankar *et al.*, 1989). Based on the parametric relationship with drought tolerance, 23 coconut genotypes have been ranked as tolerant and susceptible (Rajagopal *et al.*, 1989). In order to screen more genotypes for drought tolerance, a rapid method was developed using the measurement of leaf water potential on excised leaves as a function of the time of dehydration in the laboratory (Rajagopal *et al.*, 1988). In the present paper, some of the key distinguishing features such as the pattern of soil moisture depletion, transpirational loss of leaf water and the activities of two important enzymes between the tolerant and susceptible genotypes are described.

MATERIALS AND METHODS

Six coconut genotypes each of tolerant and susceptible groups (Fig 1) were selected from the randomized block design comprising three replications of four palms each. The growth conditions, soil type and other details have been reported elsewhere (Rajagopal *et al.*, 1988). Transpiration rate was determined on the excised leaflets with the steady state parameter as described earlier (Rajagopal *et al.*, 1986b). Soil moisture content was determined gravimetrically during November (prestress) and March (stress) months at three depths from the soil surface (0-25, 25-50, 50-75 and 75-100 cm). From this, the soil water deficit (SWD) was calculated following the method of Dastane (1972). Epicuticular wax (ECW) was determined as per the method described by Ebercon *et al.*, (1977). Acid phosphatase (APH) and glutamate oxalacetic transaminase (GOT) were assayed following Linhardt and Walter (1963) and Bergmeyer (1963) respectively only in four genotypes viz., WCT, COD, WCT x COD and COD x WCT.

RESULTS AND DISCUSSION

The soil water deficit expressed as the difference between the stress and prestress, showed marked variations among the tolerant and susceptible genotypes. In general, the tolerant genotypes recorded significantly higher SWD than the susceptible types. The SWD increased with increasing soil depth in the case of WCT x WCT, WCT and Andaman Giant (tolerant) and MOD and Gangabondam (susceptible) (Fig 1). The SWD exceeded 7.0 mm at 50-100 cm depth in only two of the tolerant genotypes (LO x COD and WCT) but none among the susceptible ones. Surface layer (0.25 cm) had relatively higher SWD in LO x COD and WCT x COD (tolerant) and COD x WCT (susceptible). Table 1 gives the details pertaining to the genotypes, soil depths, prestress and stress stages. The rate of transpiration was less than 3.0 $\mu g\ s^{-1}\ cm^{-2}$, the highest being in GB (Fig 1). Genotype, prestress vs stress and prestress, stress and genotype interaction were found to be significant within the tolerant and susceptible groups (Tolerant: 467.68**, 5.68** and 2.81**; Susceptible: 116.71**, 15.31** and 5.11** respectively). The interaction between tolerant and susceptible groups was found to be significant (20.13**).

The ECW ranged from 99.25 to 132.62 $\mu g\ cm^{-2}$ (mean 110.95) among the tolerant while it ranged from 77.33 to 110.48 $\mu g\ cm^{-2}$ (mean 90.15) among the susceptibles. LO x GB had the highest content (132.62 $\mu g\ cm^{-2}$) while the lowest was exhibited by MOD (77.33 $\mu g\ cm^{-2}$). Fig 2 illustrates the relationship between ECW and transpiration rate.

The activity of APH did not differ much between a tolerant (WCT) and a susceptible (COD x WCT) genotype under pre-stress conditions (195 and 210 nmole $h^{-1}g^{-1}$ fresh weight respectively) whereas with the onset of stress, the activities increased by 78.6 per cent (over prestress) in COD x WCT as against only 43 per cent in WCT (Fig 3). Moisture stress enhanced the activity of GOT two to three fold among the four genotypes; the difference in the increase between the tolerant and susceptible was less than that observed in the case of APH.

Coconut palm experiences severe stress during summer months (January to May) as a result of high evaporative demand in the atmosphere (Light : 1250 to 1700 $\mu E\ m^{-2}\ s^{-1}$; Temp : 30 to 36°C; RH : 32 to 45 per cent; Pan evaporation : 4.5 to 6.0 mm per day) which reflects on the depletion of soil moisture with time. Thus, both soil and atmosphere droughts co-exist in coconut plantations. From the data on the SWD and plant response, the critical soil moisture level at which coconut expresses stress

Table 1. Anova table for soil water deficit

Source	DF	SS	MSS	F
Tolerant vs susceptible	1	2492.70	2492.70	47.20**
Within tolerant	35	31068.56	887.67	16.81**
Stress levels (S)	1	1132.37	1132.37	21.44**
Depth (D)	2	19750.32	9875.16	186.99**
Genotypes	5	9305.89	1861.17	35.24**
S x D	2	254.34	127.17	2.41
S x Geno	5	69.46	13.89	<1
D x Geno	10	489.01	48.90	<1
S x D x Geno	10	67.14	6.71	<1
Within susceptible	35	39096.37	1117.04	21.15**
Stress levels (S)	1	715.27	715.27	13.54**
Depth (D)	2	17783.77	8891.88	168.38**
Genotypes	5	19048.35	3809.67	72.14**
S x D	2	87.54	43.77	<1
S x Geno	5	31.61	6.32	<1
D x Geno	10	1337.63	133.76	2.53*
S x D x Geno	10	92.17	9.21	<1
Error	72	3802.25	52.81	
Total	143	73967.18		

symptoms could be established (Rajagopal *et al.*, 1989a). Based on the relationship between SWD and stomatal resistance, it becomes clear that coconut palm is subject to severe stress when the SWD exceeds 115 mm. This value can be taken as the critical level for starting irrigation and planning of water application schedules. Similarly, the investigations on the effect of weather variables on stress development in coconut showed that when palms were exposed to an environmental situation wherein the irradiation was around 265 W m^{-2}, temperature 33°C and VPD 26 mbars, the stomatal closure sets in (Kasturibai *et al.*, 1988). Thus, the significance of both soil moisture level and agrometeorological parameters on stress development in coconut have been understood. The genotypic responses of coconut to the prevailing stress conditions in terms of stomatal regulation and water potential have been reported (Rajagopal *et al.*, 1988). When coconut genotypes were screened for drought tolerance both with the rapid method under artificial stress created dehydration (Rajagopal *et al.*, 1989b) and under field conditions (Rajagopal *et al.*, 1988) it was found that some of the talls like FMS, Andaman Giant, Fiji, Java Giant, Philippines Ordinary and hybrids like WCT x WCT, LO x GB, LO x COD and WCT x COD were relatively more tolerant to drought than the dwarfs namely MGD, MOD, MYD, GB and COD, talls like Andaman Ordinary, Laccadive Micro and the hybrid COD x WCT.

It was of interest to study the differences in the pattern of soil moisture depletion by the roots and the

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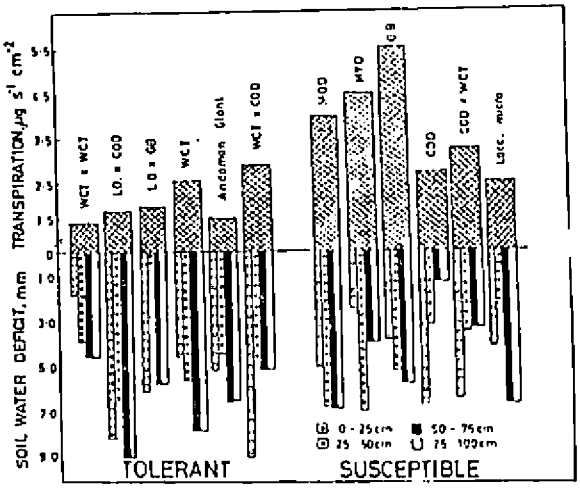

Fig 1. The soil water deficit and transpiration rate in the drought tolerant and susceptible genotypes of coconut, measured during the stress period. Values are mean of six palms

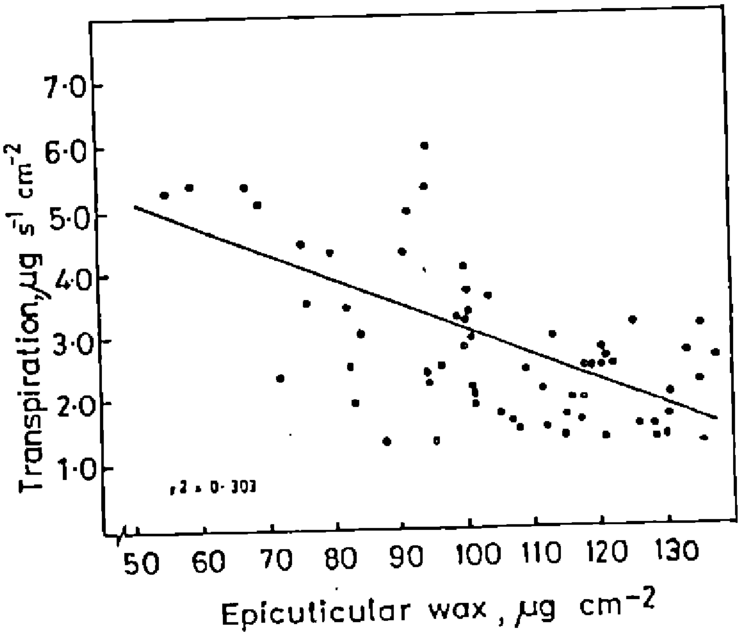

Fig 2. The relationship between epicuticular wax content and transpiration rate during stress period in coconut genotypes

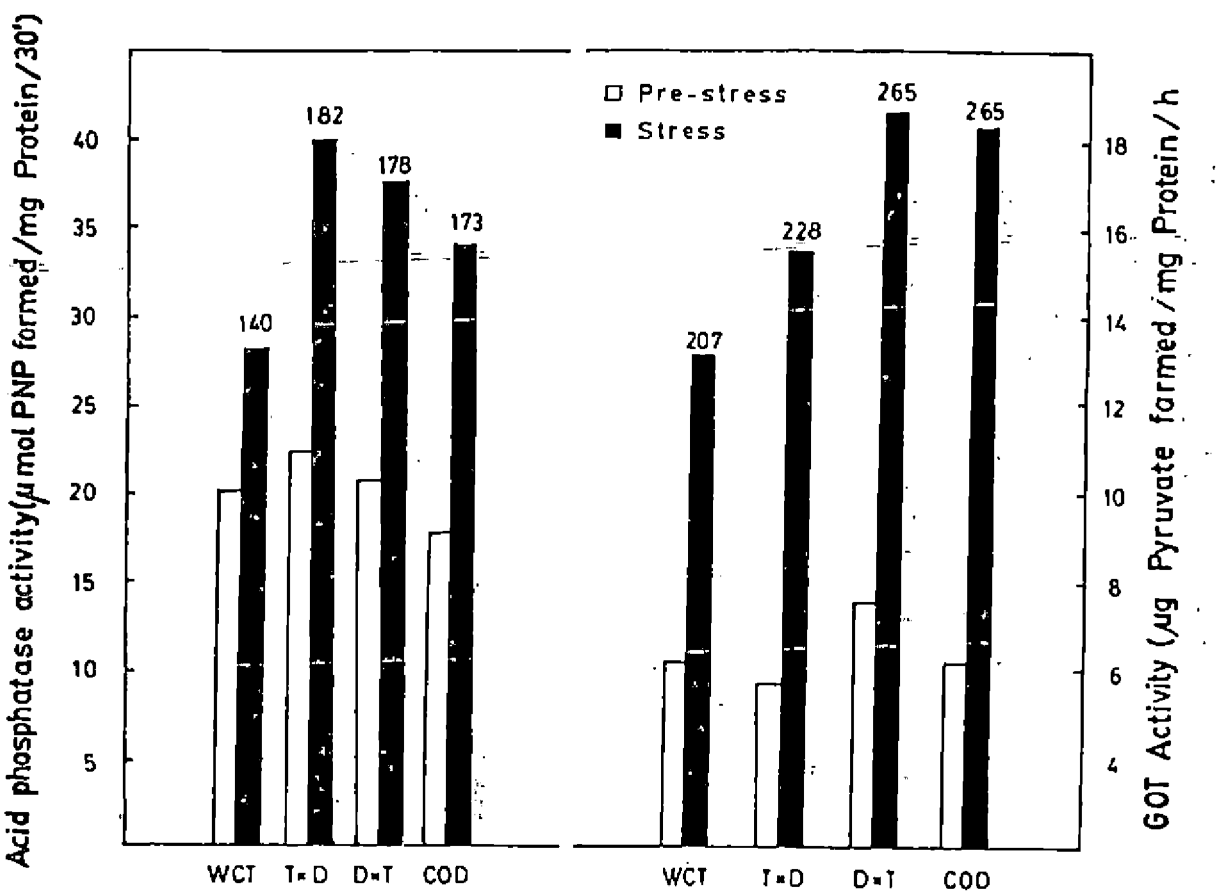

Fig 3. Activity of acid phosphatase and glutamate oxalacetic acid transaminase in four genotypes of coconut during the pre-stress and stress period. Values are mean of three palms each. Figures on the top of closed bars indicate percentage increase in enzyme activity in stressed leaves over pre-stressed leaves

transpirational loss of water through leaves between the drought tolerant and susceptible groups. The data presented in this paper clearly revealed that the tolerant genotypes, in general, extracted more soil moisture from the entire soil profile as compared to the susceptible types, despite minor variations within the groups (Fig 1). However, by reducing the transpiration rate through effective control of stomata, the tolerant genotypes could conserve water in the tissues for physiological and metabolic processes, whereas the susceptible genotypes tended to lose more water and hence became sensitive to drought conditions. For instance, although the SWD from the 0-100 cm profile was nearly the same between a tolerant genotype, WCT (26.15 mm) and a susceptible type MOD (25.7 mm) the latter transpired more water (5.5 $\mu g\ s^{-1}\ cm^{-2}$) than the former (2.8 $\mu g\ s^{-1}\ cm^{-2}$). Similarly, WCT x WCT and COD x WCT had similar SWD values (15.2 and 16.8 mm respectively) but the former proved to be more tolerant by virtue of its ability to conserve water in the tissues having a low transpiration rate (1.8 $\mu g\ s^{-1}\ cm^{-2}$) whereas a high transpiration rate of 4.0 $\mu g\ s^{-1}\ cm^{-2}$ in the latter made it susceptible to drought.

The factors described above clearly reflect on both the root development in terms of total mass and activity and the leaf characteristics like stomatal regulation. In this context, the role of ECW in checking the loss of water in different plant species deserves mention (Hall and Jones, 1961; Baker, 1974). The fact that the most tolerant genotypes like LO x GB and LO x COD have significantly higher ECW content (> 120 $\mu g\ cm^{-2}$) than the susceptible ones like MYD and MOD (< 80 $\mu g\ cm^{-2}$) clearly indicates the significance of cuticular wax in imparting tolerance to drought. Such genotypic variations in ECW was shown in sorghum (Ebercon *et al.*, 1977), oat (Bengston *et al.*, 1978, and cocoa (Balasimha *et al.*, 1985). As an important component in reducing the transpirational loss of water, deposition of wax on the leaf surface was correlated with the drought resistance in the above crops. Clarke and Levitt (1956) reported an increase in ECW in the stressed leaves of soyabean accompanied by a reduction in transpiration rate. In the present study, there is a clear indication of a negative relationship between ECW and transpiration in that MOD (susceptible) having an ECW of 77.3 $\mu g\ cm^{-2}$ had high transpiration rate of 4.5 $\mu g\ s^{-1}\ cm^{-2}$ while high value of ECW, 132.6 $\mu g\ cm^{-2}$ in LO x GB (tolerant) was associated with a low transpiration rate of 1.96 $\mu g\ s^{-1}\ cm^{-2}$. The linear regression equation fitted for transpiration versus ECW was found to be significant (Fig 2) (r^2 = 0.303).

From the foregoing it is evident that the internal water balance is well regulated in tolerant genotypes by the development of an efficient root system and favourable leaf characteristics, whereas in the susceptible genotypes even though soil moisture extraction in some cases like MOD, GB and LM is as much as that in the tolerant genotypes the relatively high rate of water loss played crucial role in rendering them sensitive to water stress.

As a consequence of changes in leaf water potential in the tissues during stress, the metabolic status in terms of enzyme activities also showed variations among genotypes (Shivashankar, 1988; Shivashankar *et al.*, 1989).

Among the enzymes studied, the activities of APH and GOT were found to be highly sensitive to stress. The activities of these two enzymes were higher in the dehydrated leaves of susceptible genotypes like LO, GB and COD x WCT than in those of tolerant ones namely, LO x GB, LO x COD and WCT (Rajagopal *et al.*, 1988). Under field conditions also there existed differences in the enzyme activities between the two groups of palms cultivated under irrigated and rainfed conditions (Shivashankar *et al.*, 1989). Relatively high activity was recorded in COD x WCT as compared to WCT. Considering the metabolic role of these enzymes and their localization in the cell, it is evident that WCT shows better ability to tolerate stress than COD x WCT. From earlier studies on crop plants (Silva, 1974) it has been hypothesized that the increase in activity is due to increased solubilization of APH enzyme following membrane damage. Tolerant varieties possessing more stable membranes show increased activity. The data on tolerant and susceptible genotypes of coconut corroborate the above hypothesis. Thus, the measurement of enzyme activities during stress development could serve to monitor degree of tolerance of coconut genotypes to stress.

Thus, the close relationship between the soil water components and the physiological and biochemical responses of the coconut palm reflecting on the cellular processes could be established in coconut genotypes differing in their tolerance to drought.

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Table 1. Performance of hybrids at the end of 21st year of planting

Hybrid/ variety	Age at bearing	Average cumulative yield		Average annual yield 1984-87		Copra yield	
		no. of nuts/ palm	% WCT	No. of nuts/ palm	% WCT	kg/ palm	% WCT
COD x WCT	6.6	1200	42	99.8	36	20.8	52
WCT x COD	7.1	1019	21	88.4	20	17.5	28
WCT x GB	7.1	822	-2	65.7	-11	12.4	-10
LO x COD	8.6	1016	21	99.3	35	19.4	42
LO x GB	7.4	1079	28	101.3	38	19.8	45
WCT	6.9	840	-	73.5	-	13.7	-

Table 2. Yield performance of hybrids during the past 10 years (1978-1987), nuts/palm

Year	COD x WCT	WCT x COD	WCT x GB	LO x COD	LO x GB	WCT
1978	69.1	68.8	66.9	87.5	69.5	59.2
1979	111.0	86.4	69.7	113.3	81.1	76.2
1980	28.1	12.2	13.8	40.3	36.9	23.0
1981	126.8	102.3	92.8	77.9	96.5	87.0
1982	20.4	26.8	21.5	68.4	55.4	28.3
1983	150.7	147.6	105.6	97.8	99.3	94.6
1984	15.5	22.6	11.5	67.5	49.2	28.2
1985	148.5	135.0	105.7	96.7	146.6	102.4
1986	447.1	82.2	27.9	141.2	93.3	57.7
1987	188.0	113.6	117.6	91.6	116.2	105.8

of rain was received only at the end of May, on 30th and 31st. In effect February to May can be considered as non-rainy months. These five months of extended dry spell have adversely affected the yield of 1982. In addition to 1980, 1982 and 1984 to some extent 1978 and 1986 also showed lesser yields than the preceding and succeeding years. The rainfall and the number of rainy days were comparatively better in both 1977 and 1985 and these reduction could be attributed to the tendency of hybrids to give lesser yield succeeding

ing palms alone, in order to arrive at a reliable conclusion on population basis. The copra content was determined for each palm based on the samples (4 nuts per palm) drawn during summer months when the variation was found to be least (Mathew *et al.*, 1978).

RESULTS AND DISCUSSION

Flowering and yield performance

Among the five hybrid combinations, maximum number of palms came to bearing in the sixth year was in COD x WCT while in LO x COD maximum number of palms came to flowering in the eighth year. The average age at bearing was comparatively less in WCT than the remaining four Tall x Dwarf combinations namely, WCT x COD, WCT x GB, LO x COD and LO x GB (Table 1). Combinations involving LO as the female parent were comparatively late bearers than those which had WCT as female parent. When all the combinations are considered, 97 per cent of the palms came to bearing at the end of 10th year and the remaining in the 11th year. Precocity in bearing of COD was possibly inherited in hybrids only when it was used as female parent in COD x WCT combinations. In both the combinations (LO x COD and WCT x COD) where it was used as male parent maximum number of palms came to bearing only in the 8th year.

Yield performance at the end of 21st year is presented in Table 2. COD x WCT with 1200 nuts per palm average cumulative yield was superior to WCT by about 42 per cent. All the hybrid combinations gave higher cumulative yield than the WCT, except WCT x GB which recorded slightly lesser yield than WCT. Stabilized yield (1984-87) of these hybrid combinations ranged between 66 nuts/palm/year in WCT x GB to 101 in LO x GB. COD x WCT gave highest copra out-turn with 20.8 kg per palm per year which is about 52 per cent more than WCT. Both the hybrid combinations with LO as female parent also gave 42 and 45 per cent higher yield in terms of copra than WCT. The copra yield of WCT x GB was poorer by 11 per cent. In order to understand the stability of performance over a period of time the yield of last 10 years (1978-87) was considered (Table 2). Yields were higher during alternate years commencing 1978. In 1980 and 1984 there was marked decline in yield in almost all the combinations. To an extent the yields in 1982 were also poorer in almost all the hybrids as well as WCT.

Performance of hybrid during drought situations

In order to understand the fluctuations in the yield, the data on rainfall and number of rainy days during November of the previous year to May of next year were examined (Table 3). During the past 10 years, 1979 has only 168.8 mm rainfall and 6 rainy days (November 1978 to May 1979). During 1983, only 5 mm rainfall was received with only one rainy day. These two years can be classified as drought years. Therefore, the yield reduction in 1980 and 1984 could be the direct effect of extended period of drought during the preceding years. This is in agreement with the observation made by Mathew *et al.*. (1988) that the duration of drought period affects the yield of coconut in the succeeding two years. They also stressed that the length of dry spell is more important than the total rainfall *per se*. The yield of 1982 was also as poor as that of 1984 in almost all the combinations. Even though 219.6 mm rainfall was recorded from November 1980 to May 1981, from February to April was a total dry spell. Even out of the three rainy days recorded during April/May months substantial quantity

Table 1. Performance of hybrids at the end of 21st year of planting

Hybrid/ variety	Age at bearing	Average cumulative yield		Average annual yield 1984-87		Copra yield	
		no. of nuts/ palm	% WCT	No. of nuts/ palm	% WCT	kg/ palm	% WCT
COD x WCT	6.6	1200	42	99.8	36	20.8	52
WCT x COD	7.1	1019	21	88.4	20	17.5	28
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LO x COD	8.6	1016	21	99.3	35	19.4	42
LO x GB	7.4	1079	28	101.3	38	19.8	45
WCT	6.9	840	-	73.5	-	13.7	-

Table 2. Yield performance of hybrids during the past 10 years (1978-1987), nuts/palm

Year	COD x WCT	WCT x COD	WCT x GB	LO x COD	LO x GB	WCT
1978	69.1	68.8	66.9	87.5	69.5	59.2
1979	111.0	86.4	69.7	113.3	81.1	76.2
1980	28.1	12.2	13.8	40.3	36.9	23.0
1981	126.8	102.3	92.8	77.9	96.5	87.0
1982	20.4	26.8	21.5	68.4	55.4	28.3
1983	150.7	147.6	105.6	97.8	99.3	94.6
1984	15.5	22.6	11.5	67.5	49.2	28.2
1985	148.5	135.0	105.7	96.7	146.6	102.4
1986	447.1	82.2	27.9	141.2	93.3	57.7
1987	188.0	113.6	117.6	91.6	116.2	105.8

of rain was received only at the end of May, on 30th and 31st. In effect February to May can be considered as non-rainy months. These five months of extended dry spell have adversely affected the yield of 1982. In addition to 1980, 1982 and 1984 to some extent 1978 and 1986 also showed lesser yields than the preceding and succeeding years. The rainfall and the number of rainy days were comparatively better in both 1977 and 1985 and these reduction could be attributed to the tendency of hybrids to give lesser yield succeeding

Table 3. Rainfall and number of rainy days during November - May*

Year	Nov-May rainfall mm	No. of rainy days	No. of rainy days in Apr/May	Non-rainy months	
1977	411.0	22	9	Jan, Feb	(2)
1978	886.1	35	20	Jan-Mar	(3)
1979	168.8	6	1	Jan-Mar,May	(4)
1980	290.5	21	11	Jan-Mar	(3)
1981	219.6	11	3	Dec, Feb-Apr	(4)
1982	152.9	12	6	Dec-Apr	(5)
1983	5.0	1	1	Nov-Apr	(6)
1984	441.1	20	9	Dec, Feb	(2)
1985	377.7	17	13	Dec, Feb	(2)
1986	209.5	11	3	Jan, Feb	(2)
1987	264.6	10	3	Jan-Apr	(4)

(* November of previous year to May of current year)

to a bumper crop in the previous years. However, when these years coincide with drought conditions in the preceding year, the effects appear to be much more pronounced as noticed in the case of 1980, 1982 and 1984.

For understanding the stability of performance of these hybrids the yield data for good years (1979, 1981, 1983, 1985 and 1987) and bad years (1978, 1980, 1982, 1984 and 1986) were analysed separately (Table 4).

During the drought influenced years least number of bunches (6.1 per year) was recorded in COD x WCT which accounted for 42 per cent reduction in the number of bunches. Highest reduction in number of bunches was recorded in WCT x GB (45%) and to an extent WCT x COD also showed greater reduction in number of bunches (31%) compared to LO x COD and LO x GB (19 and 21% respectively). The order of reduction in number of female flowers per bunch due to drought influence is comparatively less. LO x COD has recorded more number of female flowers during the drought influenced years (11%) while in all the remaining hybrids and WCT the order of decrease in female flowers during the drought influenced years ranged between 11 per cent in LO x GB to 26 per cent in WCT x GB. The setting percentage also was influenced due to the drought situation in the preceding year. In COD x WCT higher reduction to an extent of 43 per cent was noticed, while in LO x COD the reduction was only 5 per cent. In the remaining hybrids and WCT the setting was lower by 22 to 30 per cent during the drought influenced years.

Drought influence was much more

Table 4. Performance of hybrid during good and drought influenced years

	Characters	COD x WCT	WCT x COD	WCT x GB	LO x COD	LO x GB
Number of bunches	Good years	10.5	10.4	9.9	9.5	9.8
	DI years	6.1	7.2	5.1	7.7	7.7
	% reduction	42	31	45	19	21
No. of female flowers/bunch	Good years	35.0	32.5	33.3	26.8	30.1
	DI years	27.4	24.5	24.5	29.9	26.7
	% reduction	22	25	26	+11	11
Setting %	Good years	39	35	30	37	37
	DI years	22	25	21	35	29
	% reduction	46	29	30	5	22
Yield, nuts/ palm	Good years	145	117	98	95	108
	DI years	36	43	28	81	60
	% reduction	75	64	72	15	44

DI = Drought influenced years

pronounced on the yield of nuts than other characters which have been described above. The reduction in the bunches, female flowers and setting percentage together contributed to a variation of 75% in yield between the good years and drought influenced years in COD x WCT. However, this hybrid combination recorded highest number of nuts during the good years (145 nuts/palm/year). Further it also performed better with 36 nuts/palm/year than WCT x GB in which only 28 nuts/palm/year were recorded during drought influenced years. The best yield performance during the drought influenced years was recorded in LO x COD and LO x GB which had 81 and 60 nuts per palm per year.

The above characters clearly indicated that LO x COD has been least influenced by drought situation and the reduction in drought influenced years was only 19 per cent in number of bunches, 5 per cent in setting percentage and 15 per cent in over all yield, as compared to the reduction of 42 per cent in bunches, 46 per cent in setting percentage and 75 per cent over all yield in COD x WCT. Similarly, the hybrid combinations WCT x COD and WCT x GB also showed greater fluctuations between the drought influenced and good years for these parameters than LO x GB. Even though LO xGB has recorded 44 per cent reduction in yield, the annual yield at stabilized stage is about 38 per cent more than WCT in terms of number of nuts and 45 per cent more in terms of copra yield, which is higher than the LO x COD hybrid in both the annual yield and copra out-turn. However, viewed from the angle of drought influence , the performance under drought situations was better with LO x COD exhibiting greater tolerance but higher yield potential.

This is also supported by the study of Rajagopal *et al.* (1988) who have recorded higher epicuticular wax content (EWC), low stomatal frequency and high leaf diffusive resistance in LO x COD and classified it as drought tolerant type among the genotypes studied by them. The hybrids WCT x COD and WCT x GB are more prone to the drought influence. In addition, their over all performance in terms of average annual yield and copra yield is lesser than COD x WCT, LO x COD and LO x GB. Thus the performance of LO x COD and LO x GB in the drought situations and over all performance of COD x WCT over a period of time appeared to be superior to the other combinations.

Only the combinations of LO as female parent have shown the drought tolerance as well as better yield performance during the drought situations. It is presumed that the drought tolerance is inherited only from LO parent and not from either of the male parents (COD and GB). This is borne out of the fact that WCT x COD or WCT x GB had shown and recorded greater influence of drought on yield performance. Further it may also be mentioned that among these two dwarfs GB is more susceptible to drought as wherever GB is involved as male parent, the performance of the hybrid is inferior to the hybrids with COD as male patent. Similarly, COD x WCT even though in terms of yield was superior, was found to be highly susceptible to the drought influence. This also rules out the possibility of either of the parents namely, COD or WCT having drought tolerance. Hence, among the parents used in the hybrid combinations in the present study only LO appears to have the possible tolerance to drought influence. This specifically indicates the possibility that with careful selection in the parentage it is possible to combine the drought tolerance and high yield in coconut breeding programmes and raise a hybrid genotype which can perform in a stable manner under fluctuating rainfall pattern. In a perennial crop like coconut which has a life span of 60 years it is essential to breed varieties for drought tolerance and other abiotic stresses.

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PERFORMANCE OF T x D COCONUT HYBRIDS IN DROUGHT YEARS UNDER IRRIGATED CONDITIONS IN RED SANDY LOAM

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Abstract: The per palm annual nut yield of T x D was higher than that of the West Coast Tall even in years during which prolonged dry spells occurred in the summer months. Both the varieties exhibited no alternating bearing character if the annual nut yield of the entire block was taken into consideration during the stabilized yield period. The nut yield decline of T x D was noticed since 1981 onwards (planted in 1936).

The per palm nut yield of T x D was low in the years 1965 (41.9), 1980 (40.6) and 1984 (24.7) due to the occurrence of severe droughts during the summer 1964, 1979 and 1983, respectively. This was probably due to the demand of high transpiration rate of the overlying air layer of crop canopy at which the palm may not be able to supply under stress conditions because of strong advective air currents. High evaporation and surface air temperatures, low relative humidity and high soil temperature and its range in the coconut root zone were noticed in drought years when compared to that of the summer 1984 in which the distribution of rainfall was good from March to May. This resulted in better nut yield in 1985 (47.8 nuts per palm as against 24.7 in 1984). It is inferred that the summer rains from March to May which maintain the microclimate conducive in addition to the better soil moisture profile are essential for obtaining good yield in the following year even under irrigated conditions.

INTRODUCTION

The area under coconut hybrids is negligibly small though the hybrids exhibit better nut yield when compared to that of local tall varieties under better management conditions. One of the reasons for this, is the farmers' belief that the hybrids are the worst casualties in drought years which are not uncommon in the northern districts of Kerala. No doubt, irrigation is essential in these districts during the summer to mitigate the effects of drought as rain ceases practically from the mid November to the first week of June. Even in areas where irrigation is provided during the summer, the impact of prolonged droughts as occurred in 1979 and 1983 was seen in the decline of nut yield of the following year. Keeping this in view, an attempt has been made to study the performance of WCT x CDG in drought years under irrigated conditions in red sandy loam soils.

MATERIALS AND METHODS

The annual nut yield of WCT x CDG (planted in 1936) and WCT (planted in 1942) was collected from the records maintained at the Regional Agricultural Research Station, Pilicode for the period from 1961 to 1985. The palms are grown under the uniform management practices in red sandy loam under irrigated conditions at Nileswar. The monthly as well as seasonal variations in nut yield of WCT x CDG was studied and coefficient of variation was worked out to explain variability. The simple 't' test was carried out after grouping the mean annual nut yield in alternate years to study the alternate bearing tendency. The weekly climatic water balances for the standard weeks starting from 5th November to till the onset of monsoon were worked out based on the weekly rainfall and pan evaporation through the Thornthwaite's book following the water balance procedure (Subramanyam, 1982)

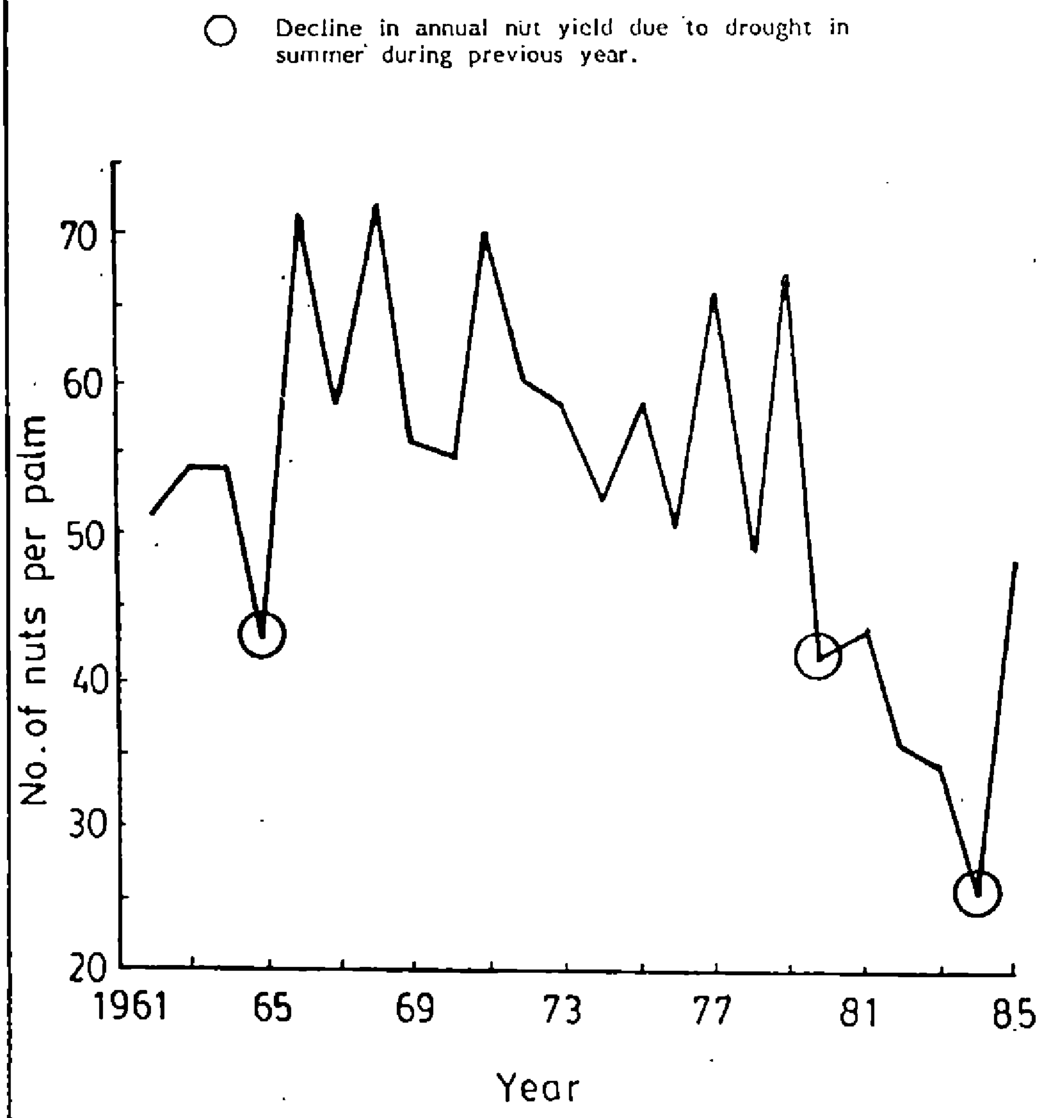

Fig 1. Annual nut yield of T x D at Nileswar

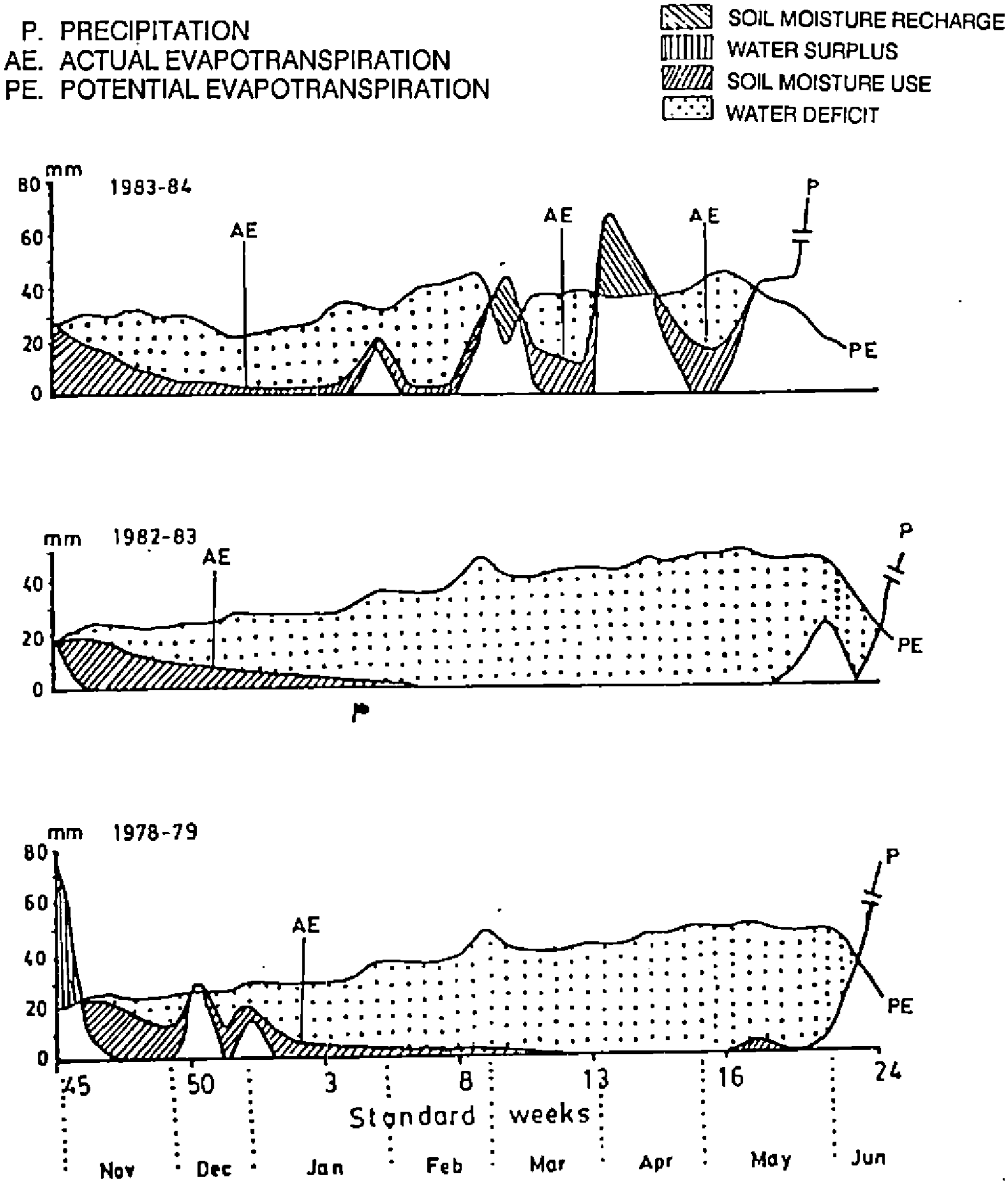

Fig 2. Weekly water balance at Nileswar

Table 1. Mean monthly nut yield of WCT x CDG and its coefficient of variation

Month	Nut yield per palm	CV (%)
January	5.6	17.0
February	7.2	21.5
March	11.0	16.8
April	12.7	18.1
May	9.4	20.1
June	7.0	22.2
July	6.5	24.6
August	6.3	10.9
September	5.9	15.3
October	5.3	16.7
November	4.4	15.1
December	4.4	21.9
Annual/mean	85.7	18.4

Table 2. Mean seasonal nut yield of WCT x CDG and its coefficient of variation

Season	Nut yield per palm	CV (%)
Summer (March - May)	11.0	18.3
SW monsoon (June - Sept)	6.5	18.3
Post-monsoon (Oct - Nov)	4.9	15.9
Winter (Dec - Feb)	5.7	20.1

for the drought years 1978-79 and 1982-83, and for the year 1983-84 (no-drought year) for understanding the intensity and duration of drought and the utilization of soil moisture.

RESULTS AND DISCUSSION

The mean monthly nut yield and its coefficient of variation of WCT x CDG are given in Table 1. The maximum nut yield 12.7 nuts/palm was noticed in April and the minimum (4.4 nuts/palm) in November and December. The annual yield was 85.7 nuts/palm and the coefficient of variation was only 18.4 per cent, being low (10.9%) in August and high (24.6%) in July. The seasonal nut yield and its coefficient of variation of WCT x CDG are given in Table 2. The mean monthly nut yield was high (11 nuts/palm) during the summer (March-May), followed by the south west monsoon (6.5 nuts/palm) and low (4.9 nuts/palm) in the post-monsoon (October-November). The coefficient of variation of nut yield was relatively higher (20.1%) in winter (December-February), followed by the other two seasons viz., summer and south west monsoon (18.3%). It was low (15.9%) in post-monsoon season.

The nut yield of WCT x CDG was higher in all the years when compared to that of WCT, indicating that the performance of WCT x CDG was better under the uniform management conditions (Table 3). In both the varieties, the difference in nut yield of alternate years was significantly low (3.68 nuts/palm in case of WCT x CDG and 2.36 nuts/palm in WCT) and the 't' value was not significant which showed that there was no significant difference in nut yield of alternate years if the mean annual yield of the entire block was taken into consideration. A drastic decline in nut yield of WCT x CDG was noticed in 1965 (41.9 nuts/palm), 1980 (40.6 nuts/palm) and 1984 (24.7 nuts/palm) due to the abnormal droughts occurred from November to till the onset of monsoon in 1963-64, 1978-79 and 1982-83, respectively (Fig 1). A continuous decline in nut yield was also noticed after 1980 which was improved only in 1985 (47.8 nuts/palm). A con-

Table 3. Mean annual nut yield of WCT x CDG and WCT from 1961-1980

Alternate Year	Annual yield (nuts/palm)		Alternate year	Annual yield (nuts/palm)	
	WCT x CDG	WCT		WCT x CDG	WCT
1961	59.9	27.6	1962	50.7	16.7
1963	53.6	23.4	1964	53.8	41.3
1965	41.9	22.4	1966	70.8	40.9
1967	58.5	39.2	1968	71.4	51.7
1969	55.6	31.6	1970	54.5	30.4
1971	70.0	45.0	1972	59.5	56.5
1973	58.1	51.9	1974	50.8	45.7
1975	58.2	57.6	1976	49.6	34.6
1977	64.6	54.5	1978	48.1	35.1
1979	66.2	36.4	1980	40.6	13.1
Mean	58.66	38.96		54.98	36.6

't' = 0.9528 in case of WCT x CDG and 0.3935 in case of WCT. Both values are much lower than the 5 per cent value of 't'.

siderable amount of summer rains received during March, April and May in 1984 would have influenced favourably the nut yield in 1985. It gave an indication that even under irrigated conditions, the summer rains are essential for obtaining better yield.

The climatic water balances in the standard weeks during the period from the second week of November to till the onset of monsoon in the drought years 1978-79, 1982-83 and 1983-84 (no drought) are depicted in Fig 2. The soil moisture deficiency was noticed from the 46th week (12th November) to the 22nd week (3rd June) during the year 1978-79 while it was from the 46th week to 23rd week (10th June) in the year 1982-83 as the onset of monsoon delayed. The soil moisture deficiency in the initial period was around 25 mm till the 21st January and gradually increased from the 4th week of January, reaching a peak of around 50 mm per week in May. The total soil moisture deficiency was 969 mm in a span of 30 weeks starting from 12th November to 10th June during the year 1982-83 while it was 894 mm in a span of 29 weeks during 1978-79. The soil moisture deficiency till the 9th week (4th March) in 1984 was similar to that of 1983 and then decreased sharply due to good summer showers in March, April and May. The soil moisture deficiency in summer 1984 was only 536 mm in a span of 24 weeks, that too intermittent. This resulted in good yield in 1985 (47.8 nuts/palm) as against 1980 (41 nuts/palm) and 1984 (24.8 nuts/palm) though the palms were in yield declining stage after 1980. As the irrigation was practised during the summer starting from December/January to till the onset of monsoon, the figures mentioned against the soil moisture deficiency may not be real. However, the duration and intensity of drought period in 1978-79 and 1982-83 showed the aggravation of the situation when no rainfall was received during the summer and the onset of monsoon delayed by another two weeks. Though the crop-water requirement was met fully through irrigation during the summer months, still the influence of drought on nut yield was seen in the following year. Also, the rainfall received during March, April and May influenced favourably the nut yield of the following year. The rains received during the summer may provide conducive phytoclimate by bringing down considerably the atmospheric and soil temperatures in addition to the better soil moisture profile in the root zone. This may lead to better nut yield in the following year. Rao and Nair (1988) reported that a significant difference (0.5 to 4.1°C) in soil temperature of the coconut root zone was noticed during the summer between 1983 (drought year) and 1984 (no-drought year). Similarly, it was noticed that there was a decrease in maximum temperature (0.8°C) and increase in atmospheric relative humidity (5-7%) during the summer of 1984 when compared to that of 1983. It is evident that the summer rains from March to May are essential to maintain the phytoclimate conducive for obtaining better yield in the following year even under irrigated conditions.

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REACTION OF CERTAIN VARIETIES AND HYBRIDS OF COCONUT TO NATURAL INFECTION OF LEAF BLIGHT CAUSED BY *PESTALOSPHAERIA ELAEIDIS* (BOOTH & ROBERTSON) VAN DER AA

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Abstract: Leaf blight of coconut caused by *Pestalosphaeria elaeidis* (Booth & Robertson) Van der Aa is found to occur in very severe manner in certain parts of Kerala. Hence a study was undertaken to determine whether there is any genetic source of resistance or tolerance among different cultivars and hybrids of coconut. Eight varieties and 12 hybrids grown in the coconut grove at the Regional Agricultural Research Station, Pilicode were selected for the study. Results indicated that none of the varieties or hybrids is immune to this disease. However, MDY had less disease incidence regarding percentage of leaves and leaflets affected. This was followed by CDG. In both these varieties the area of infection recorded also was low. WCT x GB followed by WCT recorded maximum percentage of leaves affected.

Leaf spot or grey blight of coconut caused by *Pestalotia palmarum* Cke & Grew is known to occur in all the coconut growing areas in the world (Menon and Pandalai, 1958). Recently *Pestalosphaeria elaeidis* (Booth & Robertson) Van der Aa is found to be the pathogen associated with leaf blight in coconut (Sathiarajan and Govindan, unpublished). In certain parts of Kerala the disease causes severe damage to the foliage which may affect the yield. Hence a study was undertaken to determine the reaction of coconut varieties and hybrids for *Pestalosphaeria elaeidis* under natural infection and to find out whether there is any genetic source of resistance or tolerance to this pathogen under field conditions.

Eight coconut varieties and twelve hybrids listed in Table 1 grown under gravelly laterite soil conditions in the coconut grove at the Regional Agricultural Research Station, Pilicode were selected for the study. All the palms were under rainfed conditions and received uniform cultural practices. Five plants of each variety or hybrid were selected and data on number of leaves infected and total number of leaves on the crown were recorded and percentage of leaves infected was worked out. The third leaf from below was selected and the percentage of leaflets infected was recorded. Based on the area of infection of the leaf a scoring was given. This scoring was used to work out the disease index as suggested by Horsefall and Heuberger (1942). The scores and their corresponding extent of symptoms were (0) for no remarkable symptoms and (1), (3), (5), (7) and (9) for blighted patches covering 1-5%, 6-25%, 26-50%, 51-75% and more than 75% of the leaf area respectively.

It is observed from the results that none of the varieties or hybrids is immune to this disease (Table 1). However, the intensity of incidence differed significantly between the different cultivars as well as the hybrids. Among the cultivars the lowest disease index of 4.44 was observed in the dwarf variety Malayan Dwarf Yellow. This was followed by CDG and LO with disease index 6.66 and 8.88 respectively. The local cultivar, WCT exhibited the maximum incidence of disease (index 35.55). Up to a maximum of 20 leaves was found infected in one of the palms of

Table 1. Reaction of certain coconut varieties and hybrids to leaf blight

Hybrids/cultivars of coconut	*Percentage of leaves infected	*Percentage of leaflets infected	Disease index
WCT	40.86	38.01	35.55
Lac. Small	20.03	40.37	15.44
LO	13.29	16.48	8.88
CDO	25.14	40.70	24.44
CDG	10.21	13.01	6.66
Gangabondam	23.74	46.62	24.44
Ayiramkachi	14.37	16.16	15.44
MDY	6.70	3.54	4.44
Spicata x WCT	27.72	9.64	15.55
LO x AO	27.77	47.72	33.74
WCT x CDG	26.94	23.61	11.11
WCT x MDY	32.59	40.39	24.44
CDO x WCT	29.74	30.61	24.44
WCT x Gangabondam	44.19	36.56	24.44
CDG x WCT	33.76	19.84	11.11
AO x Gangabondam	30.44	11.93	11.11
CC x Gangabondam	30.16	27.63	11.11
Spicata x Spicata	38.46	41.57	37.77
Spicata x CDG	31.00	47.06	37.77
CD (0.05)	9.67	24.52	

Data represent mean of 5 replications * Percentage values in angles

WCT with heavy damage. The hybrids also differed significantly with respect to their disease incidence. The disease index in the 12 hybrid combinations varied from 11.11 to as high as 37.77.

The significant difference exhibited by the different cultivars and hybrids is indicative of the possibility that it may be a varietal phenomenon. The response to the disease shown by most of the hybrids is intermediate to the disease index of the parents. This also suggests some genetic basis to the tolerance to this disease shown by some of the cultivars. This can be a polygenic trait, a favourable combination of which may render a cultivar considerably tolerant to the disease.

The observations made during this study points to the possibility of identifying suitable genotypes and exploiting them for breeding purposes. The information made available here may have far reaching implications in coconut improvement programme.

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SUSCEPTIBILITY OF HYBRID COCONUT VARIETIES TO *ORYCTES RHINOCEROS* LINN. (SCARABAEIDAE) UNDER RAINFED CONDITIONS AT PILICODE

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Abstract: The rhinoceros beetle *Oryctes rhinoceros* Linn. is one of the most destructive pests of coconut and is very common all over the world. Occurrence of the pest varies from variety to variety and season to season. The beetles destroy on an average one inflorescence per palm causing a 10 per cent reduction in the yield every year.

With a view to study the fluctuations in the susceptibility of different coconut hybrids, observations on the percentage leaf damage due to beetle attack was recorded from a 13 year old hybrid coconut plantation at the Regional Agricultural Research Station, Pilicode maintained under rainfed conditions during the period from 1986 to 1988. Among the 16 hybrid combinations, CC x CDO was found to be the most susceptible (21.1%), followed by WCT x LO, AO x CDO and Fiji x CDO. The lowest damage was recorded by CDO x WCT (8%) followed by WCT x CDG and WCT x GB.

The rhinoceros beetle *Oryctes rhinoceros* is one of the key pests of coconut throughout the coconut growing areas of the world. In general, it is reported that the leaf damage and the nut loss were about 40-50 per cent and 10 per cent, respectively in a severely affected garden. Ramachandran and Kurian (1959) reported that direct attack on spathe alone caused 5.7 per cent loss in nut yield and the intensity of attack varied from place to place, garden to garden and even from tree to tree of the same locality. Earlier studies conducted at the Regional Agricultural Research Station, Pilicode revealed that there was varietal variation in the incidence of rhinoceros beetle and the attack was maximum during the summer months from March to June (Anon., 1955). Considering the limitations of the conventional methods of pest control, minimising the damage due to pests by breeding resistant varieties was emphasised by Kurian (1960). The hybrid coconut varieties are popular among the cultivators as they yield better and it is advantageous to evolve a relatively less susceptible variety to this particular pest. Keeping this in view an attempt has been made to study the susceptibility of different coconut hybrid combinations to *Oryctes rhinoceros* under the rainfed conditions at Pilicode, Kerala.

Fifteen cross combinations and West Coast Tall as a test variety grown in the N-VI block of the Regional Agricultural Research Station, Pilicode were the material for this study. The seedlings were planted in 1973 in a randomised block design with five palms in each combination. Observations on the incidence of beetle were recorded based on the symptoms on leaves and spathes. The total number of functional leaves present and the affected leaves were recorded during the first week of July for the three years starting from 1986 to 1988 and the spathe damage was observed at the time of monthly harvest. The percentage leaf damage was worked out for each variety. A simple RBD analysis was carried out to test the difference in leaf damage among the varieties due to the beetle attack.

Table 1. Varietal difference in leaf damage due to rhinoceros beetle from 1986 to 1988 at Pilicode

Name of hybrid	Percentage leaf damage			Mean
	1986	1987	1988	
WCT x CDO	17.4	12.6	20.4	16.8
CC x CDO	18.9	16.8	27.8	21.1
AO x CDO	18.7	13.0	23.2	18.3
Fiji x CDO	16.8	19.4	18.2	18.1
LO x CDY	13.4	10.0	19.7	14.3
WCT x MDY	8.6	7.9	12.1	9.5
WCT x TBL	7.6	8.8	22.3	12.9
WCT x SS	6.3	9.9	15.8	10.6
Fiji x GB	4.4	8.3	14.1	8.3
WCT x GB	7.2	9.0	10.1	8.7
WCT x CDG	6.1	9.6	9.3	8.3
CDO x WCT	7.2	6.7	10.1	8.0
CDO x LO	13.6	14.4	18.6	15.5
GB x LO	13.6	12.6	16.4	14.2
WCT x LO	18.2	14.0	23.6	18.6
WCT	9.2	11.3	14.0	11.5

Analysis of variance

Source	df	MS	F
Rep.	2	168.69	25.11**
Treat.	15	54.77	8.15**
Err.	30	6.71	

CD (0.05) = 4.32 ** Significant at 0.01 level

The varietal difference in leaf damage due to rhinoceros beetle is presented in Table 1. The mean percentage leaf damage was the maximum (21.1%) in CC x CDO followed by WCT x LO (18.6%), AO x CDO (18.3%) and Fiji x CDO (18.1%) and the minimum (8.0%) was recorded by CDO x WCT. Though the CDO x WCT recorded the lowest incidence, other hybrids viz., WCT x CDG, Fiji x GB, WCT x GB and WCT x MDY also fall under the same group (8-10%). It is indicated that when CDO was taken as pollen parent the percentage leaf damage was invariably high. Interestingly, no spathe damage was noticed in any of the varieties.

As studies on palm characters in relation to selective infestation by insect pest are of great importance in breeding resistant varieties, this type of information is essential. Also it is suggested that more and more combinations of tall and semitall varieties may be included in the resistance breeding programmes

Table 1. Reaction of exotic cultivars of coconut to root (wilt) and leaf rot diseases

Rank No.	Test varieties	Mean root (wilt) disease index	Mean number of leaves affected by leaf rot
1	San Ramon	12.22	0.08
2	Guam	19.86	0.95
3	St. Vincent	22.64	0.00
4	Kenya	23.04	0.55
5	SS Green	23.64	1.19
6	FMS	25.45	1.08
7	BSI	25.99	1.00
8	Jamaica	26.51	2.00
9	Fiji	30.18	1.86
10	Java	30.91	2.64
11	WCT (Local check)	39.83	3.17

CD (0.05) for comparison of root (wilt) disease index betwen SR and Guam 10.38, St. Vincent and SR 11.27, Kenya and SR 10.29, SSG and SR 10.95, FMS and SR 10.01, BSI and SR 10.81, Jamaica and SR 12.28, Fiji and SR 10.38, Java and SR 10.29, WCT and SR 10.69, SSG and WCT 9.86, FMS and WCT 8.79, BSI and WCT 9.70, Jamaica and WCT 11.31, Fiji and WCT 9.21 and Java and WCT 9.12

significantly superior to all other varieties. However, the other exotic varieties like SSG, FMS, BSI, Jamaica and Fiji were significantly superior to the local check variety WCT. The coconut cultivars WCT and Java were observed to be highly susceptible to root (wilt), showing significantly higher disease indices. Mathai *et al.* (1985) reported similar results. They also observed root (wilt) tolerance in Andaman Ordinary, SSG and Cochin China. In the present study all the exotic cultivars are found susceptible to the disease with varying degrees of intensity under the conditions prevailing in the back water region of Kerala. According to Maramorosch and Hunt (1981) exotic palms are often prone to locally endemic diseases when introduced into new areas. This is in agreement with the present observation. The ability of some of the cultivars to endure the invasion of the disease can be utilized in resistance breeding.

The degree of tolerance of the varieties to leaf rot disease caused by *Bipolaris halodes* (Drechsler) Shoem. was also studied. The number of leaves affected by leaf rot disease indicated a comparatively low trend in San Ramon, Guam, St. Vincent and Kenya. As in the case of root (wilt) disease, the incidence of leaf rot was high in WCT and Java. The results obtained in the present study confirm the observations made by Mathai et al. (1985).

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REACTION OF EXOTIC CULTIVARS OF COCONUT (*COCOS NUCIFERA* L.) TO ROOT (WILT) DISEASE OF KERALA

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Abstract: The degree of resistance/tolerance of ten exotic and geographically distinct cultivars of coconut to root (wilt) disease of unknown etiology was studied at the Regional Agricultural Research Station, Kumarakom, Kerala. All the exotic cultivars tested were found susceptible to the disease with varying degrees of intensity. However, the coconut cultivar San Ramon recorded significantly lower disease incidence followed by Guam, St. Vincent and Kenya. The infection of leaf rot incited by *Bipolaris halodes* (Drechsler) Shoem. was also low in these cultivars.

The root (wilt) disease, a complex malady of coconut, has affected nearly one third of the seven lakh hectares of the crop in the State of Kerala. The annual yield loss due to this disease is estimated to be 97 crores of nuts. No specific measure for the control of this disease has been evolved so far. Control of diseases using resistant varieties has been described as the "painless method" that does not levy on the farmer's pocket. The powdery mildew of grapes, mosaic disease of sugarcane, curly top virus of sugarbeet, lethal yellowing of coconut etc. are some of the diseases in which resistance breeding has been successfully resorted to. The deliberate selection and hybridization in coconut for disease resistance using germplasm from world-wide sources has long been neglected (Child, 1974). With the present knowledge, satisfactory control of root (wilt) disease can only be achieved by the use of resistant/tolerant varieties of coconut. With this objective in view, the present investigation was taken up at the Regional Agricultural Research Station, Kumarakom, Kerala, India.

A field trial with the following exotic cultivars of coconut having geographically distinct characters was laid out in a completely randomised block design during 1976 and maintained till date. The test varieties and the number of palms in each test variety (given in parenthesis) are: San Ramon (12), St. Vincent (14), Jamaica (10), British Solomon Island (17), Kenya (22), Guam (21), Strait Settlement Green (16), Federated Malayan States (26), Java (22), Fiji (21) and West Coast Tall (18). The palms were grown under normal management levels in the reclaimed alluvial soils of the back water region of Kerala where the disease pressure has been very high from the year of planting. The root (wilt) disease intensity was computed using standard method evolved by George and Radha (1973). The incidence of leaf rot disease was measured by recording the number of leaves affected in each palm. The root (wilt) index was statistically analysed and the trend in leaf rot incidence was worked out.

The test varieties are ranked on the basis of root (wilt) disease intensity and presented in Table 1 together with the leaf rot incidence in each case. A statistical analysis of the data on root (wilt) disease index indicated significant difference among cultivars. The lowest disease intensity was recorded by the variety San Ramon followed by Guam, St. Vincent and Kenya. They were

Table 1. Reaction of exotic cultivars of coconut to root (wilt) and leaf rot diseases

Rank No.	Test varieties	Mean root (wilt) disease index	Mean number of leaves affected by leaf rot
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8	Jamaica	26.51	2.00
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10	Java	30.91	2.64
11	WCT (Local check)	39.83	3.17

CD (0.05) for comparison of root (wilt) disease index betwen SR and Guam 10.38, St. Vincent and SR 11.27, Kenya and SR 10.29, SSG and SR 10.95, FMS and SR 10.01, BSI and SR 10.81, Jamaica and SR 12.28, Fiji and SR 10.38, Java and SR 10.29, WCT and SR 10.69, SSG and WCT 9.86, FMS and WCT 8.79, BSI and WCT 9.70, Jamaica and WCT 11.31, Fiji and WCT 9.21 and Java and WCT 9.12

significantly superior to all other varieties. However, the other exotic varieties like SSG, FMS, BSI, Jamaica and Fiji were significantly superior to the local check variety WCT. The coconut cultivars WCT and Java were observed to be highly susceptible to root (wilt), showing significantly higher disease indices. Mathai *et al.* (1985) reported similar results. They also observed root (wilt) tolerance in Andaman Ordinary, SSG and Cochin China. In the present study all the exotic cultivars are found susceptible to the disease with varying degrees of intensity under the conditions prevailing in the back water region of Kerala. According to Maramorosch and Hunt (1981) exotic palms are often prone to locally endemic diseases when introduced into new areas. This is in agreement with the present observation. The ability of some of the cultivars to endure the invasion of the disease can be utilized in resistance breeding.

The degree of tolerance of the varieties to leaf rot disease caused by *Bipolaris halodes* (Drechsler) Shoem. was also studied. The number of leaves affected by leaf rot disease indicated a comparatively low trend in San Ramon, Guam, St. Vincent and Kenya. As in the case of root (wilt) disease, the incidence of leaf rot was high in WCT and Java. The results obtained in the present study confirm the observations made by Mathai et al. (1985).

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EVALUATION OF INTENSITY OF STEM BLEEDING DISEASE OF COCONUT

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Abstract: Stem bleeding disease of coconut is recently becoming endemic in several locations in the northern parts of Kerala. The present study aims at identifying resistance in the different Gangabondam hybrids. A detailed survey was conducted among the six different Gangabondam hybrids i.e., LO x GB, LS x GB, CC x GB, AO x GB, T x GB and J x GB having a total population of 102 palms. The hybrids were screened using the scale ranging from I to IV and correlation between the disease index and the mean yield of 10 years (from 1975 to 1984) was worked out. It was found that there was positive correlation between the yields of 1975, 1976, 1977 and 1978 with the disease index. Among the hybrids, CC x GB was having the least percentage of infection (29%) while LS x GB recorded the highest percentage of infection (78%).

Stem bleeding of coconut is fast assuming an endemic proportion in the northern parts of Kerala. The disease was first reported by Petch (1908) from Ceylon and Sunderaraman (1922) from India. Petch reported the disease to be caused by a fungus *Thelaviopsis paradoxa* (de Seynes) Van Hohnel. This was confirmed recently by Nambiar *et al.* (1986). The present control methods of the disease are found inadequate due to the complexity of the disease. So it is thought that by looking for genetic resistance into the germplasm collection as well as hybrids, a better control of the disease is possible. The present study aims at identifying natural resistance in the different Gangabondam hybrids. A comparative study of the Gangabondam hybrids was made by Kannan and Nambiar (1974).

The six hybrids of Gangabondam viz., LO x GB, LS x GB, CC x GB, AO x GB, T x GB and J x GB maintained at the KA and N2 blocks of the Regional Agricultural Research Station, Pilicode were selected for the study. The total population of hybrids was 102. These palms were scored for the disease incidence using a scale of I to IV which corresponded to area of infection 0 to 100 cm^2, 101 to 200 cm^2, 201 to 400 cm^2 and above 400 cm^2 respectively. The yield data of the palms for 10 years from 1975 to 1984 were collected and the relationship between yield and disease incidence was examined.

Table 1. Percentage of stem bleeding infection of Gangabondam hybrids

Hybrids	Infected	Total	%
LO x GB	6	11	55
LS x GB	7	9	78
AO x GB	8	13	62
CC x GB	7	24	29
T x GB	12	37	32
J x GB	4	10	40

R values for 1975, 1976, 1977 and 1978 are 0.2048, 0.2790, 0.1984 and 0.2338 respectively.

It is seen that out of a total 11 palms of the cross LO x GB, six palms were infected and showed 55% infection (Table 1). The percentages of infection in LS x GB and AO x GB were 78 and 62 respectively. The lowest percentage of infection was seen in CC x GB where out of 24 palms, only 7 palms were infected (29%). The low rate of infection in CC x GB may be due to the interaction of cultivars. In the earlier study on the incidence of stem bleeding, coconut varieties had been categorised into three groups based on intensity of infection. Cochin China had shown an infection of 25.93% and had only the least intensity of the disease (Grade I). Gangabondam also recorded a similar score of mild infection of 30% (Grade I). AO, LS, WCT and Java were in high infection group (Grade III) and LO had very little infection (Grade I).

The correlations between the mean yields of the years 1975, 1976, 1977 and 1978 and the disease index were positive. In the initial stage of infection the yield was more but later the yield decreased as the infection increased.

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Technical Session 3

BIOTECHNOLOGY

PRODUCTION OF CLONAL COCONUT PALMS

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Abstract: A reliable method of producing clonal coconut palms would be a great asset to coconut breeding programmes. Qualities such as high yield, disease resistance, tolerance of drought or particular soil conditions may occur only in a few isolated specimens. Development of clones from these specimens would enable breeders to use them as parents for producing elite palms suited to particular growing conditions.

Wye College has developed a system of culturing coconut inflorescence tissue to produce calloid which will yield embryoids. Plantlets have been obtained from such embryoids and attempts are being made to define the conditions under which normal development occurs.

INTRODUCTION

A method of clonal propagation for coconut would enable more rapid progress to be made with coconut breeding programmes. Thus, although selection may be made on the basis of yield, disease resistance, tolerance of drought or other unfavourable conditions, each palm selected is an individual with unique characteristics. If individual palms could be propagated vegetatively, then elite parental lines could be produced for breeding programmes.

It may be considered that clonal palms could be planted on a plantation scale, as is already being done for oil palm, but this seems unlikely in the near future. Most coconuts are grown by small farmers who will not have the expertise to establish palms directly from culture and who will be more successful with seedling plants produced from seed gardens of elite parents.

MATERIALS, METHODS AND RESULTS

Early tissue culture work at Wye College was directed towards the production of a successful culture medium and Eeuwens (1976, 1978) developed the Y3 medium which gave good callus growth of rachis explants. This medium was also used for the culturing of flower primordia (Blake and Eeuwens, 1982) in attempts to obtain reversion of flower primordia to a vegetative state. Although the meristems of the flower primordia remained active and laid down a series of bracts, a reversion with the production of true leaves was not obtained. This technique might benefit from further research as there is less chance of mutations (e.g. somaclonal variation) occurring when material is maintained with organised meristems throughout the culture period. The present technique uses immature inflorescence tissue (var. Malayan Dwarf) which is cut into small pieces and explanted onto a basal medium to which activated charcoal, cytokinin and 2,4-D are added (Branton and Blake, 1983). Cell division occurs in the outer layers of the meristematic areas of the male flower primordia to produce a partially dedifferentiated callus, which resembles that designated as calloid by Nyman *et al.* (1983). The calloid forms nodular meristematic structures in the superficial layers when embryoids can be identified (Branton and Blake, 1983). The presence of a cytokinin such as benzyl-aminopurine, kinetin, 2-isopentenyl adenine or zeatin appears to be required, but it is not yet clear whether any particular kinin is more effective than any other.

Further development of the embryoids is obtained by sub-culturing onto media with gradually reducing levels of auxin. Normal plantlets with shoot and root systems, closely resembling those of normal seedlings, have been produced (Brackpool *et al.*, 1986; Blake, in press), but a wide range of abnormal developments have also been observed. The cultures may produce fused embryoids, fused leaves and fused roots. In these cases the shoot meristem is aborted and there is no true shoot growth, though an ever-increasing root system may be developed. In many cases a special type of tissue is produced which is very white and spongy. Its appearance suggests that it is the equivalent of the cotyledon or haustorium of the coconut. It may develop in the characteristic round shape of the haustorium (Branton and Blake, 1983) or may resemble a thickened leaf or be without any particular structure. The presence of the cotyledon/haustorial type of tissue suggests that the regeneration process is by embryogenesis rather than simply by shoot organogenesis as sometimes appears to occur in oil palm cultures. However, the continuing adventive embryogenesis observed in oil palm has not been observed with coconut and multiplication is presently confined to the calloid stage.

Work in progress is directed towards improving the medium to obtain good development of embryoids from calloid, and of normal plantlets from embryoids. There seems little difficulty in obtaining calloid from good explant material and plantlets have been produced from at least 20 different mother palms, so that the outlook for improvement of the techinique is good. It may, however, be some years before vegetatively propagated coconut palms can be authenticated as being true-to-type, and therefore it is likely to be at least ten years before they can be reliably used in coconut breeding programmes.

ACKNOWLEDGEMENTS

I am very grateful to all those who have sustained our project at Wye College: the U.K. Overseas Development Administration who funded the early work; Booker Agriculture International who contributed funds from 1985 to 1988; Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) who have supported the project since 1981 and the Coconut Industry Board of Jamaica who have supplied coconut material.

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COCONUT GERMPLASM COLLECTION THROUGH ZYGOTIC EMBRYO CULTURE

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Abstract: The *in vitro* culture of zygotic embryos solves the problems encountered in transporting and storing coconut (*Cocos nucifera* L.) seeds especially for material exchanges and under field collecting conditions. The *in vitro* technique, previously described, allows to get a development rate from 50 to 90% after 6 months of culture. The survival rate after *ex vitro* transfer is about 80%. Two methods of embryo sampling and short term storing under field conditions have been developed. Direct inoculation into culture media, enabling embryo growth under axenic conditions, has been successfully carried out. The contamination rate was about 11% and the embryo development was totally similar to that of embryos inoculated under laboratory conditions. An alternative method holds the embryos in endosperm cores in a salt solution for brief periods before excision and inoculation in a laboratory. In this case, the contamination rate is lower (5%) but the gemmule appearance is delayed. The comparative advantages of both methods are discussed. Techniques and equipment are described as well as the subsequent development of the embryo and their transfer into soil.

With a view to long term storage, culture of very small embryos which represent a choice material for cryopreservation has been successfully carried out.

INTRODUCTION

Coconut, *Cocos nucifera* L. is propagated by seed. Nonetheless, the considerable weight and size of seednuts, the absence of dormancy and phytosanitary regulations make it difficult and costly to exchange and collect planting material.

In vitro culture of excised coconut embryos (Bah, 1986; Withers, 1987) makes it possible to simplify collection, transport and short-term seednut preservation conditions.

IN VITRO CULTURE OF EMBRYOS

PB 121 seednuts (MYD x WAT hybrid created by the IRHO/CIRAD), 10-12 months after fertilization were used.

The isolated embryos were placed on a culture medium composed of Murashige and Skoog mineral elements, Morel and Wetmore vitamins, 41 mg/l of Fe-EDTA, 100 mg/l of sodium ascorbate, 20 g/l of sucrose, 8 g/l of agar and 2 g/l of activated charcoal. The pH was adjusted to 5.5. The medium was sterilized by autoclaving at 115°C for 20 minutes.

The cultures were kept in the dark at 27±1°C until the gemmule appeared, then received light 12 hours a day (3000 lux).

Embryo development into plantlets

Embryo development involves three phases: lengthening, increase in weight and appearance of the gemmule (Photo 1). After 2 months of culturing, 6 to 20 per cent of the embryos have germinated. The gemmule lengthens (Photo 2) and the embryo is then placed

Table 1. Percentage of embroyos with a gemmule after 2 and 6 months in culture

Replicate No.	Time spent in culture or or seedbed (months)	Seedbed (control)	Cultured in laboratory (control)		Storage in KCl soln and inoculation in the lab		Inoculation into culture at the collecting site	
		Germinated nuts (%)	Uncontaminated embryos	Embroyos with developed gemmule (%)	Uncontaminated embryos	Embryos with developed gemmule (%)	Uncontaminated embryos	Embryos with developed gemmule (%)
1	2	36	93	6.4	94	5.3	88	9.1
	6	97	90	63.3	90	28.9	88	71.6
2	2	30	91	8.8	85	1.2	89	2.2
	6	96	85	54.1	80	16.2	77	44.1
3	2	40	91	20.9	87	1.1	88	1.1
	6	88	90	34.4	84	28.6	80	45.0
4	2	32	85	3.5	82	0.0	84	17.9
	6	86	82	43.9	74	23.0	84	42.9
Total	2	34.5	360	10.0	348	2.0	349	7.4
	6	91.7	347	49.0	328	24.4	329	51.4

Table 2. Contamination rate observed after one month of culturing

Replicate No.	Culturing in the laboratory (control)		Storage in KCl solution & inoculation in the laboratory		Inoculation into culture at the collecting site	
	No. of embryos cultured	Contamination (%)	No. of embryos cultured	Contamination (%)	No. of embryos cultured	Contamination (%)
1	96	3.1	97	3.1	98	11.2
2	99	8.1	89	4.5	99	10.1
3	97	6.2	91	4.4	99	11.1
4	89	4.5	90	8.9	94	10.6
Total	381	5.5	367	5.2	390	10.8

Different stages of zygotic embryo-culture

1. *Appearance of the gemmule*
2. *Lengthening of the gemmule*

3 & 4. *Well developed plantlet*

Different stages of zygotic embryo-culture

5. *Plantlets transferred to natural conditions.*
6. *Collection of embryo : Removal of the solid endosperm cylinder surrounding the embryo.*

Different stages of zygotic embryo-culture (continued)

7. *The endosperm protects the embryo during storage.*
8. *Preservation of disinfected endosperm cylinders in potassium chloride solution.*

on an auxin medium. After 4 to 6 months of culturing, the well-developed plantlet (Photo 3, 4) is transferred to natural conditions (Photo 5). The survival rate after 4 months in the prenursery is 81 per cent.

COLLECTION UNDER PROSPECTION CONDITIONS

Method of sampling

Removal of the solid endosperm cylinder surrounding the embryo (Photo 6) takes place in the open air. The endosperm protects the embryo during storage and disinfection with Ca hypochlorite (70% active chlorine) at a rate of 45 g/l (Photo 7).

Method of storage

(a) *Cylinder storage:* The disinfected cylinders are preserved in KCl solution (16.2 g/l) for a maximum of 14 days (Photo 8). At the laboratory, they are disinfected and the isolated embryo is cultured *in vitro*.

(b) *In vitro culturing at the collecting site:* After disinfection, the embryo is isolated behind an upturned packing case with a bunsen burner nearby, then rinsed with sterile distilled water and placed *in vitro* on a culture medium. Cultures can be preserved 2 months under a shelter before being moved to the laboratory.

(c) *Equipment:* One bowl, 1 sponge, 1 small camping gas burner, 1 hammer, 1 knife, 2 pairs of forceps (30 cm), 2 cork borers (dia. 20 mm), a scalpel, soap, 1 litre of chlorine bleach, 3 or 4 half-litre bottles, a 2-litre beaker, 1 funnel, filter paper, a 1-litre flask. For 100 nuts the following items are required, in addition to the equipment listed above.

Equipment and consumable material	Storage in KCl solution	Direct inoc. into culture
Calcium hypochlorite, 225 g	+	+
Water, 10-15 litres	+	+
One rack of one hundred 30-ml jars each with 15 ml of sterile distilled water	–	+
Sterile petri-dishes, 20 nos	–	+
Two racks of fifty 25 x 100 mm culture tubes with 20 ml of medium	–	+
One rack of one hundred 30-ml jars each containing 15 ml of sterile distilled water + 16.2 g/l of KCl	+	–

Results

(a) Storage in KCl solution and culturing in the laboratory

This method results in a very low contamination rate (5%), identical to that obtained with laboratory *in vitro* culturing. Gemmule development, however, is delayed (Table 1).

(b) Direct culturing at the collection site

This method results in a contamination rate of 11% (Table 2), though embryo development is similar to that obtained with *in vitro* culture in the laboratory (Table 1).

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Technical Session 4

CROP MANAGEMENT

THRUST AREAS IN COCONUT MANAGEMENT

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Abstract: The productivity of coconut in India is 30 nuts per palm per year against the potential of more than 100 nuts per palm per year. Yield of the crop in the major coconut growing states in the country is also far from satisfactory, the average yields being 33, 44 and 54 nuts per palm per year in Kerala, Tamil Nadu and Karnataka respectively. There is a dire need to improve the productivity of the palm in the present context of rising oil imports to meet the ever-increasing domestic needs.

The reasons for the low productivity of coconut could be traced to (1) lack of irrigation, (2) inadequate manuring, (3) presence of a large proportion of senile and unproductive palms in every garden, (4) low genetic potential of the native palms, (5) prevalence of root (wilt) and other diseases in the major coconut growing tracts, and (6) cultivation of coconut even in the marginal and submarginal lands. For increasing and sustaining the production of coconut, three basic requirements have to be satisfied immediately, (1) irrigation (2) fertilization and (3) regular system of replanting and underplanting with productive palms.

The beneficial effect of irrigation on nut production has been quantified to range from 74.2 per cent to 209 per cent in various types of soils. In conjunction with adequate application of fertilizers, the beneficial effect of irrigation increased by 216 per cent showing conspicuous interaction between irrigation and fertilizer in nut production.There is a need to develop a sound fertilizer management technology for coconut, taking into account the soil build-up of nutrients as well as changes in other physicochemical characteristics.

Multi-storeyed cropping systems and high density multispecies cropping system are presently being tested in greater detail.

The senile palms and those that are highly diseased need a systematic replacement maintaining optimum plant population. While replanting, proven genetical materials should be made available to the farmer so as to ensure that every seedling newly planted will ultimately fall in the high yielding category.

INTRODUCTION

India is the third largest coconut producing country in the world producing annually 6887 million nuts from an area of 1.19 million hectares (Thampan, 1988). The contribution of the country to the global coconut production is 18 per cent. Among the major coconut producing states in the Indian Union, Kerala ranks first with a share of 57.74 per cent in area (0.69 million ha) and 49.3 per cent in production (3395 million nuts). The three states in the peninsular India, Kerala, Tamil Nadu and Karnataka, together account for 86.9 per cent of the area under coconut in the country.

The national average of coconut production in India is 5774 nuts per hectare per year. The yield performance of the crop in the major coconut producing states in the country is also not impressive. It is 5023 nuts per ha in Kerala, 5173 nuts per ha in Karnataka and 10987 nuts per ha in Tamil Nadu, which works out to 33, 44 and 54 nuts per palm per year,respectively. There is a dire need to improve the productivity of coconut in the country in the present context of rising oil imports to meet the ever increasing domestic needs. It is estimated that, at the present level of consumption, the demand for coconut oil towards the close of the century would be 10,400

Table 3. Influence of irrigation on yield (nuts/palm/year) in sandy loam, Chalakudy

Irrigation	Pre-experimental period (1982)	Experimental period			
		1983	1984	1985	1986
Irrigation with 500 l of water at 75 mm CPE	63.1	73.9	40.8	104.1	96.1
,, 50 mm CPE	67.1	24.5	39.8	112.8	113.9
,, 25 mm CPE	61.1	60.8	39.9	129.9	119.3
Irrigation with 200 l water once in 3 days (cultivator's practice)	65.1	69.7	41.4	124.7	131.8
No irrigation	59.2	80.8	31.7	95.9	77.1
CD (0.05)	..	...	..	15.6	24.1

Source: Annual Report, ARS, Chalakudy, 1984-85, 85-86, 86-87

from the commencement of irrigation was also maximum in the low yield group (38.3 nuts/palm) followed by medium yield group (32 nuts/palm). This suggests clearly that low and medium yield groups respond better to irrigation.

A recent study on the effect of irrigation on the growth and yield of coconut cv. WCT in Chalakudy Command Area (sandy loam) indicated that irrigation influenced the nut yield only from the third year onwards. The increases in nut yield due to basin irrigation at the rate of 500 l of water per palm when the cumulative pan evaporation reached 50 mm and 25 mm over no irrigation were 16.8 and 34.0 per palm respectively in the third year (1985) and 36.8 and 41.6 per palm respectively in the fourth year (1986) of the experimentation. The cultivators' practice of irrigating once in 3 days (200 l of water/palm) showed yield increase of 28.8 per palm and 54.8 per palm during these periods indicating the need for frequent irrigation with lesser amounts of water in the sandy loam soil.

At CPCRI, Kasaragod, it was found that irrigation with 20 mm water at an IW/CPE ratio of 0.75 led to an yield increase of 14 nuts per palm (from 55.3 to 69.3) in red sandy loam. In conjunction with manuring the yield increased to 94.8 nuts per palm per year. These experimental evidences prove conclusively that irrigation is the most important input to increase coconut production in Kerala. A comparison of the productivity of the coconut under irrigated conditions in the three major coconut producing states in India shows that Kerala has a higher potential than Tamil Nadu or Karnataka in spite of the prevalence of the deadly root (willt) disease. This would also suggest that if irrigation facilities are improved in the coconut growing tracts, the state would attain the top most position in coconut productivity. There is, therefore, every all experiments conducted in Kerala, the magnitude of response depending on the soil type. At Nileswar, where the soil type is littoral sand, the increase in yield obtained due to irrigation with 800 l of water per palm per irrigation throughout the summer months of January to May, was 85.4 nuts per palm over the pre-irrigation yield (11.2 nuts/palm). The unirrigated crop was a poor specimen with tapering stem, small crown and 6 to 10 leaves (Table 1).

Table 1. Growth and yield response of coconut cv. West Coast Tall to summer irrigation in littoral sand, Nileswar, 1959-65

Irrigation	No.of functional leaves/palm	Nut yield/palm
Pre-irrigation	9.2	11.2
Post-irrigation	43.2	96.6
Increase over pre-irrigation	34.0	85.4

In another study in the red sandy loam soils at Nileswar, 60 WCT palms belonging to four age groups were marked out based on their pre-irrigation production status as 'poor' (0-20 nuts/palm/year), 'low' (20-40 nuts/palm), 'medium'(40-60 nuts/palm) and 'high' (above 60 nuts/palm) and irrigation imposed at 1000 l per palm during the rainless months (December to May). The study lasted for 11 years from 1964. The immediate effect of irrigation was an improvement in the number of functional leaves followed by increase in the production of female flowers and setting percentage which culminated into increased yield per palm. The over all increases in female flower production and setting percentage were 28.8 per cent and 39.8 per cent, respectively (Table 2).

In this experiment the yield response of the palms was assessed separately for the 'transit' period (3 years) and 'yield response period' since it usually takes 42 to 44 months for the palm to express its response to management practices (spadix initiation to ripening of nuts). The maximum yield increase of 25.9 nuts per palm in the transit period was recorded by low yield group (25.9 nuts/palm) closely followed by the medium yield group. The high yield group recorded a comparatively low increase in yield (12 nuts per palm) during this period. Thus, the influence of irrigation on spadix characters was more pronounced in low and medium yield group. The over all increase in yield was 20 nuts per palm working out to 48.3 per cent. A further assessment of the yield over a period of 8 years showed an increase of 9, 13, 8 and 12 nuts, respectively, for poor, low, medium and high yield groups, with a mean increase of 11 nuts per palm per year. The average increase over 11 years

Table 2. Influence of irrigation on female flower production and setting percentage in WCT palms in red sandy loam, Nileswar, 1964-'75

Female flowers produced/palm			Increase in setting percentage	Nut yield/palm/year		
Pre-irrig-ation	Post-irrig-ation	Incr-ease %		Pre-irrig-ation	Post-irrig-ation	Incr-ease %
130.4	167.9	28.8	39.8	42.2	73.4	74.2

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At CPCRI, Kasaragod, it was found that irrigation with 20 mm water at an IW/CPE ratio of 0.75 led to an yield increase of 14 nuts per palm (from 55.3 to 69.3) in red sandy loam. In conjunction with manuring the yield increased to 94.8 nuts per palm per year. These experimental evidences prove conclusively that irrigation is the most important input to increase coconut production in Kerala. A comparison of the productivity of the coconut under irrigated conditions in the three major coconut producing states in India shows that Kerala has a higher potential than Tamil Nadu or Karnataka in spite of the prevalence of the deadly root (willt) disease. This would also suggest that if irrigation facilities are improved in the coconut growing tracts, the state would attain the top most position in coconut productivity. There is, therefore, every justification to invest in building up of irrigation facilities to cater to the needs of small and marginal farmers who own the majority of the coconut holdings in the state. Extension of assistance to the farmers for construction of wells and installation of pumpsets including drip irrigation system, could go a long way in bringing a substantial area under irrigation.

Fertilizer application

Coconut is a heavy consumer of soil nutrients, particularly N, K and Cl. It is, therefore, essential that adequate supply of nutrients is ensured for sustaining the productivity of the crop. Earlier fertilizer trials conducted at Pilicode has indicated that in laterite soils, a palm required 0.50 kg N, 0.25 kg P_2O_5 and 1.25 kg K_2O per year for economic yield expression. These results were later tested for confirmation in cultivators' holdings also. In the reclaimed alluvial soils of Kuttanad, the highest increase in nut yield was obtained when the crop was supplied with 0.225 kg N, 0.340 kg P_2O_5 and 0.680 kg K_2O per palm per year. At Balaramapuram, where the soil type is red loam, consistent effects on nut production have been recorded due to the application N and K. Phosphorus application has shown beneficial effects in the early years only. In this long term experiment, the response of the test variety WCT to applied NPK fertilizers has been highly conspicuous in the initial years of experimentation, but the response tended to diminish with time except for potassium. This study has clearly established the role of K in coconut nutrition (Table 4).

Table 4. Effect of NPK on the yield expression of coconut cv. WCT in red loam, Balaramapuram

Level of NPK (kg/palm/year)		Cumulative yield/palm (1976-85)
n_0	0.000	136.57
n_1	0.340	248.21
n_2	0.680	324.81
p_0	0.000	192.79
p_1	0.225	256.76
p_2	0.450	260.03
k_0	0.000	27.64
k_1	0.450	318.23
k_2	0.900	363.72
CD (0.05)		72.71

Source: Annual Report,CRS, Balaramapuram,1984-1985

Note: NP, NK, PK interactions were positive giving maximum yield at highest levels of added fertilizer doses. $N_2P_2K_2$ treatment gave the highest yield of 79.1 nuts/palm/year. Nitrogen application in the absence of K is harmful to the palm.

One of the major factors influencing the efficiency of fertilizer utilization by coconut is the concentration of the nutrients within its active root zone. Therefore, fertilizer application should be adjusted in such a way as to ensure a fair degree of concentration of the nutrients in the coconut basin. Radiotracer studies with labelled ^{32}P at the KAU have confirmed that the active root zone of coconut is within a radius of 2 m from the bole and that the vertical distribution of active roots is mainly confined to 60 cm. This implies that the fertilizer should be applied in the basin itself for maximum nutrient use efficiency. The studies conducted at Pilicode have shown that application of 0.5 kg N, 0.32 kg P_2O_5 and 1.2 kg K_2O per palm per year in two splits was more beneficial to the crop than single application. In the reclaimed alluvial soil of Kuttanad, it was found that annual application of 0.375 kg N, 0.478 kg P_2O_5

and 0.875 kg K_2O per palm in basins was more effective than the application of this dose in linear trenches or surface broadcast. These results agree with the root activity pattern of coconut established with ^{32}P studies.

Long term effects of NPK fertilizer's have both beneficial as well as harmful effects in acid soils. In the red loam soils of Balaramapuram, Anilkumar and Whahid (1988) observed that regular application of ammonium sulphate, superphosphate and potash over a period of 20 years influenced the soil characteristics to varying degrees. With increasing rates of applied ammonium sulphate the pH decreased markedly from 4.88 to 4.38 in plots receiving N at 0.320 kg per palm per year. A similar trend was noticed in the case of available Mn also. In contrast to this, available S increased with the incremental doses of N. This effect was noticed not only in the upper soil layer but also at various other depths up to 100 cm. It is likely that prolonged use of ammonium sulphate would lead to Mn erosion through excessive dissolution of Mn oxides and leaching, with resultant harmful effects on coconut. Superphosphate application has tended to increase soil build up of P necessitating to skip its application when P is over 200 ppm in the surface layer to about 40 ppm in 75 to 100 cm depth. These studies indicate the need for developing a sound fertilizer management strategy for a perennial crop like coconut taking into account the soil build up of the nutrients as well as changes in the soil physicochemical characteristics.

Varietal response to nutrients

A number of hybrids and cultivars have been popularised in recent years in order to boost coconut production. However, there has been practically no attempt to work out their nutrient requirements. With the result, the fertilizer recommendations remain the same for the different varieties although regional adjustments in fertilizer doses have been suggested. In a study at Pilicode it was observed that the leaf concentration of the plant nutrients varied significantly with the varieties or hybrids. WCT, Gangabondam, Natural Cross Dwarf, Lakshadweep Ordinary and Philippines Ordinary were found to be more efficient as compared to the others, in N absorption. WCT accumulated comparatively more P in the leaf. The varieties such as Cochin China, Philippines Ordinary, Lakshadweep Ordinary, Gangabondam and NCD contained more K in their leaves. Incidentally, the variety Java was observed to have the least concentration of N, P and K in its leaves. The leaf iron content of WCT x G hybrids was the least while that of Cochin China was the highest. Very high accumulation of Mn (521 ppm) was observed in Lakshaganga hybrids. A recent study at CPCRI indicated that the hybrid Dwarf x Tall was more efficient in the utilization of added nutrients than T x D and WCT. More studies are necessary to find out the optimum levels of plant nutrients for different coconut varieties.

Underplanting and replanting

Coconut, essentially, is a crop of the small holder in Kerala. In each holding, palms of varying age groups could be seen ranging from the recently planted seedling to senile palms. The bearing area under coconut in Kerala is 0.44 million ha out of the total area of 0.69 million ha (1984-85). The percentage of non-bearing area to the total works out to 34.89 (Department of Economics & Statistics, 1986). No detailed study has been made in India on the optimum time for underplanting and replanting coconut gardens. Underplanting is the rule in Kerala where coconut has been under cultivation for long. Very often seedlings are underplanted even before the adult palms in the gardens have ceased to give economic returns. This results in overcrowding, with consequent yield decline of the adult palms and poor growth of the young ones. Replacing the senile palms is a continuous process in coconut culture which calls for supply of elite planting materials with proven efficiency. There is sufficient justification for enhancing the production of hybrids since they have higher production potentials. The production of hybrids and stable varieties suited to specific needs has to be intensified so as make sure that every coconut newly planted will ultimately fall in the high yielding category. The varietal response to underplanting especially with reference to hybrids has to be studied. A strategy for replanting needs to be worked out in order to avoid the present tendency of over-crowding the coconut holdings.

The root (wilt) disease

The problem of root (wilt) disease complicates the coconut management scene. In the disease affected areas, the palms under varying degrees of infection could be seen with differential yielding ability. The yield decline due to root (wilt) disease has been estimated within a range of 13 to 74 nuts per palm depending on the severity of the disease. Experimental evidences pin point the need for removal of all the diseased palms so as to mitigate the chances of further spread of the disease. However, the cultivators are reluctant to oblige as there is no assurance against the resurgence of the disease. Further, they are also inclined to believe that they can 'live with the disease' since root (wilt) is not lethal, but only a debilitating disease. Any systematic replacement of these palms would meet with success, if only the coconut growers are adequately compensated. The financial facilities extended to the rubber growers could be adopted for coconut also with success. This is necessary because unless all the diseased palms in an area are removed *en bloc* and the source of infection destroyed prior to replantation, the disease is likely to occur perhaps in a more virulent form.

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COCONUT DEVELOPMENT IN INDIA AND ITS FUTURE

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Abstract: Coconut production has been stagnant in India since seventies. The present production in the country is only marginally higher than the production level of 1970-71. The production and productivity of coconut in Kerala State have been on the decline since 1960. On the other hand, production of coconut in other major states like Tamil Nadu, Karnataka and Andhra Pradesh recorded significant increases during the corresponding period. The main cause of decline in production of coconut in the country is the low productivity manifested in Kerala State which is attributed to the continuous neglect of the coconut holdings over centuries without adequate management practices, unirrigated farming system, prevalence of root (wilt) disease, preponderance of senile and uneconomic palms and the existence of "gentlemen farming".

The targeted demand for coconut by 2000 AD is estimated at 12172 million nuts which is roughly 100% more than the present production level of 6404 million nuts. To narrow down the gap between the demand and supply it is necessary to achieve a growth rate of 4.5% per annum in production in the coming years. Unless substantial increase in production takes place in Kerala which is the premier state of coconut production the production improvements that may take place in other states may not make any significant impact in the over all availability of coconut products in the country. In Kerala roughly 40% of the coconut area is in the grip of the dreaded root (wilt) disease and the coconut growers in the state are essentially small and marginal. Production and productivity programmes in the country should cover disease management in Kerala and other long term and short term measures. The future strategy of coconut development shall encompass the following components: (i) rehabilitation measures in the root (wilt) affected areas in Kerala State, (2) productivity improvement in the traditional coconut belts especially irrigation, (3) expansion of area under coconut in favourable locations, (4) production of quality planting materials and (5) development of post-harvest technology and market promotion. By adopting suitable measures it is possible to achieve the targeted production by the turn of the century.

INTRODUCTION

India ranks third in coconut production in the world. Coconut is a littoral crop wherever it is grown in the world. In India too the situation is not different except for a few pockets of cultivation in interior areas. Hence coconut continues to be a deficit commodity in the country. Sizable area although can be termed as potential for coconut production large scale expansion of area under the crop would not be realized in the normal course due to limitations imposed by agroclimatic conditions. Coconut production has been rather stagnating if not declining in the country since seventies.

AREA AND PRODUCTION

Coconut is grown in the country in an area of 12.23 lakh hectares with an annual production of 6404 million nuts. Kerala is the premier state both in area under and total production of coconuts, accounting for the major share in area of 58% and less than 50% in production. The four southern states namely Kerala, Tamil Nadu, Karnataka and Andhra Pradesh together contribute more than 90% of the area and production (Table 1).

TRENDS IN PRODUCTION

The production data over the last

Table 1 All India final estimate of coconut (1986-87)

States/Union territories	Area ('000 ha)		Production (million nuts)	
	1985-86 (Revised)	1986-87	1985-86 (Revised)	1986-87
Andhra Pradesh	47.4	48.1	195.8	198.8
Assam	8.0	8.0	54.3	54.3
Goa	22.9	22.9	106.3	106.3
Kanataka	205.6	207.7	1062.0	1072.4
Kerala	704.7	683.8	3377.0	3068.0
Maharashtra	7.0	7.0	81.2	81.2
Orissa	27.6	27.6	134.9	134.9
Tamil Nadu	149.6	171.9	1494.5	1423.3
Thripura	2.7	2.7	2.1	2.1
West Bengal	17.0	17.0	186.6	186.6
Andaman & Nicobar Islands	28.7	28.7	33.8	33.8
Lakshadweep	2.8	2.8	24.0	24.6
Pondicherry	1.6	1.6	17.8	18.1
All India	1225.6	1229.8	6770.3	6404.4

Source Directorate of Economics & Statistics, Ministry of Agriculture, Government of India

Table 2. Production of coconut in different states (million nuts)

Year	Kerala	Tamil Nadu	Karnataka	Andhra Pradesh	All India
1970-71	3981	942	732	157	6075
1975-76	3440	1099	767	167	5829
1980-81	3036	1354	890	175	5942
1985-86	3377	1494	1062	196	6770
1986-87	3068	1423	1072	199	6404

three decades reveal that there has been a steady decline in production since seventies, even though the area has increased from 0.65 million ha in 1955-56 to 1.23 million ha in 1986-87. This was mainly due to the fact that during the corresponding period there was a decline in the productivity of coconut in Kerala which became manifest on the over all production of coconut in the country. The production in the other major states like Tamil Nadu, Karnataka and Andhra Pradesh showed perceptible improvement which could offset the negative effect of the decline in production in Kerala state on the total production in the country. The increase in production in Tamil Nadu during the period from 1970-71 to 1986-87 was 51%, in Karnataka it was 46% and in Andhra Pradesh 27% (Table 2).

In Kerala there was a continuous decline in productivity also. It is only around 4500 nuts/ha as against 9973 nuts in Tamil Nadu and 5191 nuts in Karnataka. Productivity in Kerala was below the all India average of 5787 nuts in 1984-85. Kerala accounting for 58.6% of total area constituted only 45.9% of total productuion whereas Tamil Nadu with only 12.2% of total area accounted for 23.9% of production and Karnataka with 16% area produced 16.1% of total production in 1983-84. Decline in production in Kerala was drastic since 1971-72.

Reasons for the declining trend in productivity in Kerala are (1) continuous neglect of coconut holding, (2) unirrigated farming system, (3) prevalence of root (wilt) disease, senile and uneconomic palms and (5) gentlemen farming.

DEMAND FOR COCONUT AND COCONUT PRODUCTS

Coconut is in demand for edible and non-edible purposes in the country. In the edible form coconut is consumed as tender nut, as fresh mature nut, edible copra, desiccated coconut, and coconut oil for house hold uses. In the non-edible form it is in demand for seednut purposes, religious and social functions and for conversion into milling copra. The estimated consumption pattern indicates that, around 40% of the total production finds use in non-edible section or for commercial purposes.

As coconut production stagnated in recent years, the production and supply of coconut oil also have stagnated. Till early seventies coconut oil enjoyed an inelastic demand in many end uses. However, the technological advances, of late, facilitated the use of comparatively cheaper oils in different areas where coconut oil had been in use. In addition, occasional high prices and frequent price fluctuations of coconut oil accelerated the process of substitutions. As a consequence coconut oil suffered continuous erosion in its demand, even though the production and supply remained stagnant. The growth in population was the major factor in arresting the downward trend in prices of the oil since seventies. It is also interesting to note here that the prices of groundnut oil, the major edible oil in the country increased by 343% since 1970-71 whereas the increase in prices for coconut oil during the same period was only 252%.

The production of coconut oil in India varies between 0.2 and 0.24 million tonnes, out of which more than 50% finds its use in toiletary purposes. In this sector coconut oil enjoys an inelastic demand because of its special qualities. The demand also is likely to go up with the growth in population.

The availability of vegetable oils in the country from all sources is placed at 4 million tonnes of which the share of coconut is 6%. The total demand for vegetable oil for various end uses in the country is estimated at 5.85 million tonnes at a minimum per capita consumption of 5.5 kg per annum. The current demand for coconut oil could be placed at 0.35 million tonnes. Hence the demand supply gap is 0.14 million tonnes of oil equivalent to 1100 million nuts. The consumption of vegetable oil is on the increase at an estimated rate of 4.7%. The consumption rate of coconut oil also is likely to increase more or less at the same rate. Moreover, the demand for fresh nuts and edible products is also expected to go up with the increase in population and improvement in standard of living. As such, the over all demand for coconut products during the period ending 2000 AD is expected to grow at the rate of 4.5% per annum. On this basis, the demand projection for coconut till 2000 AD is shown in Table 3.

Table 3. Demand projection for coconut products in India

Year	Nuts in million
1988-89	7500
1989-90	7838
1990-91	8190
1991-92	8559
1992-93	8944
1993-94	9346
1994-95	9767
1995-96	10207
1996-97	10666
1997-98	11146
1998-99	11648
1999-2000	12172

The projected demand by 2000 AD is almost double the present level of production of 6400 million nuts. In the case of Kerala the average growth rate over a period of 16 years was negative both for area and production. Consequently, the average growth rate in the country was only 1.10% for area and 0.34% in production during the same period. The growth rate in the country would have been negative, had it not been for the encouraging trend recorded in states like Tamil Nadu, Karnataka and Andhra Pradesh.

To achieve the targeted production, it is imperative to envisage and implement suitable programmes during the next plan periods. The present situation is not at all encouraging in this respect. Although considerable area is termed as potential for coconut culture in various parts of the country, large scale expansion of area under coconut would not be realized in the immediate future due to limitations imposed by agroclimatic conditions. To narrow down the gap between the demand and supply, significant increase in production in Kerala is a prerequisite. Unless substantial increase in coconut production takes place in Kerala, production improvements that may take place in other states may not create any impact in the over all availability of coconut products in the country.

Hence the future strategy of coconut development should be based on the following components: (1) productivity improvement measures in the traditional coconut areas with special emphasis on the disease affected areas of Kerala state, (2) expansion of area in favourable locations, (3) production and supply of quality planting materials, (4) development of post-harvest technology and (5) market promotional programmes.

(1) Productivity improvement in traditional belts

To increase coconut productivity in the country there are two basic requirements viz., promotion of irrigation and regular underplanting and replanting of the unproductive, senile and disease affected palms. It was quite unfortunate that irrigation was not given attention in the previous developmental programmes implemented in the country. When water is made available in coconut lands intercropping and mixed farming could be very successfully introduced. It has been already proved that introduction of compatible crops in the garden would ensure not only increased net returns, but also could rejuvenate the palms by hastening the organic recycling process. In addition, intercropping also generates more employment opportunities to the owners. Such a farming practice could generate positive response even in the root (wilt) affected tracts.

The Coconut Development Board

since its inception has been implementing programmes to achieve these objectives. Integrated farming in coconut small holdings in Kerala aims at providing improved planting materials, promotion of irrigation and multispecies cropping in coconut gardens. The scheme is presently implemented in an area of 10000 ha in selected operational units of 500 ha each. The financial target is Rs 2.84 million.

In order to promote and popularise irrigation facilities, the Board provides a financial assistance of Rs 1000 for installation of pumpsets and up to Rs 10000 for installation of drip system of irrigation per farmer. So far 3033 pumpsets have been installed under this programme for which the Board has released Rs 2.04 million as its share of subsidy. An amount of Rs 0.3 million has been already earmarked during the current year for provision of drip irrigation and construction of pick-ups in Kerala, Karnataka, Tamil Nadu and Andhra Pradesh. The Board also assisted the state governments of Kerala, Tamil Nadu and Andhra Pradesh for the removal of disease affected palms and the rejuvenation of the existing gardens.

(2) Expansion of area in favourable locations

Maximum expansion of area under the coconut was achieved during the period between 1955-56 and 1971-72. During the last decade commencing from 1974-75 the growth rate achieved under area expansion was 0.7% per annum whereas it was 4.5% per annum until 1971-72. In both traditional and non-traditional coconut belts not less than 0.1 million ha of suitable area is available for further expansion of coconut culture. To encourage farmers for taking up coconut culture, the coconut Development Board provides capital subsidy to the tune of Rs 3000 per ha for fresh planting of coconuts. This scheme is being implemented in all the states and Union territories. About 39500 farmers have already benefited under the scheme so far. The board has already released an amount of Rs 18.4 million to bring an additional area of 17000 ha under coconut. Under the same programme of Rs 3 lakh seedlings were planted along the canal embankments in Orissa by incurring an expenditure of Rs 4.19 million. The same programme is in operation in Karnataka too where the budget provision during the VII Plan period is Rs 0.61 million. Similarly, an area of 220 ha of government waste land (*khas* lands) in Tripura was planted with coconut by incurring an expenditure of Rs 0.95 million. Total provision under the scheme during the VII Plan is Rs 2.6 million. With the capital subsidy and other incentives the area expansion programme is gaining momentum in all the traditional and non-traditional areas.

(3) Production and supply of quality planting materials

The basic requirement for any crop improvement programme is the availability of good quality planting material. For undertaking rejuvenation of the existing gardens and area expansion programme good quality planting material is a prerequisite. Annual requirement of planting material in the country, for new planting (30000 ha), replanting, underplanting and rehabilitation in root (wilt) affected areas will be 15 million seedlings. The total production of seedlings is estimated at 10 million every year, of which 6 million seedlings are produced in various state government nurseries and the balance 4 million seedlings in private nurseries and growers' gardens. It is evident that a gap in demand and supply of seedlings already exists.

In order to enhance the production potential of quality planting materials required for the regular programme of new planting and replanting the Board has been promoting production of ordinary variety and hybrid seedlings. For the production of hybrid seedlings seed gardens were established and maintained in the states of Kerala (200 ha), Karnataka (200 ha), Tamil Nadu (100 ha) and Orissa (40 ha). An amount of Rs 4.7 million has been so far incurred on the establishment of the farms. The board also has been assisting the states of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and Orissa for the production of T x D hybrids. During the VII Plan period an amount of Rs 5.7 million has been spent on this programme for a production of 0.41 million T x D seedlings. The Board is also assisting various state governments and other agencies to procure good quality seednuts for the production of seedlings. So far the Board has procured 32 lakhs seednuts and supplied to various state governments. Similarly, 10 regional coconut nurseries for the production of ordinary variety seedlings were established in different states during the VI plan period. In addition, four demonstration cum seed production farms are being established, with the objective of utilizing them as sources of reliable planting materials of all improved cultivars and hybrids and also for demonstration purposes. An amount of Rs 3.1 million has been already spent on these farms. When all these farms attain full production capacity, 1.5 to 2.0 million hybrid seedlings are expected to be produced per annum by 2000 AD.

(4) Development of post-harvest technology

Post-harvest processing in coconut as such is limited to copra drying and oil milling at present. Development of appropriate processing technologies for the fuller utilization of the major products and byproducts assumes considerable significance under the prevailing conditions in our country. At present the entire coconut industry is dependent on coconut oil. This situation creates considerable hardships to the farmers and processors alike.

Preparation of desiccated coconut and coconut cream, utilization of coconut water and skimmed milk in various food products, preservation of sweet toddy, utilization of coconut shell for the manufacture of activated carbon and shell flour of required mesh size and briquetting of coir pith are some of the areas where intensified efforts are to be directed. Under the coconut technology development centres, the Board promotes and sponsors technology research, extends aid to industries for adoption of new technology and assists artisans for the manufacture of handicrafts. The fund earmarked for this purpose is Rs 4.5 million of which Rs 3.0 million has been spent already.

With the introduction of various coconut products in the market, the exclusive dependence on coconut oil would vanish, and the farmers are certain to get economic prices for their produce. Moreover, the industries would generate more employment opportunities to the people who are otherwise unemployed/underemployed in the present Indian context.

(5) Market promotional programmes

To promote marketing of coconuts and its products the Board has conducted a series of studies on consumption, acceptability of desiccated coconut and other market research studies on price spread, demand and consumption. Sales counters are also being opened at the head-quarters of the Board and other sub-offices, in different cities, to promote marketing of various coconut products.

It is expected that with the implementation of the programmes and with the active participation of the multitude of farmers the production base would be strengthened and the targeted production would be achieved by the turn of the century.

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COCONUT HYBRIDS FOR THE SOUTH PACIFIC ISLANDS

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Abstract: Coconut palm area in South Pacific covers more than 600,000 hectares. For this part of the world the coconut palm is an important source of product (foods, materials) and exchange earnings (copra, coconut beverage, coconut milk, desiccated coconut etc.). It is often the primary source of exports. The trees (for the majority talls) are senile and the whole of the South Pacific countries need or are on replanting programme. Without vegetal material and the constraints imposed on the introduction of coconut varities (FAO guideline, local decision) these programmes do not always take into account the latest results of the research and particularly concerning hybrids utilization. It is the work of the Coconut Research Centres to as yet confirm details of specific coconut varieties available in the region and their combining ability or to discover new promising hybrids. But results obtained presently permit to realize in a short time (5 years) that in coconut development programmes using known hybrids in all South Pacific countries, the precocity and yield are plainly superior to the traditional tall varieties.

INTRODUCTION

Coconut palm area in the South Pacific Islands covers more than 600,000 hectares : Papua New Guinea (265,000), Western Samoa (67,500), Fiji (66,000), Solomon Islands (59,000), Tonga (40,000), Tahiti (40,000), Kiribati (8,000), Cook Islands (7,000), New Caledonia (6,000), Niue (3,200), Tuvalu (2,100), Vanuatu (70,000) and others (15,000). The South Pacific Region is a minor producer compared to the Philippines (3,200,000 ha) and Indonesia (2,800,000 ha) and has very little influence on determining the world market prices for copra and coconut oil. However, for almost all South Pacific Island countries, coconut provides an important source of foreign exchange and for many it is the primary source of export earnings. In addition to this it provides the food, fibre and energy needs of the small holders in many ways : coconut kernel and water for food and animal feed, wood for timber and fuel wood, leaves for roofing house, carry-bag, mat and broom and husk fibres for rope and mattress. It is estimated that about 40% of the coconut produced is used for food. Since the coconut palm provides the many needs of the small holder it will always have a sgnificant position in the future development of agriculture in the region. In the coral atoll islands of the South Pacific, coconut is the most adapted crop and is likely to remain the most important crop.

Over the last two or three decades there has been significant decrease in production and yield of coconut in the South Pacific. Perhaps the major cause of the decline has been the senility of the palm and poor management. For instance in Fiji it has been estimated that about 40% of palms are over 50 years old and give very low yields. Production in Fiji has declined from about 40,000 t copra in early 1960's to about 20000-25000 t in recent years. Similar trend is seen in many other Pacific Islands.

Development programmes have been initiated in some South Pacific Islands to replace the old palms with selected talls or hybrids palms. Replanting the old palms grove with improved genetic material is the only realistic solution to increase production.

The majority of the coconut area in the South Pacific is planted with tall palms. Some programmes such as in Vanuatu, Unilever project in Solomon Islands and Tahiti, selected hybrids are used for the replanting programmes. However, some countries still use mass selection from the talls for their replanting programmes. With such planting improvement is likely to be very limited. Lamothe and Rognon (1986) showed that selection of tall population can only give very limited improvement. It is now well established that hybrids can substantially outyield the local tall varieties. Some countries have not taken up hybrids because of lack of testing of hybrids in the country and difficulties in obtaining the other and male parents from onside for hybridization work. Also lack of knowledge to manage the hybrids and insufficient staffs to carry out the testing and development work have discouraged some countries from taking up hybrids. Some very small countries also lack sufficient isolation and facilities to develop hybrid seed garden.

In this paper the availability of information on hybrid for various growing conditions in the region is discussed and attempt is made to predict suitable hybrids for various growing conditions.

To develop coconut in the region, in addition to planting improved hybrids, industries to process coconut and byproducts to higher value products need to be developed. In Brazil and elsewhere technology is available to process coconut into desiccated coconuts, coconut jam, coconut drinks and coconut cream. Banzon (1980) has showed the importance of coconut as a renewable energy source in Philippines. Introduction of some processing industries needs to be seriously considered to improve the export earnings from coconut.

SOIL AND CLIMATIC CONDITIONS

Soils

Due to its high adaptability, coconut is grown in most soil types in the South Pacific. Soils of the South Pacific Island can be categorised into two main types based on their origin, the volcanic soils of the high islands and the coralline soils of the low lying coral atolls. In the high islands coconut is generally confined to the coastal soils.

The coralline soils of the atolls and the sandy coastal soils of some high islands are generally very poor in organic matter but very rich in calcium. The degree of weathering and the amount of organic matter determine their fertility. They have very poor moisture retention capacity but are well drained and aerated. Mineral nutrition is a major limiting factor in these soils. In coralline soils pH values of around 8 or 9 inhibit the absorption of trace elements such as iron and manganese. Pomier (1969) found a good way of applying these trace elements and obtained very good absorption and growth of coconut. Later he found that nitrogen and potassium deficiencies occurred but these can be easily rectified with appropriate fertilizers.

In some countries, Vanuatu, Solomon Islands and Tonga, the coralline soils are overlaid with various thickness of alluvial deposits. These are generally rich soils which support good growth of coconut without additional fertilizers.

The soils of the volcanic islands vary greatly. Their fertility depends on their origin, thickness, degree of

Table 1. Iron and manganese interaction on weight of green matter per coconut palm (kg)

	Mn0	Mn1 (5g)	Mn2 (10g)	Fe levels (ppm)
Fe 0	31 (100)	35 (113)	29 (93)	28
Fe 1 (5 g)	100 (322)	120 (387)	125 (403)	37 **
Fe 2 (10 g)	125 (403)	156 (503)	158 (509)	39 **
Mn levels (ppm)	24	92 **	150 **	

( ) : per cent of Fe0 - Mn0
** : significant at 1 per cent

weathering and management by the farmers. Although the coconut palms are adapted to grow on most soils in the South Pacific they perform very poorly when grown on degraded and steepland soils. They respond well to mineral fertilization on most soils.

As mentioned earlier the first major difference between the two major types of soil is the pH value. Pomier (1969) showed that the main limiting factor for growth and yield on coralline soils, is iron and manganese deficiencies which is due to the blockage of uptake of these trace elements (Table 1).

Results obtained in Vanuatu by Eschbach and Manciot (1981) in better developed coralline soils confirmed the importance of trace element (Table 2).

Table 2. Correlations between Mn levels and growth in Vanuatu

Year	Leaf rank of foliar analysis	Average Mn level in ppm	Value of r
1	1	32	0.36 VI
2	4	27	0.73 *** VI
3	9	23	0.56 *** NL

VI : vigour index
NL : number of leaves
*** : significant at 0.1 per cent

For other types of soils (volcanic soils) more information is available on coconut fertilization in the South Pacific and agronomists concerned with fertilizer problems consider that economic returns can be obtained from fertilizer application provided good management of farm is maintained. N and K are generally most needed as large amounts of these are removed in the coconut sold out of the farms. Chlorine can become the limiting element in some countries such as Vanuatu (Daniel and Manciot, 1983). P, Mg and S deficiencies have been observed in many different countries, Tonga, Tahiti, Solomon Islands and Papua New Guinea. As regards the trace elements it appears that boron plays an important role in young stage of the coconut palm; deficiency can provoke the sudden stoppage of growth (in Vanuatu and Solomon Islands).

Climatic conditions

The South Pacific countries have humid tropical climate. The high volcanic islands generally have a wet windward side and a dry leeward side. Rainfall varies from under 2000 mm per year in the leeward side to over 3000 mm on the windward side. Moisture deficits can occur from about 2 months to 6 months between June and Novem-

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Climatic conditions

The South Pacific countries have humid tropical climate. The high volcanic islands generally have a wet windward side and a dry leeward side. Rainfall varies from under 2000 mm per year in the leeward side to over 3000 mm on the windward side. Moisture deficits can occur from about 2 months to 6 months between June and November in the leeward side. Relative humidity is generally high and evapotranspiration of between 2.5 mm to 6 mm/day is normal. Temperatures are generally moderate 20°C to 30°C but in some southern islands like Tonga and New Caledonia temperatures can be as low as 15°C in winter. Sunshine hours are generally between 1800 to 2400 per year. Between November and March tropical storms and cyclones can occur and pose serious problems for coconuts.

Water deficit is the most important factor in coconut growth and yield. The ideal rainfall is 150 mm per month, or 5 mm per day. Prolonged drought causes reduction of yield, but high water table level can reduce the effect of drought. For instance even though the annual water deficit is between 300 to 500 mm, coconut palms in Tongatapu island and Tonga produce good yields because the water table is stable at 1 to 4 m where the roots can easily reach. The high relative humidity generally occurring in the Pacific Islands reduces evapotranspiration and favour good growth and yield of trees.

Temperature determines the location of coconut palms which is a typical tropical crop. Zushun (1986) defined the limit for commercial coconut cultivation as areas having an annual mean temperature of about 23°C with a minimum monthly mean of at least 20°C and a continuous low temperature of below 13°C lasting no longer than 20 days. Zushun added that with an annual temperature of 22°C, with a minimum monthly mean of not less than 19°C and a low temperature of below 13°C lasting no longer than 30 days, the coconut palm can winter safely to produce a certain quantity of nuts, but when a very strong cold spell occurs all nuts are lost, the palms are affected to a certain degree and some even die. In New Caledonia and Loyalty Islands, where temperature goes down to 3°C to 8°C, fruit formation is affected and abortion of fruits is observed. But in Tonga where the temperature records below 15°C during the winter for short periods only, the yield of the coconut palms is not greatly affected. However, most South Pacific Islands have temperatures well above the limit and are well suitable for coconuts.

Coconut palm needs a minimum of 1800 hours of sunshine. Though it may be difficult to quantify energy received by coconut it is known that coconut can grow well and give yield with sunshine lower at 1800 hours per year (Mancoit, 1980). However, it is recommended to avoid areas receiving only part of the days sunshine, such as shaded areas close to mountains.

Wind can cause grave damage when in form of tropical storms or cyclones. Marty (1986) observed that trees with large bulbs are more resistant to storms. The talls and tall x dwarf hybrids withstand such conditions better. In addition to higher yields, the tall x dwarf hybrids produce leaves faster and hence develop the canopy quickly after damage by storms. Hence they have considerable advantage over the talls. For dwarfs to be utilized in seed garden they should be planted slightly deeper to facilitate anchorage of the root systems. Good mineral nutrition also make trees more resistant to tropical storms and cyclones.

VARIETAL TRIALS

Vanuatu varietal trial NH GC 1

This was the first varietal trial planted in Vanuatu. Two months after the start of research work at Saraoutou Research Station in 1962, Vanuatu imported seednuts of different varieties from Fiji and Solomon Islands with assistance from the South Pacific Commission. In January 1964 the imported and local varieties were planted in alternate lines to produce hybrids . Four hybrids Vanuatu Tall x Solomon Tall (VTT x SNT), Vanuatu Tall x Rennell Tall (VTT x RLT), Rennell Tall x Solomon Tall (RLT x SNT) and Malayan Red Dwarf x Rennell Tall (MRD x RLT) were obtained by artificial pollination or controlled natural pollination and three talls Vanuatu Tall (VTT), Rennell Tall (RLT) and Markham Valley Tall (MVY) by natural pollination. Six replications of these talls and hybrids were planted on volcanic (rich clay) soil with 18 palms per plot in 1969.

Vanuatu varietal trial NH GC 12

For this experiment four hybrids Vanuatu Red Dwarf x Vanuatu Tall (VRD x VTT), Vanuatu Red Dwarf x Rennell Tall (VRD x RLT), Vanuatu Red Dwarf x Rotuman Tall (VRD x ROT) and Vanuatu Red Dwarf x Tonga Tall (VRD x TGT) were obtained by artificial pollination. These hybrids were compared to Malayan Red Dwarf (MRD), a variety very susceptible to foliar decay *Mindus taffini* (FDMT). The trial was planted on rich coralline soil in 1980 in a randomised complete block design with 13 palms per plot.

Tahiti varietal trial

For this trial artificial pollination was carried out between the following talls and dwarfs, Tahiti Tall x Equatorial Green Dwarf (Brazilian Green Dwarf) (PYT2 x EGD), Tahiti Tall x Malayan Yellow Dwarf (PYT2 x MYD), Tahiti Tall x Tahiti Red Dwarf (PYT2 x YRD), Tahiti Tall x Niu Leka Dwarf (PYT2 x NLD) and Rennell Tall x Tahiti Red Dwarf (RLT x YRD). These were compared to Tahiti Tall (PYT2) and the trial was planted in sandy coral soil in 1965.

Papua New Guinea varietal trial

This experiment began in 1975 with five dwarf x tall hybrids : Malayan Red Dwarf x Rennell Tall (MRD x RLT), Malayan Red Dwarf x Malayan Tall (MRD x MLT), Malayan Red Dwarf x Solomon Tall (MRD x SNT), Malayan Red Dwarf x Gazelle Tall (MRD x GZT) and Malayan Yellow Dwarf x West African Tall (MYD x WAT or PB 121), and four talls: Rennell Tall (RLT), Karkar Tall (KKT), Markham Valley Tall (MVT) and Gazelle Tall (GZT). These were planted at two sites, at Keravat with 12 palms per plot, three spacings and two replications, and at Bubia with 12 palms per plot, two spacings and one replication.

Fiji varietal trial 1/70

The Fiji trial was planted in 1972 at Wainigata Research Station using seven hybrids: Malayan Red Dwarf x Niu Leka Dwarf (MRD x NLD), Malayan Red Dwarf x Tahiti Tall (MRD x PYT2), Malayan Red Dwarf x West African Tall (MRD x WAT), Malayan Red Dwarf x Markham Valley Tall (MRD x MVT), Malayan Red Dwarf x Malayan Tall (MRD x MLT), Malayan Red Dwarf x Rennell Tall (MRD x RLT) and Malayan Red Dwarf x Fiji Tall (MRD x FJT) and four local varieties, Fiji Tall (FJT), Routuman Tall (ROT), Niu Leka Dwarf (NLD) and Malayan Red Dwarf (MRD). The trial consisted of 9 single palm plots planted on sloped latosolic soil.

VARIETAL TRIAL RESULTS

Hybrid for volcanic islands

In the Vanuatu trial NH GC 1, since 1965 foliar decay caused by *Mindus taffini* (FDMT) destroyed most hybrids and tall varieties but this trial confirmed the tolerance of VTT x RLT hybrid to FDMT disease which was earlier observed in another planting at Saraoutou Research Station.

However, the information obtained from the NH GC 1 trial showed that the coconut hybrid MRD x RLT (Fig 1,2,3 and Table 3) was the most precocious and gave the highest copra yield per hectare corresponding to over twice that from the Vanuatu Tall. Unfortunately this interesting result cannot be applied in Vanuatu where the susceptibility of this hybrid to FDMT disease is high. However, this result is useful for other countries where this disease is not present.

The Papua New Guinea varietal trial was attacked by *Scapanes australis* and *Rhyncophorus bilineatus* and a lot of hybrid coconuts died. But Brook (1985) confirmed that MRD x RLT was the most vigorous of the trees and the most precocious. Yield of this hybrid is considerably higher than the other hybrids and talls in this experiment. Cumulative copra per hectare of this hybrid was over 700% better than the Gazelle Tall or Karkar Tall from Papua New Guinea. The hybrid MYD x WAT (PB 121), one of the hybrids most planted in the world, which is represented in this experiment did not give good yield. In Vanuatu, where approximately 40 coconut trees of this hybrid were planted in 1968, the yield was also lower than many other hybrids.

In Fiji, the low production recorded for between 6 and 10 years is due to the experiment being planted on a very poor hill slope site. Also here the hybrid MRD x RLT was found to be most precocious and better than the other hybrids and talls. Yields of only this hybrid was superior to the Fiji Tall Which was the control. Unfortunately this experiment was abandoned due to poor replication and hurricane damage but it again showed that MRD x RLT as the best hybrid.

In all these three experiment MRD x RLT has been compared to twelve hybrids, seven talls and two dwarfs. Its productivity was better than all other hybrids, talls or dwarfs.

Results to date show that MRD x RLT is the best hybrid for many areas in South Pacific. Unilever in Russell Islands, Solomon Islands, has already replanted several thousand hectares of this hybrid which gives more than 4.5 t of copra per ha per year.

Hybrid for atoll islands

The most important research work on atoll soil was carried out by Rangiroa Research Station (Pomier, 1983). Hybrid MRD x RLT was not tested because the yields of the coconut palm varieties RLT, VTT, MYD, NLD and PYT2 introduced from Tahiti island between 1963 and 1965 were disappointing. Also the hybrid obtained between Tahiti Red Dwarf and Rennell Tall gave low production (see Table 3).

Two hybrids that yielded well on coralline soils are EGD x PYT2 and YRD x PYT2. However, the first hybrid was found to be more precocious and its copra yield per nut, 290 g was higher than the second hybrid, 230 g. Hence EGD X PYT2 (Fig 4, 5 and 6) appears to be best suited for the coral atolls or islands with coralline soils.

Demonstration plots planted in Tahiti (Taravao) and Raiatea islands (Fetuna and Opoa) where Tahiti Tall PYT2 was compared to EGD x PYT2 and MYD x WAT (PB 121) also showed superiority of the Green Dwarf hybrid to the PB 121.

Faaroa seed garden in Raiatea island planted between 1978 and 1983 has produced 125,000 hybrid seednuts of EGD x PYT2 from 1984 to 1987 and the

Fig 1. Malayan Red Dwarf, Saraoutou Research Station, Vanuatu, 1968

Fig 2. Rennell Tall, Saraoutou Research Station, Vanuatu, 1969

Fig 3. Hybrid Malayan Red Dwarf x Rennell Tall, Saraoutou Research Station, Vanuatu, 1974

Fig 4. Brazilian Green Dwarf equivalent to Equatorial Guinea Green Dwarf, Faaroa Seed Garden, Tahiti Islands, 1988

Fig 5. Cook Tall equivalent to Tahiti Tall, Totokoitu Research Station, Cook Islands 1988

Fig 6. Hybrid Brazilian Green Dwarf x Tahiti Tall, Raiatea Island, Tahiti Islands, 1988

Fig 7. Natural hybrid Niu Leka Dwarf x Tonga Tall, Tongatapu Island, Tonga Islands, 1988

Fig 8. Natural hybrid Niu Leka Dwarf x Rotuman Tall, Oinafa, Rotuma Island, 1987

Fig 9. Hybrid Vanuatu Red Dwarf x Vanuatu Tall, Saraoutou Research Station, Vanuatu, 1987

Table 3. Yield of some coconut hybrids in South Pacific

	Soils of volcanic origin						Atoll soil Tahiti		FDMT disease Vanuatu NH GC 12
	Vanuatu NH GC 1		Papua New Guinea		Fiji 1/70				
	(1)	%	(2)	%	(3)	%	(4)	%	(5)
MRD x RLT	24.15	209	11.08	846	4.04	140			
MRD x MLT			3.74	285	2.35	81			
MRD x SNT			6.02	459					
MRD x GZT			6.20	473					
MRD x MVT					1.77	61			
MRD x WAT					2.45	85			
MRD x FJT					2.81	97			
MRD x PYT2					2.33	81			
MYD x WAT			4.41	337					
VTT x RLT	14.64	127							
VTT x SNT	13.42	116							
RLT x SNT	10.50	91							
RLT x YRD							4.75	30	
VRD x VTT									400 (77)
VRD x RLT									260 (30)
VRD x ROT									289 (37)
VRD x TGT									277 (54)
PYT2 x EGD							22.68	141	
PYT2 x MYD							19.70	123	
PYT2 x YRD							21.96	137	
PYT2 x NLD							12.22	76	
MRD x NLD					2.45	85			
VTT	11.56	100							
RLT	7.85	68	3.07	234					
MVT	5.51	48	2.94	224					
KKT			1.57	120					
GZT			1.31	100					
ROT					1.75	61			
FJT					2.89	100			
PYT2							16.03	100	
MRD					2.18	75			0
NLD					1.51	52			

(1) Cumulative yield, copra t/ha between 3.5 and 9.5 years
(2) " " to 1982 at Bubia
(3) " " between 6 and 10 years
(4) " " between 4 and 14 years
(5) Yield, copra kg/ha between 4 and 4.5 years
In round brackets : number of nuts for 6 months at 6 years

seedlings have been planted in atoll areas where they are growing well.

Hybrid for Vanuatu

Presence of FDMT in Vanuatu was first observed in Santo island in introduced varieties. Later this disease was discovered in other islands (Vate, Malekula) where trials with imported varieties were planted. Vanuatu Red Dwarf introduced several decades ago was noticed to be resistant to FDMT and seednuts collected by Marty, Field Manager at Saraoutou Research Station, were planted in seedbed in 1973. Later the natural hybrids were separated from the pure Vanuatu Red Dwarf variety. This was used to start a new breeding programmes.

The objective was to obtain the best hybrid resistant to FDMT disease and giving the high yield.

In the first lot collected in 1973 by Marty, ten coconut palms were natural hybrids, VRD x VTT (Fig 9). Yield estimate per hectare after 10 years from this hybrid is 3.5 to 4 t copra per ha. Although the copra per nut is very low (129 g), the high number of nuts compensate to give good production of copra per ha . Experiment planted in 1980 (Table 3) also show superiority of cross VRD x VTT over MRD and three other hybrids. Unfortunately, a recent cyclone has damaged this experiment. The productivity of this hybrid will be confirmed later in the trial NH GC 16 planted between 1982 and 1984. The first indications are in favour of this hybrid which is being produced in seed garden.

DISCUSSION

Hybrids, disease and pest problems

With the knowledge available at present, the above mentioned hybrids, MRD x RLT for the volcanic islands, EGD x PYT2 for the coral atolls and VRD x VTT for Vanuatu appear to be most suitable in the region.

At present with some 42 different hybrids being studied of which 20 are already in the field and with increase in collection of coconut germplasm and breeding work in the region, new hybrids better suited for the Pacific region are bound to appear. Saraoutou Research Station in Vanuatu is planning to test a greater number of hybrids suited for the region. A programme has also been started in Fiji to increase the collection of local and introduced germplasm of coconut and test a number of hybrids of tall and dwarf that appear of interest in the region.

Observation records taken in Rotuma, in Fiji where natural hybrids of Rotuman Tall and Niu Leka Dwarf occur have shown yield of about 43 kg of copra per tree (Anon., 1986) corresponding to a yield of about 6.5 t/ha/year (Fig 8). Similarly observations on natural hybrids of Niu Leka Dwarf with Tonga Tall in Tongatapu (Fig 7), in Tonga and with Cook Tall in Rarotonga, in Cook Islands also show high yielding abililty of the hybrids with this dwarf. However, since Niu Leka Dwarf is predominantly a cross-pollinated variety, selection of pure palms for breeding work will take time, a minimum of five years to obtain the true to type and about another ten years to develop and test the hybrids, and to produce the hybrids in the seed garden for distribution. New technique of tissue culture could reduce the time needed to develop sufficient number of pure line of Niu Leka Dwarf, but new hybrids with this dwarf will still need to be produced by artificial pollination.

Due to experiences in some

countries such as attack of *Scapanes australis* and *Rhynchophorus bilineatus* in Papua New Guinea, severe boron deficiency (Baeroko seed garden) and lethal bole rot (dry bud rot) in Solomon Islands, chlorotic Malayan Red Dwarf due to excess of magnesium induced calcium deficiency and presence of lethal bole rot in New Caledonia, FDMT disease in Vanuatu, low percentage of germination of hybrid seednuts in Western Samoa and Tahiti where plant pathologists have concluded without ever demonstrating that the fungus *Marasmiellus* sp. is responsible of the loss of seednuts (many signs are against this *Marasmiellus* hypothesis) and discovery of cadang-cadang disease in one oil palm tree in Guadalcanal in Solomon Islands, the national programme in many countries prefer to use mass selection of the local varieties for the replanting programmes or to test crosses among the locally available varieties. In the past Fiji crossed Malayan Red Dwarf with the Fiji Tall and obtained more than 75,000 hybrid seednuts but only fifteen years later it is not possible to find any plots of this hybrid in good condition since its superiority has not impressed the farmers. In Tonga the first coconut replanting scheme started in 1965 using seednut selection of local variety also did not give any satisfactory results. In 1987 FAO project for Tonga proposed a similar programme of selection. It is known in many countries that the severe selection ends in high consanguinity and consequently the second generation of coconut palms is worse compared to first selected mother palms. This was observed in Ivory Coast where the first generation of the selected seednuts from Benin Tall gave higher production than the progeny. Hence, mass selection of talls will not improve the coconuts in the South Pacific. The two principal hybrids recommended EGD x PYT2 for coralline soils and MRD x RLT for other soils have considerable yield advantage over the local talls. Climatic conditions in the region are good for coconut palms except in some areas as discussed earlier and it is possible to start a national replanting programme in all countries in the South Pacific with the improved hybrids. Vanuatu is an exception where it is necessary to take FDMT disease into account.

Most countries prefer to produce hybrid seednuts locally and not to buy from overseas. This is largely due to the fright of introduction of new disease to this very important crop in the islands. In 1965 a new disease was observed on coconut palms in Vanuatu, identified seventeen years later as FDMT disease and another four years later as virus disease. Quarantine restriction was placed to avoid spreading of disease to other countries. However, it is known that during many years before the disease was identified, a lot of Vanuatu Tall seednuts were exported to other countries without transmission of FDMT disease. By taking precautionary measures it is now possible to exchange coconut germplasm safely.

The problem observed in Papua New Guinea where the hybrid coconut palms died due to attacks of *Scapanes australis* and *Rhynchophorus bilineatus* can be easily overcome now. Morin *et al.* (1986) gave preventive measures and traps made from oil palm cubes reduced the incidence of *Rhynchophorus palmarum*. These measures can be used in Papua New Guinea to reduce damages caused by this insect.

In 1979 a quarantine restriction on movement of coconut seednuts from Russell Islands, Solomon Islands, was placed following detection of a basal stem rot disease which occurred in nursery. Hypothesis was that *Marasmiellus cocophilus* was the causal organism. In 1986 this quarantine restriction was lifted because the disease has not occurred since 1979 and the artifical infections with *M. cocophilus* failed to reproduce the symptoms. Manciot (1987) discovered that lethal bole rot or *M. cocophilus* basal stem rot was same as the dry bud rot studied in detail by IRHO in Ivory Coast between 1975 and 1982. The causal agent is not known but the disease is transmitted by leaf hopper *Sogatella kolophon* and not by fungus. The disease can be controlled by Temik spray or by erecting shade in the nursery. Since the discovery by Manciot, lethal bole rot or dry bud rot has been identified in Fiji, New Caledonia, Tonga, Vanuatu and Western Samoa. It appears that it is not present in Cook Islands and Tahiti.

Recently the discovery of cadang-cadang disease in an oil palm tree in Guadalcanal, Solomon Islands by Randles (Abington and Eta, 1987) has caused serious apprehension in many South Pacific Island countries. Investigations continue but as such there is no evidence that the cadang-cadang disease can cross infect to coconut palms. At present the disease is also confined to a very small area.

Other pests existing in South Pacific such as *Oryctes rhinoceros, Amblypelta cocophaga, Homoeosoma* sp., *Agonoxena argaula, Brontispa longissima* and fungus *Phytophthora palmivora* and *Dreschlera incurvata*, are not considered very dangerous for many countries due to good existing biological control or good progress being made in establishing control measures.

Although the presence of FDMT disease in Vanuatu and cadang-cadang disease in oil palm in Guadalcanal, Solomon Islands is of concern, the South Pacific region has tremendous potential to improve coconut production with the use of hybrids. The hybrids recommended can be produced by most countries in South Pacific.

Seed garden for hybrids

The choice of the model for the seed garden will depend on the technical staff responsible for the seednuts production. Generally the regional staffs in the South Pacific prefer to manage a classical seed garden with controlled natural pollination. This technique is the simplest and easier to manage but does not allow quick change of male parents if better male parents are identified. In the South Pacific none of the countries has selected high yielding male parents of RLT or PYT2. In Ivory Coast the first result observed in individual cross with selected RLT and PYT2 confirms the great advantage of the male parents selection (Saint *et al.*, 1986), but it is not possible to introduce seednuts or plantlets from these plants because of export restriction in Ivory Coast.

Isolation of the seed garden with natural jungle barrier or planted trees (*Pinus carribae, Anthocephalus chinensis,* etc) is essential for hybrid seednut production. Planting in an isolated island is also possible. The number of male parents to the palms will need to be adjusted depending on the degree of isolation. With good isolation the number of male parents can be about 15 to 20 for every 100 mother palms. Where isolation is not very good the number of male parent palms may need to be increased to 30 to 35 for every 100 mother palms.

It is not realistic for any one small South Pacific Island country to have many seed gardens. Generally one seed garden is enough per country and must be established close to the area to be replanted. The management of seed garden is not easy and if many small gardens are established these will increase the problems of management.

The seednuts for mother palms and male parents are readily available in South Pacific region. The MRD variety is widely distributed in the countries. Each country can collect MRD seednuts from the existing palms and selected pure Malayan Red Dwarf in nursery. In case there is not sufficient seednuts, they can get it from neighbouring country (Fiji has sent 6,000 MRD seednuts to FAO project in Vietnam in 1987 and 200 MRD seednuts to New Caledonian seed garden). Some countries already have Rennell Tall variety and this variety if needed can also be imported from Yandina Research Station in Solomon Islands which has more than 100 ha of this variety or directly from Rennell Island which is also free from disease. However, it is not easy to travel to the area of Rennell Island where pure Rennell Talls occur and Yandina Research Station is at the moment the best source of this variety.

For variety EGD, Tahiti can provide about 400 to 500 seednuts per month and this is enough for any country interested in hybrid that is adapted to the coral soils. Tahiti Tall is susceptible to *Dreschlera incurvatum*. A progeny resistant to this fungus is available in Ivory Coast but with the export restrictions from this country it is not possible to obtain seednuts from this source for the South Pacific. Another similar population of Tahiti Tall exists in Cook Islands as Cook Talls at Totokoitu Research Station and these are also high producers and can be used in the breeding work.

Extension of hybrids to farmers

The specialists in coconut palms in the region in addition to research work must take responsibility to produce hybrid seednuts, hybrid seedlings, and to plant demonstration plots. They must also take active part in advising the farmers to obtain success in replanting programmes. To assist the coconut development programme in the region a minimum set of trials are necessary. The trials should clearly establish the superiority of the hybrids in terms of yield and profitability to the farmers. Production of hybrids will require additional inputs by the farmers such as fertilizers. Currently the farmers in the region use little or no inputs and yields are low. It should be clearly demonstrated to the farmers that additional yield obtained from the hybrids will give returns highly in excess of the cost of the inputs. Better management practices to inter-crop coconut need also to be developed to make replanting of coconuts more attractive to the growers.

The experiments should have sufficient number of trees to detect adequate response to the treatment. Experience has shown that 20 trees in the net plot corresponding to about 42 trees in the gross plot are sufficient (Daniel, 1984).

Research and development of hybrids in Fiji

The coconut industry in Fiji has declined substantially over the last two to three decades. Although the area has remained almost same, production now is only about half of that about three decades ago. Ageing palms and poor management as a consequent of poor returns have been the major reasons for the downturn.

Since coconut is an important food and cash crop for the poorer sections of the community most of whom live in remote areas of islands, coconut development is now given high priority in the government's research and development programme.

To develop the hybrid seed garden and research centre to test hybrids, develop management practices for hybrids and maintain germplasm and seed multiplication block, 380 ha of land has been obtained in the third largest island Taveuni and development work has been in progress since 1986. Seed garden to produce hybrids of RLT and ROT with MRD and MYD consisting of 169 ha of land of which 78.5 ha is planted with palms and the remaining area with forest trees for isolation has been established. For the seed garden MRD, MYD and ROT were obtained locally and RLT introduced from Yandina Research Station with proper quarantine. It is envisaged that hybrids from the seed garden will become available to the farmers from about 1991.

In the meantime on established block of MRD at Wainigata Research Station, hybrids of this dwarf with talls FJT, ROT and RLT and dwarf NLD have been produced and these will be planted in the variety trial and fertilizer trial in 1989. This established block of MRD will also shortly be used to produce hybrids with RLT and ROT to establish demonstration blocks in various centres in the main coconut growing areas.

Work has also started at the research centre to develop true to type of NLD for future breeding and research work, and to collect and establish germplasm and multiplication blocks for local varieties.

CONCLUSION

Result available to date show that the best coconut hybrids for the South Pacific are EGD x PYT2 for the coralline soils and MRD x RLT for all the other soil types except that in Vanuatu where due to the presence of FDMT disease VRD x VTT appear most suitable. The hybrids are more precocious and yield considerably higher than the talls. It is recommended that these hybrids be used in the replanting programme in the South Pacific. Mass selection from the local talls for replanting is not recommended as these have low yield potential.

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MANAGEMENT OF COCONUT PALMS

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Abstract: Coconut, responds well to the management conditions right from the planting. Addition of organics such as coir dust, coconut shredding, forest leaves and cattle manure along with recommended dose of NPK imporved the initial growth and establishment of coconut seedlings from 17% to 50% in coastal sandy soil. Nutrient and irrigation management play a vital role in increasing the production and productivity of coconut. A young palm manured and irrigated regularly comes to flowering within three and half years in case of hybrid and four years in case of tall. A neglcted old coconut garden rejuvenated with fertilizer management with double dose in the first year and single dose subsequently could increase the nut yield by 265% within four years.

Phosphorus management of palms indicate that skipping of phosphorus for five to six years is possible if available P level is 60 ppm or above. Evaluations of different hybrids and talls have indicated that COD x WCT hybrid can exploit the native fertility of the soil and also applied nutrients more efficiently than WCT.

Palms with early to middle stage of root (wilt) disease respond well to the management practices like addition of organics, application of NPK and Mg, basin management with green manure, irrigation during summer and leaf rot control with sequential application of Bordeaux mixture and Dithane M45. Similarly, Thanjavur/ganoderma wilt affected palms at the initial stages respond well to the management practices like addition of organics, application of neem cake, addition of NPK, drenching of Bordeaux mixture, root feeding of Aureofungin sol + copper sulphate, providing isolation trenches and controlled irrigation.

Management of drought situations in palms with the addition of coir dust or leaves, addition of silt, forming bunds etc. to conserve moisture and supply of water through drip is also necessary to protect the palm without any detrimental effect. Management of palms under inter/mixed cropping systems with adequate manuring and organic recycling increased the nut yield of palms. Management of palms for major and minor pests at various stages of growth is also essential to get economic yield.

INTRODUCTION

Coconut is grown in more than 90 countries of the world and India occupies third position with an area of 1.22 million ha and an annual production of 6000 to 6500 million nuts. The area under coconut has doubled during the last four decades, increasing from 0.59 million ha in 1949-50 to 1.22 million ha in 1986-87. The production during the same period increased from 3448 to 6404 million nuts. While the production increase is comparable to that of other coconut growing countries, the productivity remains very low at 35 nuts/palm/year. As the major area under coconut is covered with tall cultivars which cannot be replanted with high yielding hybrids in the near future, our top most priority is to increase the productivity of existing palms.

MANAGEMENT OF COCONUT PALMS

Management of palms for higher production involves (i) soil and nutrient management (ii) crop management (iii) management under irrigated and water stress conditions and (iv) management of pests and diseases. The research carried out at the Central Plantation Crops Research Institute (CPCRI), Agricultural Universities and centres of All India Co-ordinated Research Project on Palms have clearly shown the positive influence of management practices on the yield of coconut.

SOIL AND NUTRIENT MANAGEMENT

Soil types that support coconut in the west coast comprise of laterite, coastal sands, red sandy loam, alluvium, reclaimed marshy and low land valley soils. Coral soils are the major group in Lakshadweep Islands. The soils of east coast comprise of coastal alluvium, deltaic alluvium, red loam, coastal sandy loam and clay loam. Coconut growing soils of Assam are of recent alluvial origin while that of Andaman and Nicobar Islands are coastal sandy to sandy loams.

Application of coir dust and river silt, which are easily available is an economical practice for the reclamation of marshes (kaipad lands). Addition of 50 kg of organics such as coir dust, coconut sheddings, forest leaves and cattle manure along with recommended doses of N, P and K helps in the successful establishment of coconut in coastal sandy soil. For successful establishment of coconut in 'kari' soils (marshy) with high aluminium and seasonal floodings, mounds with a mixture of sand, soil and organic matter are to be formed before planting and the mounds are to be widened as the coconut grows. Addition of silt, coir dust and calcium silicate will further improve the situation. Low lying valley lands also require mounds before planting similar to that of marshy lands. Split application of fertilizers, liming or dolomite application and summer irrigation are the management practices in these soils for successful coconut cultivation. In laterite soil, application of rock phosphate increased the nut yield by 77% as against 35% with superphosphate and rock phosphate was the cheapest source (Khan *et al.*, 1985). Enrichment of the top layer of soil by organic matter recycling, enhancing the availability of limiting micronutrients, restricted use of inorganic fertilizers and use of urea instead of ammonium sulphate to prevent volatilization loss are beneficial in coral soils of Lakshadweep (Velayutham and Singh, 1978). For reducing the toxicity of heavy metals such as bismuth, nickel and chromium, large quantities of organics such as farm yard manure and phosphorus are to be added. Application of lime would also reduce the availability of metals like nickel and cadmium. Adequate drainage facilities, application of green manures and other organic matter to alkali and saline soils allow the coconut to yield better.

Fertilizer application right from the first year of planting and irrigation are essential to achieve early flowering i.e., at three and half years in hybrids and four years in the case of tall palms. Optimum management practices combining tillage, manuring and irrigation increased coconut yield by six times (Table 1). Split application of the recommended dose of fertilizers increased the nut yield by 8.4% compared to single annual application and the copra yield by 11.7% (Markose and Nelliat, 1975). Discontinuation of fertilizer application to regularly manured coconut palms reduced the foliar N and K contents and exchangeable K in the soil, but P level in the soil and leaf tissues was not affected (Wahid *et al.*, 1975). The possibility of skipping P application to adult palms when soil available P is above 24 ppm at 30-60 cm depth was suggested by Khan *et al.* (1983). COD x WCT hybrid palms receiving an annual fertilizer dose of 500 : 500 : 1000 g N, P_2O_5 and K_2O/palm/year yielded 85 nuts/palm/year as against 59 nuts by

WCT under rainfed condition at Kasaragod. In the maidan tracts of Karnataka, a dose of 680 : 450 : 900 g N, P_2O_5 and K_2O yielded 8222 and 8246 nuts/ha in red and black soils, respectively which was 18 and 56% more than that of unfertilized control (Shanthamallaiah *et al.*, 1982c). Similarly, 750 : 225 : 900 g N:P_2O_5:K_2O/palm/year was found to be the best for the coastal sandy soils of Konkan.

Even neglected adult plantations, giving very poor yield could be rejuvenated by good management. Application of double the recommended dose of fertilizers in the first year, followed by the normal dose will help in quick revival of neglected palms. In an experiment conducted in a farmer's field near Kasaragod, adoption of the above practice increased the nut yield by 65% compared to control (Nelliat *et al.*, 1982).

CROP MANAGEMENT

Crop management starts at the nursery itself. Healthy, vigorous seedlings with good girth should be selected. Planting in properly filled pits (1 m x 1 m x 1 m) with a spacing of 7.5 m x 7.5 m to maintain a palm density of 175/ha, adequate tillage, manuring and irrigation, basin management and raising inter/mixed crops are the agrotechniques suggested for boosting the yield. Green manures such as *Calopogonium mucunoides*, *Pueraria phaseoloides*, *Mimosa invisa* and *Mucuna bracteata* could be raised in basins of 1.8 m radius yielding 15-20 kg green matter. This technique enhances nut yield by improving the soil structure and fertility.

It is possible to raise a variety of annuals/biennials in the interspaces of young coconut plantations as only a small fraction of the incident sunlight is intercepted by the coconut canopy at early stages. The scope for multiple cropping is limited in plantations in the age group of 8-20/25 years because most of the available sunlight is intercepted. However, the venetian sturcture and orientation of coconut fronds and reduction in crown size facilitate greater amounts of sunlight to penetrate the coconut crown in palms aged over 20 years and a variety of crops could be profitably grown with this diffused light. Research carried out in different centres during the last two decades has helped to identify compatible crop combinations which help to obtain maximum yields and greater net returns. Tuber crops like tapioca, elephant foot yam, ginger and dioscorea in Kerala, turmeric and elephant foot yam in Andhra Pradesh, banana in Tamil Nadu and French-bean/wheat, ragi/wheat and mulberry in Karnataka are the most profitable intercrops which perform well in coconut plantations. In Tamil Nadu (Veppankulam) growing two rows of banana in between coconut gave the highest net return ranging from Rs 19500-22300/ha (Ramanathan *et al.*, 1982a). In Karnataka, French-bean/wheat combination in coconut gave a higher net income of Rs 11500/ha; coconut yield was, however, enhanced with potato/wheat combination. Similarly, growing mulberry and rearing silk worms gave an extra income of Rs 8000/ha (Shanthamallaiah *et al.*, 1982a; 1982b).

Mixed cropping with cacao under single and double hedge systems improved the coconut yields by 52 and 49%, respectively compared to 39% in control at Kasaragod. Similar results have been reported from Pilicode also. Growing cacao not only enhanced the net returns, but also improved the soil environment and enhanced the activity of beneficial micro-organisms such as nitrogen fixing and phosphorus solubilising bacteria (Nair and Rao, 1976). The four-crop-combination of

Table 1. Response of WCT coconut to different management practices (Kerala, India)

	Management	Yield (nuts/ palm/ year)	Increase over national average, %
	National average	30.0	
(i)	Rainfed		
	a) Total neglect from the time of planting	15.8	47.3
	b) Cultivated and manured	58.0	93.3
	c) Farmers field (manured)	57.1	90.3
	d) Manuring alone	55.3	84.3
	e) Palms around homes	56.0	86.6
(ii)	Irrigated		
	a) Irrigation alone at IW/CPE ratio of 0.75	92.0	206.7
	b) Manuring & irrigation	110.7	269.0

(Source : Bavappa, 1986)

multistoreyed cropping involving coconut-pepper-cocao-pineapple further increased the productivity, returns and employment potential of the cropping systems. Studies conducted at CPCRI, Kasaragod have also shown that fodder grasses like Guinea grass and NB21 grow well under coconut palms and a mixed farming unit involving coconut, pepper, fodder grasses/legumes, dairy animals (cows) and a biogas plant could be profitably established to ensure more efficient utilization of available resources and effective recycling of byproducts and waste materials. The economic analysis revealed that to establish a mixed farming unit in 1 ha, an amount of Rs 56500 is required and the net returns realized by the farm family is Rs 35000.

MANAGEMENT UNDER IRRIGATION AND WATER STRESS CONDITIONS

Most of the coconut growing soils have low water holding capacity, which aggravates the deleterious effects of drought. Drooping of leaves, breaking of petioles, shedding of buttons and immature nut-fall are the common symptoms of drought injury. Under severe drought situations, water conservation measures such as mulching, growing cover crops, basin management by raising green manure crops, cutting coconut leaves and using them as a mulch and burying coconut husk could mitigate the adverse effect of drought to certain extent. Similarly, application of coir dust (50 kg/palm/year), application of tank silt, application of green manure and soil conservation measures such as bunding, trenching, contour bunding etc. will also be useful in overcoming drought effects.

A healthy coconut palm, on an average, absorbs 3-24 litres of water per day and the daily loss from a palm varies from 28-74 litres. Irrigation with 22.5 litres of water once in 2 days or with 45 litres once in 4 days is recommended for the young palms in sandy soil during their pre-bearing period (Nelliat, 1968). For adult palms, irrigation at IW/CPE ratio of 0.75 increased the nut yield by 72%. Systems like drip irrigation to supply about 30 l water/palm/day could be successfully used to maximise the water use efficiency and obtain excellent yield even under limited availability of irrigation water. In Tamil Nadu, irrigation once in 10 and 15 days recorded 56 and 30% higher yields, respectively over un-irrigated control. Nut weight, kernel weight and thickness of kernel were also improved in palms receiving irrigation once in 10 days (Ramanathan *et al.*, 1982b). Coconut, being a semi-halophyte in nature, is capable of withstanding saline water irrigation using water containing up to 10000 ppm total soluble salts. No permanent injury was observed when adult coconut palms were irrigated using saline water in sandy or sandy loam soils over a period of years. Use of a mixture of sea water and fresh water in 1:2.5 ratio increased nut yield by 15.8% over no irrigation. Use of saline water for irrigation through drip sustem could be useful in obtaining higher yields.

MANAGEMENT OF DISEASES AND PESTS

Root (wilt) disease of coconut is a serious problem especially in the southern districts of Kerala and the total loss due to this disease is estimated to be around 968 million nuts/year. Even the palms affected by this debilitating but non-lethal disease, especially those in the early and middle stages of the disease, respond very well to management. Application of 500-300-1000-500 g N, P_2O_5, K_2O, and MgO/palm/year and irrigation are very useful in enhancing the productivity of diseased palms. The leaf rot casused by *Bipolaris halodes* associated with root (wilt) disease could be curtailed by sequential spraying of Bordeaux mixture, Dithane and copper fungicides.

The Thanjavur/ganoderma wilt prevailing in Tamil Nadu, Karnataka and Andhra can be managed by adopting suitable control measures and field sanitation. Burning of palms which died due to the disease, application of organic manures, neem cake (5 kg/palm/year), irrigation and root feeding of 2 g Aureofungin sol, 2 g Calixin, and 1 g copper sulphate in 100 ml water twice a year was found effective in reducing the intensity of the disease and improving the yield (Rethinam, 1984).

Crown choking disease prevalent in Assam and West Bengal was found to be associated with boron deficiency and it could be controlled by the application of borax.

Leaf eating caterpillar *(Opisina arenosella)*, rhinoceros beetle *(Oryctes rhinoceros)* and red palm weevil *(Rhynchophorus ferrugineus)* could be managed by suitable biological or integrated pest management practices.

FUTURE LINES OF RESEARCH

Deficiency symptoms of certain nutrients such as sulphur, magnesium and boron sometimes overlap and hence studies are required to fix critical concentrations and deficiency symptoms of these elements. Studies on nutrient interactions, nutrient budgeting, use of slow release fertilizers and identification of cultivars with better nutrient use efficiency also require urgent attention. Role of nitrogen fixing and P solublizing organisms in coconut based cropping systems and complementary and competitive interactions between component crops are to be studied in detail. Compatible crops should be identified based on canopy and root architecture. Studies on mechanisms for drought adaptation such as physiological and biological processes, use of poor quality irrigation water (through drip system), breeding and identification of drought and disease tolerant hybrids and efficient irrigation techniques should also be intensified.

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PRODUCTION OF COCONUT HYBRIDS – PRESENT AND FUTURE

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Abstract: Inspite of the fact that the coconut area in India has increased from 5,96,000 ha in 1949-50 to 12,29,800 ha in 1986-87 the area covered by hybrids is negligible. The main constraint for the low coverage of hybrids is the non-availability of dwarf palms on the one hand and finance on the other. The centrally sponsored scheme for production of T x D seednuts could make only a marginal impact because of the limited target due to the difficulty in crossing.

Out of the present annual production of 100 lakhs coconut seedlings in the country the contribution of T x D is only about 7.0 lakhs. While the Coconut Development Council/Board could sponsor the production of 34 lakh seednuts of T x D in the states of Kerala, Tamil Nadu, Andhra Pradesh, Karnataka and Orissa since 1980, Tamil Nadu alone could produce additional 39 lakhs of T x D seednuts during the same period. At the same time, the production of D x T hybrids is only meagre. Out of the 10 seed gardens which have been established in the country for the production of D x T hybrids (Chandrasankara) only four seed gardens have started production in a very limited scale inspite of the fact that it is possible to produce over a lakh of seednuts as on today.

In addition to D x T, there is a need to produce planting material of the four Tall x Dwarf hybrids viz. LO x CDO (Chandralakhsa), LO x GB (Lakshaganga), ECT x DG (VHC 1) and ECT x MDY (VHC 2) recommended for large scale cultivation in the states of Kerala and Tamil Nadu. Utilizing the existing mother palms and by establishing additional Laccadive Ordinary sources it will be possible to produce about 10 lakhs T x D hybrid nuts annually. This can be further augmented provided the tissue culture technique in coconut is perfected and commercialised. If this is achieved, the country's requirement of hybrid seedlings will be met. Moreover, the planting of tall seedlings cannot be replaced by hybrids because of the limitations in the infrastructural facilities available and also the existing conditions under which coconut is being cultivated.

INTRODUCTION

In india the coconut area has increased from 0.59 million ha in 1949-50 to 1.23 million ha in 1986-87. The production has increased from 3448 million nuts to 6485 million nuts during the above period. Inspite of the fact that India being the first to produce hybrid as early as in 1932 and to plant in 1934 at Nileswar of Kerala, the major production of planting material to a tune of 10 million every year is only from tall cultivars, viz., West Coast Tall, East Coast Tall, Orissa Tall, Tiptur Tall, Gujarat, Zanzibar Tall and Benaulim. Hybrid seed production did not make any impact in the country for the simple reason that adequate and organized seed gardens with dwarf and tall mother palms are not available.

DEVELOPING HYBRIDS

With a view to increase the production and productivity of coconut, the coconut breeding was reoriented to produce hybrid coconut. India is the first to produce coconut hybrid right in 1932. The first T x D planting was done at Nileswar in 1934. Likewise the seedling possessing a good vigour with changed petioles, colour of Chowghat Orange Dwarf (COD) later named as natural cross dwarf (D x T) was planted at Kasaragod in 1939. Patel (1937) was produced by various state government nurseries from the seednuts of selected mother palms from farmers' fields and the balance of 4.0 million by private nurseries and coconut growers (Anon., 1988). Out of the 10.0 million seedlings the annual production of T x D hybrid is only about 0.70 million most of which are produced mainly in the farmers' field.

Though large scale production of T x D was initiated right in 1960s only 0.34 million seedlings could be produced annually through the centrally sponsored scheme in the states of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and Orissa. In addition, the state sector scheme of Tamil Nadu produced about 3.5 lakhs T x D seedling annually, and the target for the current year is seven lakhs. From this it is evident that there is an increased awareness in Tamil Nadu for T x D hybrid seedlings. The production of D x T hybrid is about 15,000 to 20,000 from the various available sources in Tamil Nadu and Kerala.

PRESENT AND FUTURE PRODUCTION POTENTIAL OF D x T HYBRIDS

Even though from the existing seed gardens it is possible to produce about 88,000 D x T hybrid seeds as on date the actual production is far below this figure. This can be definitely further augmented to 0.6 million by the end of VIII Plan and 0.94 million by the turn of this century if all the impediments are removed and more infrastructural facilities are provided (Table 2).

When the proposed seed gardens as well as the seed gardens established by Tamil Nadu under the state sector come to full bearing, the production figure of D x T will further go up to 1.5 million seednuts annually.

Table 2. India's production potential of D x T coconut hybrids through seed gardens

	Seednuts ('000)	
	Present	Future
Kerala		
Nileswar	5	60
Aralam	12	75
CPCRI, Kasaragod	6	6
Chowghat Taluk	20	20
Karnataka		
Dharmaveera	5	90
CPCRI, Kidu	20	60
Mandya (CDB)	..	..
Tamil Nadu		
Ranipet	20	300
Ettankulam	..	120
Orissa		
Biswanagakani	..	180
Konark	0.5	30
Total	88.5	941

REQUIREMENT OF PLANTING MATERIALS FOR THE FUTURE

The requirement based on (1) area expansion in traditional and non-traditional areas, (2) regular under-planting and replanting in traditional states, and (3) rehabilitation of root (wilt) disease affected areas in Kerala; will be 15 million seedlings (Table 3) as estimated during the Group Meeting on Strategy for Production of Planting Materials in Coconut held at Kasaragod (Anon., 1988). While the existing seed gardens including the four new seed gardens of 80 ha can produe about 1.5 million Dwarf x Tall seedlings, it is necessary to further augment the production of released T x D hybrid planting materials. This requires setting up of seed gardens with West Coast Tall, Laccadive Ordinary, Andaman Ordinary and East Coast Tall as tall parents and Chowghat Orange Dwarf, Malayan Yellow Dwarf and Gangabondam as dwarf parents.

YIELD PREDICTION IN COCONUT BASED ON FOLIAR NUTRIENT LEVELS

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Abstract: Standardization of leaf tissue for foliar diagnosis of N, P and K in relation to yield was carried out in WCT coconut palms of varying fertility gradients grown under rainfed condition at the southern, central and northern regions of Kerala. Yield of the palms was significantly correlated with N per cent of the leaf lamina of the 2nd, 10th and 14th leaves, the highest coefficient of partial correlation being registered by the 10th leaf. The partial correlation coefficients between yield and P per cent of leaf lamina of the above three leaf positions were not significant. The coefficients of partial correlation between yield and K per cent of leaf lamina of leaf positions 2 and 10 were significant, the highest value being recorded by the 10th leaf. The optimum contents of N and K in the 10th leaf for maximum yield were 2.9 and 1.8 per cent respectively. The leaf lamina of leaf position 10 is recommended as the best tissue for foliar diagnosis in coconut.

Regression models are suggested to predict the yield with an accuracy of 86.2 per cent utilizing nitrogen, phosphorus and potassium content of the leaf lamina of 10th leaf and the number of leaves retained by the palm.

INTRODUCTION

The pioneering works on foliar diagnosis in coconut were done by the scientists of IRHO in West Africa and they have standardized different aspects of foliar analysis as a diagnostic tool in coconut. Ziller and Prevot (1963) recommended the leaf lamina of the frond 14 as the index leaf for foliar analysis in coconut and defined the critical levels of different nutrient elements in this leaf. However, these studies are confined to certain climatic conditions, and hence these results cannot be applied to other parts of the world where the soil and climatic conditions under which coconut is grown may be entirely different.

In India, studies to standardize foliar diagnosis technique in coconut are scanty. Gopi and Jose (1983) attempted to standardize the leaf tissues for foliar diagnosis in relation to nitrogen, phosphorus and potassium. However, their observations were limited to a few palms of permanent manurial experiment confined to a particular coconut growing area of Kerala State, namely, Balaramapuram in Trivandrum district. The present study, therefore, aims at the standardization of the foliar diagnosis technique in coconut based on the analysis of a large number of palms from different parts of Kerala and to develop yield prediction models to forecast the yield based on the nutrient contents of the index leaf and other parameters related to yield.

MATERIALS AND METHODS

Coconut palms maintained in the Kerala Agricultural University Research Stations at the southern, central and northern regions of the State, viz., Balaramapuram in Trivandrum district, Mannuthy in Trichur district and Pilicode in Kasaragod district were made use of for the study. Details of the palms selected at these three different sites are as follows.

Southern region: The NPK experiment laid out in 3^3 factorial design in 1964 with West Coast Tall palms spaced at 7.5 x 7.5 m at the Coconut Research Station, Balaramapuram, Trivandrum was utilized for representing the palms grown in southern region of the State. The fertilizer treatments consisted of three levels of nitrogen (0, 340 and 680 g/palm/year) three levels of P_2O_5 (0, 225 and 450 g/palm/year) and three levels of K_2O (0, 450 and 900 g/palm/year). The plot size was four palms and the treatments were imposed from the seedling stage. Ammonium sulphate, superphosphate and muriate of potash were used as source of N, P and K respectively. The soil of the experimental area was deep, non-saline (EC 0.36 dS/m) moderately acidic to neutral (pH 5.4 to 7.1) and well drained lateritic red loam, the total nitrogen ranging from 0.056 to 0.168 per cent. The soil contained 1.92 to 42.13 ppm of available P (Bray No. 1) and 15.96 to 70.20 ppm of available K (neutral 1 *N* ammonium acetate). The crop was under rainfed conditon and the annual rainfall ranged from 135 to 210 cm.

Central region: Coconut palms of the Agricultural Research Station, Mannuthy in Trichur district were made use of. The soil of experimental area was typical laterite, pH ranging from 4.7 to 6.9; total nitrogen from 0.112 to 0.211 per cent, available P (Bray No. 1) from 30.67 to 41.76 ppm and available K (neutral 1 *N* ammonium acetate) 74.29 to 168.13 ppm. The palms (variety West Coast Tall) received NPK fertilizers at the rates recommended by the Kerala Agricultural University (Anon., 1972).

Northern region: Coconut palms of the Regional Agricultural Research Station, Pilicode in Kasaragod district were sampled for the study. The characteristics of this nonsaline laterite soil were pH 4.3 to 6.6, total nitrogen 0.125 to 0.266 per cent, available P 32.88 to 59.74 ppm and available K 331.50 to 570.12 ppm. The palms received fertilizers at the rates recommended by the Kerala Agricultural University (Anon., 1972).

Two hundred and sixteen palms (from 54 plots) of Balaramapuram, sixty palms of Mannuthy and sixty palms of Pilicode were selected for the study assuring varying fertility gradients. Leaf samples were collected from all the selected 336 palms. The last fully opened leaf (frond) at the centre of the crown was referred to as the leaf No. 1 and the leaves were numbered in the order of their increasing age. Leaf samples were taken from the 2nd, 10th and 14th leaves of the palm. Leaf sampling was done by cutting two leaflets from the middle portion of the leaf, from either side of the rachis with the help of a hook knife. The mid-vein as well as the marginal threads of the laminae were removed and the samples were taken by cutting 10 to 20 cm long strips from the middle of the laminae. The samples were cleaned, dried and ground. In order to furnish the stabilized yield of the palms of the three regions free from seasonal variations and alternate bearing nature of the palm if any, the average yield (nuts/palm/year) was worked out from the yield of four years viz., 1979 to 1982 (Table 1).

Chemical analyses for the estimation of N, P and K in the leaf samples collected from leaf positions 2, 10 and 14 of the palms from all the three locations were carried out and only the mean values are presented in Table 2. The coefficients of simple and partial correlation between yield and content of nitrogen, phosphorus and potassium in laminae at different leaf positions are given in Table 3.

RESULTS AND DISCUSSIONS

Analysis of the content of nitrogen

in the 2nd, 10th and 14th leaves revealed that it was highest in the 2nd leaf followed by the 10th and 14th leaves. The result is in conformity with the observations of Ziller and Prevot (1963) and Gopi *et. al.* (1982). The decrease in the content of nitrogen with increase in age of the leaf is because of the translocation of this mobile element from the older leaves to the younger leaves. The nitrogen content of the 2nd leaf was significantly correlated with yield at all the three locations under study. When palms at all the locations were pooled and analysed, there also the nitrogen content of the 2nd leaf was significantly correlated with yield, the coefficient of simple correlation being 0.475** and partial correlation coefficient (eliminating the effect of phosphorus and potassium) was 0.441**. However, the correlation between the nitrogen content of the 10th leaf and yield was higher than the corresponding values for 2nd leaf, in the case of palms at Balaramapuram and Mannuthy. Pooled analysis also showed that yield was correlated with the nitrogen percentage of the 10th leaf more than that of 2nd leaf. The simple and partial linear correlation coefficients were 0.518** and 0.499** respectively. Nitrogen content of the 14th leaf, on the other hand, showed only a less degree of correlation with yield. In the case of palms at Mannuthy, even a negative correlation was attained, though not significant. The pooled analysis indicated that the simple and partial linear correlation coefficients between the yield and nitrogen contents of the 14th leaf were 0.338** and 0.291** respectively. Gopi *et. al.* (1982) also observed significant correlation between yield and nitrogen content of 2nd, 10th and 14th leaves. The present study thus confirms the report of Gopi *et al.* (1982) that the 10th leaf will be the best reflect of nitrogen status of the palm in relation to yield. Ziller and Prevot (1963) on the other hand, have recommended the 14th leaf for revealing the nitrogen status of the palms. In the present study also, the nitrogen content of the 14th leaf was significantly correlated with yield but not to the extent of that with 10th leaf. Ziller and Prevot (1963) have defined the index leaf as the one which has attained full physiological maturity but yet to enter the phase of senescence. The palms studied by them generally retained more number of leaves as compared to palms observed under this study. For example, the average number of leaves retained was 18.29 at Balaramapuram, 28.95 at Pilicode and 32.23 at Mannuthy. There were palms with total number of leaves as low as 8 at Balaramapuram. Under these circumstances, the index leaf that has attained full physiological maturity but not entered the phase of senescence, will have a leaf number lower than 14. Perhaps the leaf number 10 can be

Table 1. Number of leaves and nut yield of the experimental palms at different locations (mean and range)

Location	No. of leaves retained	Yield of nuts/palm/ year (1979 to 1982)
Balaramapuram	18.29 (8.5 - 25.38)	25.56 (0.13 - 73.82)
Mannuthy	32.23 (20 - 41)	66.57 (30.0 - 125.75)
Pilicode	28.95 (20 - 40)	66.60 (37.5 - 102.0)

Values in parentheses are ranges

Table 2. Nutrient per cent of leaf laminae (mean and range)

Leaf position	Location	N		P		K	
		Mean	Range	Mean	Range	Mean	Range
2	BA	1.65	(1.23 - 2.12)	0.161	(0.111 - 0.211)	1.83	(0.71 - 2.86)
2	MA	2.12	(1.65 - 2.43)	0.225	(0.131 - 0.320)	2.14	(1.63 - 2.48)
2	PE	1.84	(1.19 - 2.43)	0.175	(0.061 - 0.259)	1.80	(1.25 - 2.43)
	Pooled	1.87	(1.36 - 2.33)	0.187	(0.101 - 0.263)	1.92	(1.19 - 2.59)
10	BA	1.70	(1.24 - 2.33)	0.151	(0.093 - 0.183)	1.06	(0.24 - 1.98)
10	MA	1.96	(1.60 - 2.43)	0.207	(0.077 - 0.319)	1.80	(1.30 - 2.25)
10	PE	1.70	(0.42 - 2.43)	0.156	(0.098 - 0.211)	1.50	(1.00 - 2.15)
	Pooled	1.79	(1.09 - 2.40)	0.171	(0.089 - 0.237)	1.45	(0.85 - 2.13)
14	BA	1.50	(0.91 - 2.05)	0.146	(0.092 - 0.191)	0.97	(0.27 - 1.77)
14	MA	1.89	(0.55 - 2.43)	0.211	(0.109 - 0.343)	1.61	(0.90 - 2.18)
14	PE	1.49	(0.96 - 2.05)	0.151	(0.056 - 0.205)	1.33	(0.98 - 1.88)
	Pooled	1.63	(0.81 - 2.18)	0.169	(0.085 - 0.246)	1.30	(0.72 - 1.94)

Values in parentheses are ranges; BA = Balaramapuram; MA = Mannuthy; PE = Pilicode

Table 3. Coefficients of correlation (simple linear) between yield and nutrient content of leaf lamina in relation to leaf position

Leaf position	Location	No.of Pairs	Coefficients of correlation, r		
			Nitrogen	Phosphorus	Potassium
2nd	Balaramapuram	214	0.315**	-0.031	0.319**
2nd	Mannuthy	60	0.334**	0.083	0.223
2nd	Pilicode	60	0.402**	-0.213	0.842**
2nd	Pooled	334	0.475**	-0.164**	0.355**
			(0.441**)	(NS)	(0.417**)
10th	Balaramapuram	192	0.611**	0.027	0.191**
10th	Mannuthy	60	0.488**	0.145	0.215
10th	Pilicode	60	0.369**	-0.103	0.563**
10th	Pooled	312	0.518**	0.199**	0.448**
			(0.499**)	(NS)	(0.432**)
14th	Balaramapuram	163	0.365**	-0.009	-0.172*
14th	Mannuthy	60	-0.071	0.036	0.270*
14th	Pilicode	60	0.366**	0.014	0.185
14th	Pooled	283	0.338**	0.205**	0.223**
			(0.291**)	(NS)	(NS)

Values in parentheses are partial correlation coefficients

* Significant at 5 per cent level

** Significant at 1 per cent level

recognised as the one that will satisfy the attributes of index leaf as suggested by Ziller and Prevot under Kerala conditions. Perhaps this would explain the high correlation of the nitrogen content of the 10th leaf as compared to that of 2nd and 14th leaves.

Simple linear regression of yield on the nitrogen content of the 10th leaf was $Y = -33.98 + 44.27$ N%. This reveals that, unit increase in the nitrogen per cent of leaf lamina of leaf number 10 will result in an increase in yield to the tune of 44.27 nuts/palm/year. This also indicates that for the very expression of yield, the minimum percentage of nitrogen to be retained in the 10th leaf will be 0.77. Assuming the leaf number 10 as the index leaf for predicting the yield based on the nitrogen content, the optimum level of nitrogen for obtaining maximum yield was worked out to be 2.90 per cent. According to Fremond *et al.* (1966), the optimum levels of nitrogen was 1.8 to 2.0 per cent based on the analysis of the 14th leaf. The optimum level suggested by the present study is higher than Fremond's optimum. Evidently it is because, the 10th leaf being younger retains a higher content of nitrogen than the 14th leaf.

The content of phosphorus was highest in the 2nd leaf follwed by the 10th and 14th leaves. This observation is similar to the report of Ziller and Prevot (1963) and Gopi and Jose (1983). In general, the content of phosphorus was only 1/10th of the content of nitrogen and 1/8th of the content of potassium in the leaves. This shows that the requirement of phosphorus is much less when compared to the requirement of nitrogen and potassium. The simple linear correlation coefficient worked out between the phosphorus content and yield was significant in all the three leaf positions, the highest correlation being registered by the 14th leaf follwed by the 10th leaf. This observation is quite different from the results obtained by Gopi and Jose (1983) who failed to obtain significant correlation between phosphorus content and yield at any leaf positions. However, the partial correlation coefficients were not significant showing that the yield is not significantly correlated with the phosphorus content of the leaf when effects of other nutrients, namely nitrogen and potassium are removed.

Results reveal that the content of potassium is highest in the 2nd leaf followed by 10th and 14th leaves. This observation also agrees with the findings of Ziller and Prevot (1963) and Gopi and Jose (1983) who observed a decrease in the content of this element, with increase in age of the leaf. Potassium being a mobile element as nitrogen, there will be translocation of potassium from the older leaves to the younger tissues of the palm thereby resulting in its accumulation in younger leaves.

Simple linear correlation coefficients between the potassium content of the 2nd leaf and yield were significant in the case of palms at Balaramapuram and Mannuthy. The pooled analysis registered a simple correlation coefficient of 0.355** whereas the partial correlation coefficient was 0.417**. Potassium content of the 10th leaf also was significantly correlated with yield in the case of palms at Balaramapuram and Pilicode. The simple and partial correlation coefficients for the pooled data were 0.448** and 0.432** respectively. Potassium content of the 14th leaf failed to show correlation with yield at one per cent level at all the three locations. However, the simple correlation coefficient for the pooled data was 0.223** which was significant at one per cent level. On the other hand, the partial correlation coefficient worked out was not significant. The above results confirm the findings of Gopi and Jose (1983) that the potassium content of 2nd and 10th leaves are significantly correlated with yield and the correlation coefficient was highest for the 2nd leaf in the case of palms at Balaramapuram. However, when the pooled data was analysed, the potassium per cent of the 10th leaf was highly correlated with yield than that of the 2nd leaf. This is quite understandable as the average number of leaves retained by the palms at Balaramapuram was much lower than the number of leaves retained by the palms at other sites. In general, the potassium content of the 10th leaf will best reflect the potassium status of the palm in relation to yield under the prevailing experimental conditions. It should be pointed out that this leaf position was also the best reflect of the nitrogen status of the palm. Thus, the leaf number 10 can be recommended as an index leaf for the simultaneous determination of the nitrogen and potassium status of the palm. Moreover, the phosphorus content of this leaf also was significantly correlated with yield.

The simple linear regression of yield on potassium per cent of 10th leaf was Y = 7.79 + 27.13 K%. This would mean that a unit increase in the potassium per cent of the leaf number 10 will result in an increase in yield by 27.13 nuts/palm/year. This indicates that the relative contribution of the potassium per cent of the leaf number 10 to yield is less when compared to the contribution by the nitrogen per cent of the same.

The optimum content of potassium in the leaf lamina of the leaf number 10 was found to be 1.80 per cent. According to Fremond *et al.* (1966) the optimum level of potassium was 0.8 to 1.0 per cent whereas Kanapathy (1971) suggested 0.81 to 1.1 per cent as the optimum in the 14th leaf.

Considering the leaf number 10 as the index leaf, a multiple regression model was worked out from the values of nitrogen (N), phosphorus (P), and potassium (K) per cent of the leaf lamina and the number of leaves retained (L) by the palm.

$$Y = -92.924 + 44.682\ N - 0.0004\ P + 49.397\ K + 6.292\ L - 6.970\ NxP + 30.729\ NxK - 2.218\ LxN + 17.449\ PxK - 0.205\ LxK$$

Yield can be predicted with an accuracy of 85.3 per cent ($R^2 = 0.853^{**}$) with this model.

The quadratic form of the above regression model was also constructed, which is

$$Y = -34.619 + 29.594\ N - 33.827\ P + 51.279\ K + 6.547\ L + 23.646\ N^2 - 0.932\ NxP + 10.044\ NxK - 2.493\ LxN + 20.294\ PxK - 54.768\ K^2 + 0.379\ LxK$$

The variable, P^2 was eliminated from the model as it had only low correlation with yield. The predicted yield and the experimental yield were highly correlated ($R^2 = 0.862^{**}$). This means that the quadratic model helps to predict the yield with an accuracy of 86.2 per cent, while the linear model helps to predict the yield with an accuracy of 85.3 per cent. The linear model is almost as efficient as the quadratic model and may be adopted for its simplicity.

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CALCIUM AND MAGNESIUM NUTRITION OF COCONUT PALM

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Abstract: Crop removal studies suggested that the quantitative requirements of coconut for Ca and Mg are much higher than that of P. Calcium is mainly concerned for the proper growth and functioning of stem and leaves of the palm rather than its productivity of nuts. Instances of Ca deficiency conditions of the palm were rarely found and the direct effects of Ca on growth or yield were seldom reported except when the leaf Ca levels were extremely low. The critical level of 0.3 per cent Ca (frond 14) appears to have a broader applicability as a diagnostic aid for regulating the Ca nutrition of the palm. Intensive liming is not needed for the management of the palm. Nevertheless, regulated additions of Ca through Ca-bearing fertilizers like rockphosphate, superphosphate or light additions of lime may be followed for supplying the Ca requirement of the palm.

Magnesium is observed to be one of the limiting nutrient elements in the nutrition of the palm, particularly on seedlings and young palms. Deficiency of Mg is common on soils that are poor in this element, particularly on acid sandy soils, and is also induced by high K/Mg ratio. Magnesium saturation of 15-20% of the exchange complex and exchangeable Mg/K ratio of 2.0 to 2.5 in the soil, and a foliar level of 0.2% Mg in frond 14 may be considered as critical for regulating the Mg nutrition of the palm. Application of Mg salts, usually epsom/kieserite, corrects the deficiency conditions faster while dolomite may be used for long term remedy or prevention. The increase in yield of nuts on correction can be as high as 40 per cent. Regular Mg addition in the form of magnesium sulphate (hydrated) at the rate of 500 g MgO/palm/year from the time of field planting on a Mg-deficient acid sandy soil in the west coast of Kerala had increased all the growth parameters at a highly significant level, reduced the pre-bearing age of the palm by 9.1 months and increased the initial yields up to the 14th year by 34 per cent with simultaneous improvements in soil and foliar Mg to desirable levels. However, the dose of Mg may be regulated based on the extent of limitation of Mg and the exchangeable Mg/K ratio of the soil and also the foliar Mg levels of a particular situation. The incidence of coconut root (wilt) disease did not show any relation with Ca or Mg nutrition of the palm. However, correction of Mg deficiency showed more favourable response on growth and yield of diseased palms compared to healthy.

INTRODUCTION

The quantity of Ca and Mg removed by coconut palm is much higher than that of P bringing to the forefront the need for taking adequate care for the nutrition of these two secondary nutrients, particularly in acidic soil situations. The proportion of Ca used for the development of bunches is the least while that used for the growth of stem and leaves is the highest suggesting the importance of Ca for the growth and functioning of stem and leaves. When all the major nutrients had been regularly applied since planting in the main field, the length and breadth of leaflets were significantly increased only with Ca treatment. The studies generally indicate that in coconut palm, Ca is mainly concerned for the vegetative growth of the palm rather than its productivity of nuts (Cecil, 1981).

Irrespective of the type of the palm, the proportion of Mg removed for the growth of stem and leaves is about 60% while that exhausted through the harvest of bunches is about 40%. Thus Mg is mostly required for the effective functioning of the leaves, and through its photosynthetic function, it regulates very much the growth as well as the productivity of the palm.

CRITICAL LEVELS

The foliar critical levels initially suggested by IRHO for Ca and Mg were 0.5 and 0.3 per cent respectively for the tall variety (Fremond, 1964). However, values lower than these levels have been widely reported on healthy plantations without any adverse effect on yield or foliar conditions (Nethsinghe, 1963; Devi *et al.*, 1973; Burrant, 1977; Manciot *et al.*, 1979b and Mangate *et al.*, 1979a). Cecil (1969) reported 0.49% Ca and 0.29% Mg in palms under excellent growth conditions, 0.38% Ca and 0.08% Mg in palms showing severe Mg deficiency symptoms, and 0.37% Ca and 0.18% Mg in apparently healthy palms without any visual symptoms of deficiency. Magat (1976) reported that the critical level of Ca and Mg initially suggested by IRHO appeared to be too high for Philippine conditions. According to him the critical level of Ca and Mg followed in the Philippines are 0.3 and 0.2 per cent respectively.

Cecil (1981) conducted a systematic study on the mineral nutrition of the palm (West Coast Tall) with special emphasis on Ca and Mg in a field fertility experiment over a period of 10 years from the time of field planting. The mean Ca levels in the absence of Ca treatment ranged from 0.32 to 0.37% which was more than the critical level of 0.3% suggested by Magat (1976). Even though there was significant improvement in the foliar Ca levels due to regular Ca treatment, the favourable effects of Ca on growth/yield appeared to be indirect. Foliar Ca values were not correlated with growth, onset of bearing or initial yields. In the absence of Mg treatment the mean foliar Mg level was 0.18% or less. Regular Mg additions had brought about highly significant increase in leaf Mg levels and simultaneous improvements in all growth parameters which ultimately resulted in a significant increase in initial yields (Table 1) and reduction in the prebearing age (Table 2). The leaf Mg levels reached above 0.2% at the 5th year and onwards. Correlation analysis showed that among the major nutrients in the foliage, only Mg was significantly correlated with initial yields (r = 0.282**) and yield attributes (r = 0.230* for the number of bunches/palm; r = 0.276** for the number of female flowers/bunch; r = 0.247** for the number of nuts/palm). The proportion of palms in flower at 74th month was also significantly correlated (r = 0.238*) only with foliar Mg levels. It is suggested that the critical level of 0.3% Ca (frond 14) has a broader applicability as a diagnostic aid for regulating the Ca nutrition of the palm while that of 0.2% Mg may be adopted under west coast conditions until specific critical levels for each variety/type are established.

It was observed that regular Ca treatment had increased the percentage Ca saturation of the soil from 28.4 to 49.8 at the ninth year which resulted in

Table 1. Main effects of Ca and Mg on cumulative yield of nuts harvested up to 14th year of planting

Levels	Nuts/palm	% increase
Ca 0	346.4	
Ca 1	386.3	11.5
Mg 0	313.4	
Mg 1	419.4**	33.8

Ca 0 = No calcium; Ca 1 = Lime requirement (pH 6.5);
Mg 0 = No magnesium; Mg 1 = 500 g MgO/palm/year

Table 2. Main effects of Ca and Mg on flowering

Levels	Proportion of palms (%) in flowering at			Pre-bearing age (months)	Leaf[1] No.
	62 months	74 months	86 months		
Ca 0	10.5	41.8	75.2	75.1	55.7
Ca 1	14.2	49.4	80.7	72.6*	54.4
Mg 0	6.2	31.4	65.9	78.4	57.9
Mg 1	18.5**	59.77**	90.1**	69.3**	52.2**

1 The axil of which the first inflorescence opened
* Significant at 5% level
** Significant at 1% level

highly significant increase in foliar Ca levels. Mg saturation of 15-20% in the 0-50 cm soil is ideal for coconut. In the absence of Mg treatment, the values of Mg/K ratio were very low (0.6-0.7) in the 0-50 cm soil and around 1.0 in the 50-100 cm soil. The comparatively higher values in the lower layers was probably the favourable factor for the gradual decrease in the severity of Mg deficiency yellowing and the gradual improvement in foliar Mg levels with advancing age of young palms grown on Mg deficient soils, as the enlargement of the root system to lower depths increased with the age of the palm. Regular Mg treatment gradually raised the ratio to 1.3 in the 0-50 cm soil and 2.0 in the 50-100 cm soil, but did not reach the ideal value of 2.5 suggested by Manciot *et al.* (1979a). The ratio of exchangeable Mg/K is the dominant determinant factor for assessing the Mg availability of coconut soils. It is also quite probable that the palms grown on soils with low exchangeable Mg/K ratio are more susceptible to K induced Mg deficiency.

NUTRIENT INTERACTIONS

Liming of acid soils under coconut improved the foliar N levels while Mg additions had a reverse effect. The leaf P level as well as the available soil P was increased by both Ca and Mg treatments. On the other hand, both Ca and Mg depressed the availability of K. The foliar Ca levels were generally increased by N and P treatments while K and Mg application decreased the level of Ca in leaf. A depressive effect of K on leaf Mg levels when the soil as well as the leaf Mg levels were low, was observed and when Mg was regularly supplied, the level of leaf K decreased. The action of K fertilizers on leaf Mg content largely depends upon the balance between K and Mg in the soil. More critical studies are needed to understand the problem at greater depth. Calcium treatment exerted a favourable effect on foliar Mg levels and the interaction between Ca and Mg on leaf Mg had been positive (Table 3) which reflected on growth, onset of bearing and initial yields.

Favourable effects of Ca treatment on growth of young palms and their initial yields could be noticed but the increase in yield was not significant. Magnesium has been observed to be one of the most limiting nutrient elements in the nutrition of seedlings and young palms, especially when the soil is poorly

Table 3. Ca-Mg interaction on foliar Mg (%)

	Ca 0	Ca 1	Mean
Mg 0	0.167	0.167	0.167
Mg 1	0.203	0.221	0.212**
Mean	0.185	0.194*	0.189
CD (P = 0.05)		0.012	

* Significant at 5% level

** Significant at 1% level

supplied with Mg, and the application of Mg fertilizers corrected the deficiency very well, raised the Mg levels of leaf, improved the growth and increased productivity. Manciot *et al.* (1979b) reported that the main effect of Mg could be as much as 40% when K was in the sufficiency level, but unlike K, Mg had no effect on the copra content. Cecil (1981) observed that regular Mg addition in the form of magnesium sulphate (hydrated) at the rate of 500 g MgO/palm/year from the time of field planting on a Mg deficient acid sandy soil in west coast of Kerala had increased all the growth parameters at a highly significant level, reduced the pre-bearing age of the palm by 9.1 months and increased the initial yields up to the 14th year by 34% with simultaneous improvement in soil and foliar Mg to desired levels.

ROOT (WILT) DISEASE

Most of the soil and nutritional studies conducted on the root (wilt) disease indicated that the palms in the disease affected areas, whether they were apparently healthy or visibly diseased, were in a state of imbalance, possibly the result of a relatively higher content of N, P and/or K on the one hand and a lower content of Ca, Mg and/or S on the other (Pandalai, 1959; Varghese, 1966; Pillai *et al.*, 1975; Cecil, 1975 & 1981). Different field fertility studies showed that the disease could not be cured or prevented by mineral manuring even though beneficial effects on yield and foliar yellowing were observed in some cases, especially when treated with magnesium and calcium salts (Nair and Radha, 1959; Lal, 1964; David, 1964; Davis and Pillai, 1966; Varkey *et al.*, 1979; Cecil, 1981). Lal (1968) reported that the foliar yellowing associated with the disease was largely due to Mg deficiency which could be improved markedly when the palms were sprayed with 2.0% magnesium sulphate solution at quarterly intervals (Anon, 1966). The study of the role of Ca and Mg on the incidence and severity of the disease revealed that the disease development in young palms was independent of Ca and Mg nutrition of the palm. However, correction of Mg deficiency prevalent in disease affected areas resulted in significant increase in growth and initial yields, and the effects were more pronounced on diseased than on healthy palms. When the increase in the yield of nuts by Mg treatment in healthy palm was 37%, the corresponding increase in diseased palms was 60% (Cecil *et al.*, 1982). Such preferential response of Mg on diseased palms over healthy was reported earlier by Davis and Pillai (1966) and Varkey *et al.*, (1979). More critical studies are needed to elaborate the beneficial role of Mg in the nutrition of diseased palms.

DEFICIENCY SYMPTOMS

Heavy liming is not needed for the management of the palm. Nevertheless, regulated additions of Ca through Ca-bearing fertilizers like rock phosphate/superphosphate and/or light additions of liming materials may be followed for supplying the Ca requirement of the palm. This is all the more important in view of the heavy loss of

Ca by crop removal and also by excessive leaching under tropical conditions. Magnesium deficiency has been more common on acid sandy soils with a low Mg content, and is also induced by imbalance of nutrients like high K/Mg or Ca/Mg ratios in soils as well as leaf tissues. Prolonged use of K fertilizers, especially at high rates, depresses foliar Mg content and induces Mg deficiency conditions.

Symptoms of Mg deficiency is more common on young palms and seedlings, and is usually manifested as yellowing of the outer whorls of leaves. The very first symptom is the development of yellowing at the tip of leaflets at the distal parts of mature leaves which gradually spreads towards the basal part of the leaflet as well as the leaf. In the advancing stage, yellowing becomes intense near the periphery of the leaf blade, and only a narrow longitudinal green band parallel to the midrib on either side of the leaflet is visible. When the deficiency gets worse, yellowing intensifies, the number of green leaves becomes less, necrosis sets in at the tips of the leaflets, and numerous brown blotches develop on the yellow surface. Mg deficient leaves are more sensitive to sunlight as the part exposed to sunlight shows an intense discolouration while the shaded part of the same leaflet remains green. When the deficiency becomes severe, intense yellowing accompanied by severe necrosis and browning develops and the mature leaves wither away prematurely leading ultimately to a lesser number of functioning leaves on the crown. The frond production rate is reduced, onset of bearing is delayed, and the productivity of the palm is adversely affected.

Application of Mg salts, particularly the sulphate, corrects the deficiency very well resulting in the re-greening of the chlorotic foliage/prevention of chlorosis accompanied by increase in foliar Mg levels and improvement in growth and yield of nuts. Amma *et al.* (1982) applied two levels of Mg viz., 500 g and 1000 g MgO/palm/year as magnesium sulphate along with three levels of NPK to D x T hybrids since planting. The second level of Mg did not generally show any significant increase over the first. However, the second level of Mg with the second level of NPK showed maximum response on the earliness of flowering. Cecil (1981) observed highly significant response on growth and initial yields of young palms with 500 g MgO/palm/year.

Even though the importance of Mg nutrition on growth and productivity of the palm has been well brought out by research carried out in different parts of the world, critical studies are needed to assess the optimum dose for different soil/agroclimatic zones as well as a cheap but effective source of Mg for economic management of the crop. More studies are also needed to elaborate the beneficial role of Mg on root (wilt) affected palms, and also to study the exchangeable Mg/K balance, in coconut soils for maintaining a favourable balance of the two important nutrients (K & Mg) which may help to avoid excessive K fertilization and prevent the loss in yield caused by Mg deficiency.

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RESPONSE OF COCONUT PALM TO N, P AND K FERTILIZERS FROM SEEDLING STAGE

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Abstract: Coconut is a crop which responds well to the nutrient elements nitrogen, phosphorus and potassium. A 3^3 factorial experiment initiated in 1964 on young coconut seedlings (WCT) at the Coconut Research Station, Balaramapuram, Trivandrum, Kerala revealed good response to N, P and K as evidenced from the analysis of the cumulative average yield of palms for twelve years from 1976 to 1987.

Though the main effects of P in increasing the dose of P from 225 to 450 g P_2O_5 per palm per year was not significant, the interaction effects showed the importance of keeping a balance among these individual nutrient elements for increased production. The highest yield of 73 nuts per palm per year was obtained from palms treated with 680 g N, 450 g P_2O_5 and 900 g K_2O.

INTRODUCTION

Coconut is a crop which generally respond to N, P and K and the real extent of yield response will become manifest only after several years of regular and systematic manuring. Fertilizer studies on coconut starting from young seedlings are seldom attempted. Among the major nutrients, K has been proved to be the most important nutrient required by the palm followed by N, and the production of nuts is highly influenced by these two nutrients in the soil. Results of fertilizer experiments in coconut have been reported by a few workers.

An NPK experiment conducted during 1953-65 on bearing coconut palms (WCT) showed good response to N at a lower level of 340 g and a depression at a higher level of 680 g (Muliyar and Nelliat, 1971). Fertilizer experiment conducted in Fiji and Sri Lanka during 1970-73 have shown the beneficial effects of NPK and in all these experiments K had been established as the dominant nutrient required by coconut palm (Sumbak and Best, 1976 and Vernon *et al.*, 1976).

Significant NP and NK interactions have been reported by Murti (1972). Based on the NPK experiments conducted in the Ivory Coast, Fremond (1964) and Fremond *et al.* (1966) highlighted the usefulness of phosphorus nutrition in increasing the yield in the presence of K. In a ten year long NPK experiment conducted at CPCRI, Kasaragod, a combination of 340 g N, 340 g P_2O_5 and 680 g K_2O per palm per year gave the highest mean yield of 62 nuts/palm under rainfed condition. The optimum doses of different nutrients were found to be about 500 g N, 320 g P_2O_5 and 1200 g K_2O per palm per year (Nelliat *et al.*, 1976). However, fertilizer recommendations suitable for the southern most part of India with red loam soil under rainfed conditions have not been evolved.

MATERIALS AND METHODS

An NPK trial was laid out with young coconut seedlings of WCT variety

Table 1. Main effects of N, P and K and interaction effects of NP, NK and PK (cumulative average yield of nuts per palm, 1976-'87)

Levels of N	Levels of P			Levels of K			Marginal means (N)
	p0	p1	p2	k0	k1	k2	
n0	144	141	153	38	199	202	146
n1	174	371	238	33	338	413	261
n2	291	381	500	26	495	651	391
Marginal means (P/K)	203	298	297	32	344	422	
Levels of K							
k0	57	26	13				
k1	274	416	342				
k2	278	451	536				

n0, n1, n2 = 0, 340, 680 g N/palm/year

p0, p1, p2 = 0, 225, 450 g P_2O_5/palm/year

k0, k1, k2 = 0, 450, 900 g K_2O/palm/year

CD (0.05) for marginal means = 61

CD (0.05) for combinations = 107

in the red loam soil of the Coconut Research Station, Balaramapuram (Trivandrum district) in 1964. The treatments consisted of 27 possible combinations of N, P and K, each at three levels. The levels were 0, 340 and 680 g/palm/year for N; 0, 225 and 450 g/palm/year for P_2O_5; and 0, 450 and 900 g/palm/year for K_2O.

The design of the experiment was a 3^3 factorial, confounding NPK^2 and NP^2K^2 in replication 1 and 2 respectively. The seedlings were planted at a spacing of 7.5 x 7.5 m with four seedlings per plot. Border rows were provided with the same spacing. Nitrogen was applied in the form of ammonium sulphate, P as superphosphate and K as muriate of potash by a single application in June every year. No organic manure was applied and the trial was managed under rainfed condition. The palms started bearing from 1972 onwards but gave stabilized yield from 1976 only. The mean cumulative yield of palms for 12 years (1976 to 1987) with respect to each treatment was utilized for the study.

RESULTS AND DISCUSSION

The analysis of variance of the data revealed that all main effects and two-factor interaction effects were significant.

Increase in the level of N up to 680 g/palm/year and K up to 900 g/palm/year was found to increase the production of nuts while an increase in the level of P from 225 to 450 g/palm/year was not beneficial (Table 1). The cumulative yield increased by 115 and 245 nuts respectively with the application of 340 and 680 g N/palm/year (over control). The yield increased from 203 to 298 nuts with the application of P_2O_5 at 225 g and there was no further increase in yield by the application at 450 g, thereby indicating the non-beneficial effect of P above 225 g P_2O_5/palm/year. There was marked increase due to the application of K, the increase in cumulative yield being 312 and 390 nuts with application of K_2O at 450 and 900 g/palm/year (26 and 33 nuts/palm/year) respectively.

In the absence of N, no significant

Table 2. Cumulative average yield of nuts per palm with respect to individual treatments, 1976-'87

Treatment	Yield	Treatment	Yield	Treatment	Yield
$n_0p_0k_0$	76	$n_1p_0k_0$	57	$n_2p_0k_0$	39
$n_0p_0k_1$	147	$n_1p_0k_1$	279	$n_2p_0k_1$	395
$n_0p_0k_2$	210	$n_1p_0k_2$	186	$n_2p_0k_2$	439
$n_0p_1k_0$	22	$n_1p_1k_0$	30	$n_2p_1k_0$	26
$n_0p_1k_1$	275	$n_1p_1k_1$	496	$n_2p_1k_1$	478
$n_0p_1k_2$	127	$n_1p_1k_2$	589	$n_2p_1k_2$	640
$n_0p_2k_0$	15	$n_1p_2k_0$	12	$n_2p_2k_0$	12
$n_0p_2k_1$	174	$n_1p_2k_1$	240	$n_2p_2k_1$	611
$n_0p_2k_2$	271	$n_1p_2k_2$	463	$n_2p_2k_2$	875

difference in yield was seen at the three levels of P. When P was combined with 340 g N/palm/year, a quadratic trend in production was observed and the highest yield was obtained from n_1p_1 treatment (371 nuts). This was significantly superior to those obtained at n_1p_0 (174 nuts) and n_1p_2 (238 nuts) which were on par. P levels with 680 g N showed a linear increase in yield with increasing levels of P and the highest yield of 500 nuts was obtained from n_2p_2 treated palms. The response to N was linear and a significant increase in yield was obtained with the highest level of N combined with p_2. The results on NP interaction show the need for keeping a balanced N:P ratio for maximum yield. Significant NP interaction in coconut have been earlier reported by Murti (1972) and Loganathan and Murti (1975).

An increase in both N and K was found to result in better nut production. In the absence of K the response of N was very poor resulting in 2-3 nuts/palm/year. In the presence of K significant increase in production was seen at all the levels of N. When n_1 was combined with k_1 and k_2 the production increased by 139 and 211 nuts respectively, as compared to those treated with n_0k_1 and n_0k_2. The combinations n_2k_1 and n_2k_2 again resulted in increased production giving 495 and 651 nuts respectively. The per palm yield was 54 nuts/year on an average with the combined application of n_2 and k_2. Similar effects of NK interaction were reported from fertilizer experiments conducted in Sri Lanka by Almoyda (1963).

In the absence of K, the response to P was poor giving 1 to 5 nuts/palm/year. The effect of P with k_1 was quadratic while that with k_2 showed a linear trend. The level p_2 combined with k_2 gave a cumulative yield of 536 nuts which was superior to that obtined at p_1k_1 (416 nuts) and p_2k_1 (342 nuts). Fremond (1964) and Fremond *et al.* (1966) from Ivory Coast reported the effect of NPK interaction in increasing the number of nuts.

The cumulative yield of palms against different NPK combinations (Table 2) showed that the maximum yield was obtained at $n_2p_2k_2$ (875 nuts). The average nut per palm per year was

73 at this treatment. A substantial increase in production due to higher doses of N, P and K (0.68 kg N, 1.14 kg P_2O_5 and 1.14 kg K_2O) was reported by John and Jacob (1959).

In the present study the response of P and K was found to be quadratic while that of N was linear. So a quadratic response function with respect to N, P and K could not be fitted to the data. The above result shows that the maximum dose of 680 g N/palm/year is not sufficent for the maximum production of nuts. It could be noticed that no organic manure was applied to the expermient and hence a higher requirement of N is needed.

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EFFECT OF SPACING AND MANURING ON THE NUT PRODUCTION IN COCONUT

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Abstract: Analysis of the cumulative average yield of palm for a period of twelve years from 1976 to 1987, recorded from a spacing cum manurial trial conducted at the Coconut Research Station, Balaramapuram, Trivandrum, Kerala showed significant interaction between spacing and manuring. The cumulative yield of nuts per palm increased by 457 and 621 nuts respectively by the application of 340 g N, 225 g P_2O_5 and 450 g K_2O and double the above quantitiy of fertilizer per palm per year. An increase in spacing was also found to increase the individual palm yield but to decrease the per hectare production. The yield increased by 307 and 373 nuts when the spacing was kept as 7.5 x 7.5 m and 10 x 10 m respectively in comparision with 5 x 5 m spacing. However, the difference in yield at spacings 7.5 x 7.5 m and 10 x 10 m was not significant.

The response of palm in the absence or presence of fertilizer was different. In the absence of manuring no significant difference in nut production was observed at the three spacings tried while in the presence of fertilizer there was a significant increase in nut production at wider spacings, 7.5 x 7.5 m and 10 x 10 m. As far as the per palm yield and per hectare yield are considered, 7.5 x 7.5 m spacing was found to be suitable for the palm with better management.

INTRODUCTION

Different spacings are adopted for planting coconut in different countries. The choice of spacing depends upon the crop grown as monoculture or in combination with others. A closer spacing may fail to give better production due to competition for environment, moisture and radiant energy. A wider spacing is expected to be good for interculture. In India 7.5 m to 9.0 m spacing is recommended for monculture. The yield data for a period from 1925 to 1966 collected from a spacing trial conducted at the Coconut Research Station, Pilicode with three spacings (6.7, 7.6 and 9.1 m) in triangular method of planting revealed that there was no significant difference in the individual palm yield with respect to the three spacings but the gross yield per unit area was maximum in the lower spacing (Kannan *et al.*, 1978). This trial was undertaken to standardize the spacing to be adopted for the red loam region in the southern most part of the country.

MATERIALS AND METHODS

A spacing cum manurial trial was laid out at the Coconut Research Station, Balaramapuram in 1964 to study the effect of different levels of fertilizer and spacing on the growth and productivity of coconut. WCT coconut seedlings from Nileswar were planted in the deep red loam soil and the experiment was managed under rainfed conditions. The treatments consisted of all the possible combinations of three levels of spacing and three levels of manuring. The spacings followed were 5 x 5 m (S_1), 7.5 x 7.5 m (S_2) and 10 x 10 m (S_3). The levels of manuring was 0:0:0 (m_0), 340:225:450 (m_1) and 680:450:900 (m_2) of $N:P_2O_5:K_2O$ (g/palm/year). The nine treatment combinations were tried in

Table 1. Effect of spacing and manuring on the cumulative nut yield of palms 1976-'87

Spacing	Manuring			Mean(s)
	m_0	m_1	m_2	
s_1	20.61	271.50	370.84	200.98
s_2	135.07	608.04	779.85	507.65
s_3	69.25	716.00	936.50	573.92
Mean (m)	74.98	531.85	695.73	

CD (0.05) (s or m) = 98.94 CD (0.05) (s x m) = 171.37

three randomised blocks. The plot size for all the treatments was kept the same (30 x 30 m) but the number of palms per plot varied according to spacings i.e., 25 palms with 5 x 5 m spacing, 9 palms with 7.5 x 7.5 m spacing and 4 palms with 10 x 10 m spacing. The border palms were planted at a uniform distance of 7.5 m along the border line of all treatment plots. Nitrogen was supplied in the form of ammonium sulphate, phosphorus as superphosphate and potassium as muriate of potash by a single application in June-July every year. No organic manure was applied.

RESULTS AND DISCUSSION

The analysis of variance of the cumulative yield for a period of twelve years form 1976 to 1987 showed significant effect for manuring and spacing and also for their interaction (Table 1). In the absence of manuring (m_0) the response of palms was very poor giving the cumulative average yield per palm as 21, 135 and 69 nuts respectively at the 5 x 5 m, 7.5 x 7.5 m and 10 x 10 m spacings (Table 1). Though the highest yield of 135 nuts was obtained at 7.5 x 7.5 m spacing, the yield differences at these spacings were not significant in the absence of manuring. When the palms were given 340 g N, 225 g P_2O_5 and 450 g K_2O they produced 272, 608 and 716 nuts respectivley at the three spacings tried during the twelve year period (average yield per palm per year was 23, 51 and 60 nuts at the three spacings). However, the difference in yield between 7.5 x 7.5 m and 10 x 10 m spacings was not significant. When the palms received double the quantity of fertilizers (m_2) they produced 371, 780 and 937 nuts (Table 1) at the three spacings, giving an average yield per palm per year of 31, 65 and 78 nuts (Table 2). At this level of manuring also, no significant difference in yield was seen between 7.5 x 7.5 m and 10 x 10 m spacings. But there was a significant increase in yield at m_2 compared to m_1 at s_2 and s_3 spacings. The palms planted at 7.5 x 7.5 m spacing produced 172 nuts more (14 nuts/palm/year) and those planted at 10 x 10 m spacing produced 221 nuts more (18 nuts/palm/year) as the influence of m_2 over m_1 and the differences in yield were significant (Table 1).

There was an increase of 457 nuts and 621 nuts (38 and 52 nuts/palm/year) on an average, during the twelve year period respectively by the application of m_1 and m_2 in comparison with m_0, when the main effects of manuring are investigated. Similarly, a comparison of the main effect of spacings showed an increase of 307 and 373 nuts (26 and 31 nuts/palm/year) at s_2 and s_3 spacings in comparison with s_1, the difference in yield being not significant between s_2 and s_3 (Table 1).

STATISTICAL TECHNIQUES FOR EXPERIMENTS WITH COCONUT

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Abstract: The statistical techniques followed in experiments with annual crops and perennial crops are essentially the same. However, while experimenting with perennial crops, the problems faced with are somewhat different from those with annual crops. Difficulties arise because of the perennial nature of the crops, long duration of experiments, large size of the plots, lack of uniformity in the experimental material, differences in the pre-bearing period coupled with long bearing period, time lag between application of treatments and manifestation of their effects etc. Even among perennial crops, coconut gives yield throughout the year unlike in many other crops. Recent studies have shown that the annual yield data of coconuts followed a skewed distribution, thus necessitating suitable transformations, to satisfy some of the assumptions involved in the statistical analysis of data. Conclusions drawn from experiments can also differ, depending on the method of compilation of annual yield data. Year to year variation is more pronounced in the case of calender year tabulation, as compared to agricultural years. Also achieving greater homogeneity between plots, within a block, by creating greater heterogeneity within plot has been found to be the best design approach.

In this paper an attempt has been made to review the work done in India and abroad in estimating the optimum plot size for field experiments, pooled analysis of data relating to long term experiments, efficiency of covariance analysis, yield forecasting methodologies, regularity of bearings, indexing the severity of disease symptoms, etc.

INTRODUCTION

The statistical techniques followed in experiments with annual crops and perennial crops are essentially the same. However, while experimenting with perennial crops, the problems faced with are somewhat different from those with annual crops. Difficulties arise because of the perennial nature of the crops, long duration of experiments, large size of plots, lack of uniformity in experimental material, differences in pre-bearing age, time lag between application of treatments and manifestation of their effects, large error variance, etc. Even among perennial crops, coconut stands separate, because nuts are harvested throughout the year, whereas in many other crops, fruiting is only seasonal. In this paper, an attempt has been made to compile the work done in India and abroad on the field lay-out of coconut experiments, analysis of data and interpretation of results and other techniques like yield forecasting methodologies and indexing the severity of disease symptoms.

FIELD LAYOUT OF EXPERIMENTS

Field experimentation techniques in fruit trees and other perennial crops have been discussed in detail by Pearce (1976), Choudhary *et al.* (1979) and Anon. (1986). Daniel (1984a, b) and Daniel and Bonnat (1987) have also specifically dealt about field experimentation techniques in oil palm and coconut.

1. Size and shape of plots and blocks

Compact blocks with uniform plots is a prerequisite for field experimentation. Smith (1938) gave an emperical relationship between variance and size of the plot. He defined the variance law

Table 2. Effect of treatments on nut yield of palm

Treatments	Mean yield/ palm/year	Yield/ ha/year
s_1m_0	1.72	687
s_1m_1	22.63	9050
s_1m_2	30.90	12360
s_2m_0	11.26	2004
s_2m_1	50.67	9019
s_2m_2	64.99	11568
s_3m_0	5.77	577
s_3m_1	59.67	5967
s_3m_2	78.04	7804

Table 3. Yield in relation to spacing

Spacing	Nuts/palm/ year	Nuts/ha/ year	No. of palms/ha
s_1	18.42	7368	400
s_2	42.30	7530	178
s_3	47.83	4783	100

The response of palms in the presence of fertilizers was different. In the absence of manuring no significant difference in nut production was observed at the three spacings tried while in the presence of fertilizer there was a significant increase in nut production at wider spacings (7.5 x 7.5 m and 10 x 10 m). Significant interaction between spacing and manuring has been reported in earlier studies of Whitehead and Smith (1968) and Kannan *et al.* (1978).

Though the individual palm gave better yield at 10 x 10 m spacing (48 nuts), the per hectare yield was high at 7.5 x 7.5 m spacing with 7530 nuts followed by 5 x 5 m spacing with 7368 nuts (Table 3). But the highest yield at s_1m_2 (12360 nuts) followed by s_2m_2 (11568 nuts) is the combined effect of increased palm population and better management (manuring).

The results thus tend to conclude that 7.5 x 7.5 m is the best suitable spacing for planting coconut provided the palms are supplied with at least 680 g N, 450 g P_2O_5 and 900 g K_2O per palm per year, based on unit area production.

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as $Y = ax^{-b}$, where Y is the variance of the yield per unit area, based on plots of x units, a is the variance per plot of unit area and b is the characteristic of the soil and measure of correlation among contiguous units. In the case of trees and bushes, Pearce (1955) modified this relationship as $Y = V_1/x + V_2x^{-b}$, where V_1 (variance between individual trees) and V_2 (variance between single trees due to position) correspond to the genetic and environmental components of total variation. In tree crops, because of the wider spacing adopted, rows and columns become important, and therefore, generalisation of Smith's formula, in the form $Y = ar^{g_1}c^{-g_2}$ has also been attempted to study the row-wise and column-wise heterogeneity. While the CV of plots decreases with increase in plot size, this decrease is not proportionate. Consequently, an increase in the number of replications, with a reduced plot-size, if necessary, leads to more precise comparison of treatments. In crops where genetical component of variation is important, importance has to be given to this also, while forming plots. Number of replication is generally decided on the basis of available experimental area, the residual degrees of freedom required, the possiblity of losing some of the plots due to mishaps, and the efficiency required for estimates.

Work on optimum plot size for coconut was first done in Sri Lanka. Based on the uniformity trial data for 360 trees for one year, Joachim (1935) suggested 18-20 trees as the optimum for field trials. The CV of these plots was around 14% and for treatment differences of 15% to be considered significant, six replications were required. Pieris and Salgado (1937) also arrived at similar conclusions, based on the data for 300 coconut palms for two years. Recently many attempts have been made to study the optimum plot size for WC Tall, D x T and T x D palms under Kerala conditions. In the absence of uniformity trial data, in some cases, fertilizer trial data have also been used, after eliminating the treatment effect, by the method suggested by Ray *et al.* (1973). Data from two locations in the west coast have shown that for D x T palms, the per unit decrease in CV was minimum when the plot size exceeded eight palms (Nambiar, 1986a). Similar results were obtained for WC Tall palms also (Nambiar, 1986b). Analysis of data for T x D palms for four years has shown that a plot size of six palms is optimum, when the data are considered for individual years, and 3 to 4 when the data are considered for four years together (Anon., 1986).

Optimum plot size has been studied from the point of view of bienniality also. Abeywardena (1964) observed that with increased plot size, the effect of bienniality is nullified. It was significant for less than four palms and has suggested that six palms should be the minimum plot size for avoiding any significant bias in the interpretation of single year's data. Even with six palm plots, the CV could be kept within 10% with the aid of calibration, indicating the possibility for further reduction in plot size, in coconut experiments.

In annual crops, the plant to plant variation is mostly due to environmental reasons. In tree crops, because of their outbreeding nature, genetical factors play an important role. Shrikhande (1958) has suggested that when the plot size is four or less, it is advantageous to give importance to genetic component.

Alforja *et al.* (1978) have shown that for fertilizer experiments with polybagged coconut seedlings, significant results were obtained with 12 seedling plots.

2. Formation of blocks and plots

Blocks are arranged in such a way as to maximise differences between blocks, whereas plots are arranged within blocks as to minimise the differences among them. In annual crops this is generally achieved by clubbing together contiguous plots into blocks. In many of the tree crops, genetical component of variation is of sizable magnitude compared to the environmental component. Shrikhande (loc. cit.) has found that, in the case of coconut, the genetic and environmental components are in the ratio of 2 : 1 or 3 : 2, though Pankajakshan (1960) has later shown that environmental component is more important, when the data are considered in blocks of four or more years. For smaller plots also the genetical component is more important. Shrikhande (loc. cit.) had tried alternate methods of reducing the within block variation and increasing within plot variation, by controlling environmental and genetic components of variation, separately and in combination (Table 1).

This study has clearly brought out that the methods 2 and 3, which aim at controlling the genetic variation are more effective than method 1, which aims to control the environmental variation. He has recommended the last two methods, if the treatments to be applied are such that when a treatment is applied to a tree, the neighbouring trees are not affected. If on the grounds of practical convenience or cost considerations these methods are unsuitable, it is advisable to use method 1 with covariance.

Table 1. Coefficient of variation corresponding to plot mean and plot error (Shrikhande, 1958)

Plot size	Method 1	Method 1 with covariance	Method 2	Method 2 with covariance	Method 3	Method 3 with covariance
A. Block F of Pilicode						
1	35.22	26.82	24.27	24.36	35.22	26.82
2	27.76	20.53	16.94	16.91	22.20	19.01
4	25.26	15.54	9.96	9.99	10.54	10.05
6	15.73	11.93	9.24	8.78	13.43	11.07
8	14.58	7.64	8.99	8.99	12.04	9.89
B. Field 1 of Kasaragod						
1	37.13	19.05	20.27	20.26	37.13	19.05
4	26.05	12.37	10.12	10.19	12.07	8.80
8	21.51	10.21	7.06	7.07	9.15	9.41
12	18.11	5.57	6.94	6.06	3.98	3.77

Method 1: control of environmental variation alone. The land is divided into compact blocks and within each block, the adjacent trees are grouped to form plots. Method 2: control of genetic component of variation alone. Trees are grouped on the basis of past yield records and blocks are formed with palms of similar yields. Method 3: combination of methods 1 and 2. The land is divided into compact blocks and trees are arranged within blocks according to their past yields.

Saraswathi (1986) suggested an alternate method of grouping of palms, having marked yield differences. Based on the principle of negative intra-class correlation present among the experimental units within a plot, she suggested a method of grouping of palms having marked yield differences. This method was found to reduce the within block variation, by increasing the within plot variation.

3. Border effect and guard rows

Owing to border effect, the yield or other characters of the plants near the borders differ from those at the centre of the plot. In varietal trials the border plants of a more vigorous variety gain in competition with plants of neghbouring plots of less vigorous variety, whereas the advantage is not available to the plants in the inner portions of the plot, or under normal field conditions. To a certain extent, this anomaly can be avoided by proper orientation of plots. Similarly, in manurial trials, the manure from manured plots might seep into the adjoining plots and may vitiate the treatment effect. Apart from the possible introduction of a bias in the comparison of treatments, these border effects could lead to an inflation of error variation by increasing heterogeneity among plots. To overcome these problems, non-experimental guard rows are usually suggested.

Iyer (1958) examined the yield data from a coconut manurial experiment laid out in randomised block design, in nine-tree plots, and found that mean yields of border trees and central trees did not differ. Hence he suggested that the data obtained from all the nine trees in each plot can be used with advantage for analysis, instead of the data from the two central trees only. This is not unexpected in the light of the results (Kushwah *et al.*, 1973) from root studies, where it was noticed that 75% of the roots are confined to an area of 2 m radius around the bole of the palm. Patel (1938) has also pointed out that the surface roots at a few feet around the bole of the palm are concerned with the absorption of mineral nutrients. However, where no guard row has been provided between irrigated and unirrigated palms, have given the indication that the palms in unirrigated plot are getting benefits from the irrigation in the adjoining plot.

ANALYSIS OF DATA AND INTERPRETATION OF RESULTS

Coconut experiments are generally of long-term nature. In the case of fertilizer experiments on adult palms, it generally takes a minimum of three years for the effect of treatments to manifest on yield. Muliyar and Nelliat (1971) have reported that the effect of phosphorus treatment was not seen for the first nine years. In the case of field trials involving the comparison of different varieties, the experiments will have to run for at least 15-20 years. In most of these cases, the comparisons are made on the basis of yield of nuts (or copra or oil). Therefore, the method of compilation of annual yield, validity of assumptions involved, whether the annual data or cumulative data are to be analysed, duration of the experiment, reducing the error variance by calibration or covariance analysis, etc. are all important.

1. Analysis of yield data

Shrikhande (1958) amd Mathew and Jose (1988) have pointed out that coconut trees show a marked biennial bearing habit, giving high and low yields over successive years. Since all the trees are not usually in the same phase of yield in a year, the analysis of yearly records of individual trees of any experiment may be misleading. The average yield of a coconut tree, over an even number of consecutive years represents a good index of its performance and should be utilized in the analysis of data on coconut trees. Mathew and Kumar (1984) have also pointed out that pooling the data for consecutive years reduces the experimental error by over 60%. They have suggested to use the progressive average yields for analysis, instead of analysing the annual yield data every year.

Patterson (1939) has given the methodology for the pooled analysis of data, when the experiment has run for a certain number of years. Since the yields in the same plot in successive years are usually correlated, the experimental error in one season is not independent of that in another season. In comparing the over all yields of treatments, this difficulty is overcome by first finding for each plot the total yield over all the years. These totals are analysed by the method appropriate to the design that was used. This method provides a valid error for testing the overall treatment effects. Thus the analysis of variance table will be of error (a) error (b) type, in which the former is used to assess the the aggregate difference between treatments for the whole period covered by the experiment, and the latter to measure any differential response of the treatments of the varying seasonal condition.

2. Compilation of annual yield

In many of the perennial crops, yield is obtained during a specific period of the year only. But in the case of coconut, nuts are harvested throughout the year, about 60% of the total yield being obtained in the first half of the calendar year. Two different methods of compilation of annual yield data have been noticed – one based on calendar years (January to December) and the other based on crop year (July to June). Recent studies by Mathew *et al.* (1986) have shown that the year to year variation is more pronounced in the case of calendar year tabulation, as compared to crop years. This is because, when the yield data are considered on the basis of crop years, one half year of high yield is combined with a preceding or succeeding half year of low yield, or vice-versa, or the two half years coming together are of medium yield, thus reducing the year to year fluctuations. But in the case of calendar years, two half years of high yield, or two half years of low yield are coming together, thereby increasing the year to year variations. With the help of experimental data, it has been shown that conclusions drawn can be different, depending upon the method of compilation of yield data (Table 2). Whatever be the method of compilation, since the differences narrow down when two year averages are taken, they have recommended the analysis of mean yield for two consecutive years, over the analysis of annual yield.

3. Calibration and covariance analysis

The use of pre-treatment data in the analysis of covariance as well as the idea of calibration, for reduction of experimental errors, are in vogue since the 30s. Both these methods of analysis are intended to control the genetic variation, which is usually of greater magnitude in tree crops. As already explained, the advantages of calibration and covariance analysis have been compared in coconut by Shrikhande (loc. cit.). Reduction in experimental error could be achieved through calibration. Somewhat similar results could be obtained through covariance analysis also. Combined use of both the methods did not result in any further improvement, over what was obtained from any one

Table 2. Genotype-cum-fertilizer trial : Pooled analysis of data, based on two different methods of compilation of yields - Summary of ANOVA (MSS) (Mathew *et al.*, 1986)

Source of variation	df	Crop-year data (1978-79 to 1983-84)	Calendar year data (1979 to 1984)
Replications	2	894.77	1338.50
Genotypes	2	5571.17**	4651.59**
Fertilizers	2	35990.72**	32474.39**
Geno. x fert.	4	833.35	778.95
Error (a)	16	667.61	620.90
Years	5	7717.16**	27168.90**
Geno. x years	10	94.15	2423.23**
Fert. x years	10	320.46**	1897.27**
Geno. x fert. x years	20	64.67	537.01**
Error (b)	90	105.05	244.34

** Significant at P = 0.01

of them alone. Iyer (1958) observed that the consideration of experimental years in sets of two or more years and use of last three pre-expermiental years' data as concomittant variate will help in detecting treatment differences most efficiently. Abraham and Kulkarni (1963) have also examined the period of pre-experimental data to be used for covariance analysis. Their study of the yield data for 20 years showed that the correlation between any two years yields decreases as the number of years separating the two years, increases. They found that about two years data immediately prior to the experimental period were sufficient for covariance analysis. Abeywardena (1970) has also observed 30 to 50% reduction in experimental error, by using two years' pre-experimental yield as calibrating variate. Studies conducted at CPCRI have also confirmed the above findings (Mathew and Kumar, 1984). They had studied the inter-relationship between the yields obtained in different years. Coefficients of correlation, of the form r_{piq}, were calculated for the yields of trees between an earlier period of p (= 0, 1, 2, 3, 4 & 5) years and a later period of q (= 0, 1, 2, 3, 4 & 5) years, separated by an interval of i (= 0, 1, 2, 3, 4 & 5) years. Though the yields obtained in different years were highly correlated, the relationship was comparitively weak when the annual data for immediately preceding and succeeding years were considered, probably due to the alternate bearing tendency shown by some of the palms. Compared to this, the correlation was much higher, when there was a gap of one year, between the two years under consideration. When data for groups of years were considered, the coefficients of correlation were found to go up to 0.9. Only marginal decreases in values were noticed when the gap separating the earlier and later periods was increasing. They also reported substantial reduction in variance and consequent improvement in efficiency, when pre-experimental yield data were used in covariance analysis. Use of two years' pre-ex-

Table 3. Measurements of central tendency (mean), skewness (b_1) and kurtosis (b_2), for the yield data of coconut (Mathew and Kumar, 1984)

Year	Original data			$\sqrt{x + 10}$ transformation	
	Mean	b_1	b_2	b_1	b_2
1967	48.8	0.98**	4.41*	0.22	2.88
1968	44.2	0.83**	3.61	0.05	2.54
1969	40.2	0.88**	3.92*	0.16	2.79
1970	53.6	0.78**	3.26	0.16	2.55
1971	47.6	1.41**	7.43**	0.33*	4.07*
1972	58.2	0.73**	3.64*	-0.06	3.06
1973	50.1	0.95**	4.35**	0.18	3.01
1974	41.4	0.97**	4.09*	0.20	2.84
1975	55.0	0.52**	3.26	-0.01	2.51
1976	43.4	0.81**	4.05*	0.13	2.88

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

perimental data was found to almost double the efficiency, compared to what was obtained with single year's data. Based on this, they have suggested the use of progressive average yields for analysis, instead of analysing the annual yield data every year. Similar study by Abeysinghe (1986) has also shown that two-year pooled pre-experimental yield on four tree plot produces consistent calibration and reduces the experimental error mean square by about 73%. This brings down the mean coefficient of variance to 9.7% from its pre-calibration levels of 36 on one-tree plots and 18 on four-tree plots.

4. Transformation

For the valid application of tests of significance in the analysis of variance, an important assumption is that experimental errors are independently and normally distributed with a common variance. This in other words means that in an experiment-free material, the data should be normally distributed. Studies conducted by Mathew and Kumar (loc. cit.) have shown that the distribution of annual yield of coconut is always positively skewed and leptokurtic, generally following a Pearson Type IV distribution (Table 3).

This was due to the presence of a proportionately higher percentage of palms, giving below average yield. In the years of low production, skewness was found to be more and leptokurtic. Among the different transformations tried, square root transformation of the form $\sqrt{(x + 10)}$ was found to be the best, to bring the data to a near normal form. Such a transformation was necessary even when data for consecutive years were pooled or when palms were considered in groups.

5. Duration of experiments

Duration of the experiment generally depends on the objective of the study. In the case of varietal evaluation studies, the trial may have to continue for 15-20 years. In the case of fertilizer experiments, it may have to run for at least 10 years. Mathes (1980) studied the yield data obtained over 20 consecutive years, from a fertilizer trial carried out in a mature coconut plantation and found that the inter-annual correlation coefficients between successive pairs of years first increased, then reached a plateau, increased again and ended in an asymptote. From the eighth year onwards, these correlations remained stationary. On the basis of these results, an 8 to 10 year experimental period has been recommended to be sufficient to determine the full response of fertilizers.

YIELD FORECASTING METHODOLOGIES

Coconuts are generally harvested about 8-12 times a year. In reseach institutes and other well maintained farms, while it may be possible to monitor each of the harvests and get data on the annual yield, this may not be easy in the case of crop cutting experiments and trials in cultivator's gardens. From Philippines it has been reported (Anon., 1973) that by counting every single nut, mature as well as young ones, hanging on the tree, one can get a fair idea about the number of nuts that can be expected from the tree in a year's time. Reynolds (1979) has suggested selecting 10% of the palms in an area and counting (using binoculars) all large nuts (more than 10.0 to 12.5 cm in length) to obtain a mean figure for large nuts and multiplying the same by the number of palms/ha and increasing it by a percentage factor of 35% to compensate for not counting the smaller nuts, to get a fairly accurate estimate of annual coconut production per hectare. Mathew *et al.* (unpublished) have conducted detailed studies for four years on the number of nuts present on the crown at any time of the year and the yield of nuts in the coming one year, under rainfed Kerala conditions, for WC Tall palms. At Kasaragod, November-December was found to be the best period for estimating the annual yield and have suggested the following regression equation for the purpose: $Y = -0.527 + 0.914\ X$, where Y is the estimated annual yield and X is the count of nuts in the different stages of maturity, on the crown, at the time of observation. Under Kayamkulam condition, the best period was found to be January to March, and the corresponding equation was $Y = -3.0804 + 0.8879\ X$. Workers like Abeywardena (1968) and Kumar *et al.* (1984) have also suggested multiple regression models, for forecasting the annual yield of coconuts, based on weather variables, for selected periods of the year, during the year of harvest and the preceding one or two years.

Based on the correlation between partial harvest data and annual yield, Balakrishnan *et al.* (unpublished) have found that by adopting a technique known as component sampling, the precision of yield estimates can be greatly improved in coconut.

INDEXING THE SEVERITY OF DISEASE SYMPTOMS

The necessity for quantifying the severity of disease symptoms is felt when comparing the intensity of the disease in different genotypes and locations, and when field control trials are laid out, which may involve evaluation of different treatments. In the case of coconuts, attempts were first made in this direction by George and Radha (1973) in indexing the severity of root (wilt) disease. They suggested a method involving the scoring of all the leaves in the crown, for flaccidity, necrosis and yellowing, giving different weights for the symptoms. Separate formulae were given for indexing young palms and adult palms. Nambiar and Pillai (1985) tried to simplify this procedure and suggested that scoring the leaves in any one of the five spirals can be adopted without loss of information. For Tatipaka disease seen in Andhra Pradesh and Tanjavur wilt seen in Tamil Nadu, similar methodologies have been given by Ramapandu and Rajamannar (1983) and Gunasekharan *et al.* (1986), respectively. Recently, Mathew *et al.* (unpublished) have developed a methodology for indexing the disease severity in stem bleeding affected coconut palms, based on lesion size and score for tapering.

SUMMARY AND CONCLUSIONS

a) The present thinking is to go for small plots, with more number of replications. A plot size of six to eight palms seems to be adequate, for the usual field trials, from the point of view of low variability and for reducing the effect of bienniality.

b) Genetic variablity is of importance in coconut. Calibration and covariance analysis have been proved to be advantage in coconut experiments. Two year pre-treatment yield data are adequate for covariance analysis.

c) For field experiments, grouping of palms having marked yield differences reduces the within block variation, by increasing the within plot variation.

d) With the wide spacing adopted for coconut, and the concentration of roots near the bole of the palm, border palms can be avoided for most of the experiments. However, at least in certain soil types, when irrigation is one of the treatments, necessity of guard rows has been felt.

e) Conclusions drawn from experiments can vary depending on the method of compilation of annual yield data.

f) When yield of nuts is one of the characters to be analysed, pooling the data for consecutive years is advantageous.

g) Annual yield data of coconut palms can be estimated using the count of tender nuts in the crown.

h) Methods are available for quantifying the severity of some of the diseases, based on easily observable characters.

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FORECAST OF COCONUT YIELD USING BIOMETRIC CHARACTERS OF YOUNG PALMS

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Abstract: Correlation and path coefficient analysis of various growth characters of young coconut palms of the age group 4-7 years with long-term yield of coconut revealed that number of leaves was the major contributor towards variations in the nut yield of coconut. Selection of palms for nut yield could be done effectively on the basis of number of functioning leaves as early as in the sixth year after planting. Prediction equations were evolved for making advance estimates of probable production from young palms based on the morphological trials assuming a more or less constant environment to continue in the orchard. An attempt was also made to find the desirable characteristics of pre-potent palms to be identified as parents for further breeding. It was found that selection of plants for leaf number and leaf production rate at early stages would be a quick method of genetic improvement. Replacement or rejuvenation of undesirable young palms with sufficiently lesser number of leaves should be an important aspect of effective farm management.

INTRODUCTION

It is generally believed that the economic life of a commercially grown tall coconut is about 60-80 years. Consequently identification of uneconomic palms at early growth stages and the replacement and rejuvenation of potential low yielders is an important aspect of effective farm management. Identification of prepotent palms and using them as parents for raising the next generation is another related problem. It has been found that the process of selection of mother palms on the basis of the performance of their progenies would result in considerable genetic improvement. Forecasts of probable production from a plantation can be worked out in case the relationship between the early performance of the palm and the long-term yield is known. Liyanage (1967) reported a positive and significant correlation between number of leaves produced during the first 40 months and the yield of copra at the age of 13-14 years. He felt that selection of palms on the basis of high leaf number was a quick method of isolating palms of high breeding value. Nampoothiri *et al.* (1975) observed that collar girth and number of leaves of coconut seedlings had a positive significant relationship with the yield of adult coconut palms. But no information is available on the nature of the relationship of long-term yield of palms on the growth behaviour of older seedlings and young palms. The present study was therefore attempted to isolate the important morphological characters of older seedlings and young palms which might be associated with long-term yield of coconut and to evolve a quick method of identifying uneconomic palms at early growth stages.

MATERIALS AND METHODS

The data for the present study were collected from the available records of the Coconut Research Station, Balaramapuram. Observations on 216 experimental palms of a manurial trial from the fourth year after planting were available for analysis. The morphological characters included in the study were (X_1) girth at collar, (X_2) number of functioning leaves, (X_3) frequency of leaf production, (X_4) length of frond and (X_5) number of leaflets on one side of the leaf. Yield data for a continuous period of 8 years from each palm starting from the 13th year of planting to the 20th year were also available. Path coefficient analysis with and without eliminating treatment effects was done on the intercorrelation matrix in order to find the direct and indirect effects of each of the morphological variables on long term yield. Prediction equations were developed for predicting the long-term yield from different young palms under varying treatments.

RESULTS AND DISCUSSION

The results of path coefficient analysis to determine the influences of biometric characters on the yield of coconut based on data of 4, 5 or 6 year old experimental palms (without eliminating treatment effects) are given in Table 1. It could be seen that in the case of experimental palms during the early stages of growth fertilizer treatments exerted the major share of variability through girth at collar. But as the palms grew older, number of functioning leaves became the more important factor in the identification of high yielding palms. Direct effect of number of leaves on yield was positive and very high. The indirect effects of the other factors on this factor were negligible. Thus positive effect of treatment on the palm could be very well distinguishable from the increased number of leaves on the palm. It also appeared that for young palms of 4 or 5 years of age collar girth also had to be considered in predicting future yield. But as the palm grew older the efficiency of collar girth as a diagnosing variable diminished rapidly.

Results of path analysis using the data from relatively older plants also indicated the importance of leaf number as a predictor variable. In the case of 8 year old palms number of functioning leaves continued to be the major contributor (direct effect = 0.8694) followed by frequency of leaf production (direct effect = 0.2237).

Prediction equations were developed for predicting the expected production (in number of nuts) of young palms when they attain full maturity (Table 2). All the prediction equations possessed moderately high degree of predictability. These equations could be used to get advance estimates of production from young palms by assuming a more or less constant environment to continue in the orchard. They also serve as selection indices to identify superior young palms.

Path coefficient analysis was also conducted after eliminating the effect of treatments from observed yield. The resulting correlations were not significant during 4th year of growth. But afterwards the correlations of yield with number of leaves and leaf production were turned out to be significant (Table 3). Among the different biometric characters, number of leaves was the major character contributing to variation in nut yield. The direct effect of this trait on nut yield was relatively high and positive. The indirect effect of this character through other characters was also not very high. Another character which exerted positive direct effect on yield was rate of leaf production. Thus selection of mother palms on the basis of high leaf number in progenies is a quick method of increasing breeding value.

The 216 palms in the field were grouped into three categories according to the number of leaves/palm and the

Table 1. Results of path coefficient analysis of yield data of tall coconut palms with growth characters of young experimental palms at different stages of growth (values in italics are direct effects)

Variables	Stage of growth in years	X_1	X_2	X_3	X_4	X_5	Correlation coefficient
X_1	4	*0.7698*	0.3056	-0.2053	-0.0550	-0.0157	0.7991
	5	*0.3162*	0.3964	-0.3105	0.2376	0.1208	0.7605
	6	*-0.0981*	0.8149	-0.0783	-0.0776	0.1250	0.6859
X_2	4	0.5806	*0.4052*	-0.1702	0.0489	-0.1251	0.7394
	5	0.2588	*0.4842*	-0.3954	0.2844	0.1348	0.7668
	6	-0.0792	*1.0095*	-0.0933	-0.0864	0.1316	0.8822
X_3	4	0.4613	0.2013	*-0.3427*	0.0339	-0.0399	0.3130
	5	0.1849	0.3607	*-0.5308*	0.2417	0.0905	0.3470
	6	-0.0747	0.9167	*-0.1028*	-0.0779	0.1335	0.7948
X_4	4	0.7286	0.3411	-0.1945	*0.0381*	-0.1571	0.7562
	5	0.2457	0.4503	-0.4195	*0.3058*	0.1176	0.6999
	6	-0.0821	0.9404	-0.0863	*-0.0928*	0.1264	0.8056
X_5	4	0.6925	0.2899	-0.1762	0.9522	*-0.1748*	0.6836
	5	0.2272	0.3883	-0.2858	0.2139	*0.1631*	0.7117
	6	-0.0615	0.6665	-0.0689	-0.0588	*0.1993*	0.6766

Table 2. Prediction equation for young palms at different stages of growth

Stage of growth, years	Prediction equation	Coefficient of determination
4	$Y = 0.7467 + 0.7011^{**} X_1 - 0.088 X_2 - 12.6384 X_3$	72.6**
5	$Y = 37.1826 + 0.3551 X_1 + 4.7685^{**} X_2 - 23.6088 X_3$	75.2**
6	$Y = 4.4177^{**} X_2 - 23.24$	78.0*

Y = nuts/tree/year   ** Significant at 1% level

average stabilized yield in each group was calculated. The relationship is very evident and self-explanatory (Table 4). The palms in the C group were having above average productivity. It will not be economical to maintain palms in the A group and hence they may be removed or applied with a different treatment so as to enhance the likely yield.

Table 3. Results of path coefficient analysis of yield data of tall coconut palms with morphological character in early stages after removing treatment effects (values in italics are direct effects)

Variables	Stage of growth, years	X_1	X_2	X_3	X_4	X_5	Correlation coefficient
X_1	5	*-0.0916*	0.3612	-0.0213	-0.0118	-0.0009	0.2356
	6	*0.1612*	0.2133	-0.1208	-0.0813	0.0196	0.1920
X_2	5	-0.1216	*0.4318*	-0.0916	-0.0816	0.1562	0.2932*
	6	-0.4132	*0.3612*	0.2311	0.1002	-0.0059	0.2734*
X_3	5	0.0106	0.2108	*0.1316*	-0.1612	0.1184	0.3102*
	6	-0.0083	0.1691	*0.2110*	-0.1031	0.0281	0.2968*
X_4	5	0.1213	0.1608	0.0103	*-0.0813*	-0.0478	0.1633
	6	0.0038	0.1032	-0.0031	*0.0991*	-0.1089	0.0941
X_5	5	-0.0816	0.1342	-0.0424	0.1243	*-0.0108*	0.1237
	6	-0.0013	0.1213	-0.0032	0.1003	*-0.1284*	0.0887

* Significant at 5% level

Table 4. Relationship between leaf number of young coconut palms and their stabilized yield

Age of the tree (years)	Leaf groups (no. of leaves)	Average yield (nuts/tree/year)
6th year	A (< 8)	3
	B (8 – 15)	26
	C (> 15)	54
7th year	A (< 9)	3
	B (9 – 16)	23
	C (> 16)	43

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FERTILIZER REQUIREMENT OF WCT COCONUT PALMS IN RED LOAM SOILS – AN ALTERNATE APPROACH BASED ON THE PRINCIPLE OF GAME THEORY

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Abstract: The principle of game theory was used for the interpretation of data of a long-term fertilizer trial on WCT coconut in red loam soils at Balaramapuram and specific recommendations for farmers with varying decision environments were made. The various decision criteria such as, Wald's maxmin, Laplace, Hurvicz, the minimum regret and the excess benefit were used on the pay off matrix in the form of output and net return per tree and the optimum strategies under risk were arrived at. The results of analysis showed that application of NPK at the rate of 680 g of N/tree, 450 g of P_2O_5/tree and 900 g of K_2O/tree was the best treatment for the range of nutrients covered in the experiment. The choice of such a strategy (treatment) not only assures maximum yield and net returns to the farmer but also affords maximum security under risky environments.

INTRODUCTION

Several methods have been suggested from time to time for the analysis of data from long-term manurial trials on perennial crops. But none of them appears to be completely satisfactory. The results of most of the trials depend upon a judicious selection of levels of fertilizers which cannot always be guaranteed. Experiments are often beset with unpredictable weather and other environmental factors making them insensitive to treatment differences. In manurial trials the usual practice of having a blanket fertilizer recommendation for all types of farmers has been widely criticised. Farmers differ in their resource position, risk bearing ability, profit orientation and psychological set up. Consequently, the decisions arrived by the researchers and cultivators on the use of inputs differ leading to non-adoption of the improved technology. In fact, specific recommendations have to be formulated for different groups of farmers with varying decision environments. The principle of game theory is useful for this purpose. In this paper various decision criteria based on the game theory approach have been employed for the interpretation of results of a manurial trial in coconut. The only early work in this line on a perennial crop is by Ramachander *et al.* (1982).

MATERIALS AND METHODS

The experimental data for the present study was generated from a field trial with WCT variety of coconut conducted at the Coconut Research Station, Balaramapuram, Trivandrum from the year 1964. Eight year's yield data for the period from 1977 to 1984 were used for the statistical analysis. The experiment was laid out in a 3^3 partially confounded design in randomised blocks with two replications. The levels of nutrients tested were 0, 340 and 680 g N/palm/year; 0, 225 and 450 g P_2O_5/palm/year; and 0, 450 and 900 g K_2O/palm/year. The net plot size consisted of four palms excluding the internal border. The net income per tree for

Table 1. Recommended and the next best strategies using different criteria and their pay offs and expected values

Criteria	Yield, nuts/tree						Net returns, Rs/tree			
	Recommended strategy	Pay off	Expected yield	Next best strategy	Pay off	Expected yield	Recommended strategy	Pay off	Expected net return	Next best strategy
Wald's	$n_2p_2k_2$	45	64	$n_1p_1k_1$	43	46	$n_2p_2k_2$	104	119	$n_1p_1k_2$
Laplace's	-do-	66	64	$n_2p_1k_2$	61	62	-do-	156	119	$n_2p_1k_2$
Hurvicz's (P = 0.5)	-do-	67	64	$n_2p_1k_2$	52	62	-do-	186	119	$n_2p_1k_2$
Hurvicz's (P = 0.25)	-do-	67	64	$n_1p_1k_2$	63	46	-do-	168	119	$n_1p_1k_2$
Minimum regret	-do-	3	64	$n_1p_1k_2$	19	46	-do-	13	119	$n_1p_1k_2$
Excess benefit	-do-	81	64	$n_1p_1k_2$	84	46	-do-	219	119	$n_1p_1k_2$

each treatment combination was calculated at constant prices of Rs 5/kg N, Rs 6/kg P_2O_5 and Rs 2/kg K_2O and Rs 2/nut of coconut.

Any long term experiment can be regarded as a game between the experimenter and the nature. The treatment combinations are the strategies at the command of the expermienter, whereas varying weather conditions are the strategies of the nature. The problem for the experimenter is to choose the optimum strategy under uncertainty so as to win over the nature. Agarwal and Heady (1972) enumerated several approaches in the choice of optimum strategies. According to them, Wald's maxmin, Laplace's average, Hurvicz's optimism-pessimism, Savage's minimum regret and Agarwal's excess benefit are the major criteria employed in arriving at an optimum decision under uncertainty. Wald's criterion consists in choosing the maximum value among the minimum returns (pay offs) when the strategy is repeated. Wald's criterion is specially suitable for a decision maker who is an extreme pessimist, a subsistence farmer or a non-enterprising farmer. Laplace's criterion consists in choosing a strategy that gives maximum return man average. This is the criterion usually recommended by researchers though it does not incorporate any provision for a statistical test of significance. In effect, the estimate obtained through this method is aimed at protecting the farmer from long range risk. Hurvicz's criterion is for the farmer who looks at the worst and best of the out-comes and assigns some weight (P) to both. It is for the pessimist who is also cautious about a likely rise sooner or later. Minimum regret criterion focuses on farmers who are willing to take risk. This is especially suited for wealthy farmers who do not bother a small loss or profit but aims at getting a huge profit sooner or later. In this method the strategy which minimises the loss or regret (deviation of each value from the maximum of the year) is selected as the best strategy. The excess benefit criterion is concerned with the maximisation of additional benefit or surplus (deviation of each value from the minimum of the year). This is suitable for those farmers who desire to choose a treatment that will give them an additional benefit in years of unfavourable weather. In this sense it is a compromise between Wald's criterion and minimum regret criterion.

A square root polynomial model was also fitted to the data and expected yield and net returns from selected treatments were estimated from the fitted model.

RESULTS AND DISCUSSION

The full pay off matrices of yield and net returns obtained from the experiment were made use of. The various decision criteria were tried on the pay off matrix and the optimal strategies worked out under each situation. The results of analysis revealed that $n_2p_2k_2$ (application of NPK at the rates of 600 g N, 450 g P_2O_5 and 900 g K_2O) was the best strategy under all the different criteria (Table 1). It was found that such a recommendation would fit into the requirements of a broad spectrum of farmers with different decision environments. It is suitable not only for a wealthy farmer aiming at huge profit but also for a subsistence farmer who wants to avoid possible losses. Such a recommendation could be adopted by all groups of farmers, conservative or progressive, risk taking or risk fearing and wealthy or poor. It could be expected that the strategy would ensure in the long-run maximum net revenue and at the same time maximum protection from likely losses in years of disaster.

One draw back of the game theory approach is that one cannot predict likely responses of the crop at intermediate levels not tried in the experiment and hence the realised optimum is only an estimate in the discrete sense of the term. Estimation of the optimal point on a continuous regime is usually attempted by fitting response surface models. In this experiment the square root response function fitted to 8 years aggregate data on nut yield (Y) is given by

$$Y = 9.1963 - 0.9795\, N^{\frac{1}{2}} + 0.5054\, P^{\frac{1}{2}} + 0.4724\, K^{\frac{1}{2}} + 0.0273\, N - 0.0516\, P - 0.01573\, K + 0.0233\, NP + 3.0507\, NK + 0.0326\, PK \quad (R^2 = 98.4\%,\ F = 22.9)$$

The theoretical optimum was determined by equating the partial derivative to the respective price rates. But unfortunately the optimum levels fall outside the range of inputs included in the experiment and hence were not admissible. The failure of the response function approach, though indirectly, also indicated the need of incorporating other methods of data interpretation, including the approach of game theory.

The expected number of nuts per tree and the subsequent net return/tree were obtained for each treatment from the response model. These details along with observed pay offs of the optimal and next to optimal strategies under various entries are presented in Table 1.

The best treatment $n_2p_2k_2$ was expected to produce 64 nuts/tree/year with a profit of Rs 119/tree. The next best treatment was $n_2p_1k_2$ (600 g N, 225 g P_2O_5 and 900 g K_2O) with an yield of 62 nuts/palm and net profit of Rs 117/palm.

Even under extremely unfavourable environments (years of drought) palm applied with $n_2p_2k_2$ out yielded others (pay off 45 nuts) though closely followed by $n_1p_1k_2$ (pay off 43 nuts).

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ADOPTION RATE AND CONSTRAINTS OF ADOPTION OF NEWER TECHNOLOGIES BY COCONUT FARMERS IN NORTHERN KERALA

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Abstract: An investigation was made in the Kasaragod and Cannanore districts to study the extent of adoption and constraints in the adoption of newer technologies recommended for coconut by the Kerala Agricultural University. It revealed that only 6.51 per cent of the farmers cultivated hybrids along with local varieties. Twenty-four per cent of the farmers adopted correct spacing for planting. With regard to application of fertilizers, the study showed that farmers applied fertilizers only in partial level. Split application was done by only a few farmers to an extent of 2.96 per cent. The cultivators were applying organic manure in excess quantity than the recommended dose. When compared with the recommended dose of 0.5 kg N, 0.32 kg P_2O_5 and 1.2 kg K_2O the farmers apply 35.5 per cent of nitrogen, 58.75 per cent of phosphorus and 26.70 per cent of potassium. Only 2.96 per cent of farmers cultivated green manure crops and cover crops. Irrigation, as per the recommendation was adopted by only 16.31 per cent of the farmers. The practice of husk burial was not followed by any of the farmers in the study area. Only 3.6 per cent of farmers adopted plant protection measures against pest and disease incidence in coconut. Unawareness of the recommended technology, lack of conviction of recommendations and lack of sufficient capital were found to be the major constraints facing adoption.

INTRODUCTION

Introduction of newer agricultural technologies has made agriculture a business. The spread of newer technology is not uniform in different regions. This resulted in wide variation in the yield realized from various crops between regions and even within regions. The disparity between the technology evolved and its non-adoption by the farmers has resulted in a wide gap between the potential productivity and realized productivity (Chengappa, 1983; Venkataram, 1983; Singh and Reddy, 1987). In this context an attempt to assess the extent of adoption of improved agricultural technology by the farmers and to identify the important constraints for the yield gap is quite relevant. A study was conducted in Kasaragod district in Kerala to examine the extent of adoption of improved agricultural technology as recommended by the Kerala Agricultural University pertaining to major crops in the region. The important constraints responsible for non-adoption of the technology were also studied. This paper forms a part of the results of the study.

MATERIALS AND METHODS

The size of the sample for the study was fixed as 0.05 per cent of the total number of holdings in the district for the study. The sample size was fixed as 221 for the survey. Out of this 169 cultivators responded to the enquiries on the adoption of newer technology for coconut. The sample was selected by a multistage random sampling technique. The selected holdings were distributed among the four strata based on the size of holdings. They are Stratum I holdings having size up to 0.2 ha, Stratum II 0.21 to 0.6 ha, Stratum III 0.61 to 1.2 ha and Stratum IV above 1.2 ha. The survey work was conducted by using a well structured and pre-tested schedule. Tabular analysis was used as the main analytical test for interpretation of results. The different operations considered for the study include selection of variety, source of seedlings, spacing, application of organic manure, green manure and cover crops, irrigation and moisture conservation, husk burial, intercropping and plant protection.

RESULTS AND DISCUSSION

Selection of variety

The study has revealed that only 11 farmers to an extent of 6.51 per cent, cultivated hybrids along with local varieties. Remaining farmers (93.49%) have cultivated only local varieties. The stratum-wise analysis showed that 2 farmers (8.33%) in Stratum I, 4 farmers (7.14%) in Stratum III and two farmers in Stratum IV (4.88%) cultivated hybrids. The maximum extent of adoption was found in Stratum II (36.3%).

Among the different constraints the most important one responsible for non-adoption was the lack of awareness of the recommendation. Sixty farmers (37.97%) have expressed this difficulty. The other constraints noticed were the non-availability of hybrids (33.5%) and lack of conviction of benefits (13.29%).

Source of seedlings

The results showed that 81.06 per cent of farmers procured seedlings from local agencies, 15.98 per cent of the cultivators used seedlings raised in their own farms. Only 2.95 per cent of the farmers were found to be purchasing seedlings from government agencies. Cultivators of larger sized holdings were interested to produce seedlings in their own farms.

Spacing

The results have shown that 24 per cent of farmers adopted correct spacing for planting. Among others who have not adopted the practice, 40.4 per cent of farmers planted coconut irregularly with adequate spacing and 33.7 per cent of farmers planted irregularly with inadequate spacing.

In the stratum level, 12.5 per cent of farmers in Stratum I, 17.9 per cent in Stratum II, 40 per cent in Stratum III and 21.95 per cent in Stratum IV planted the seedlings with correct spacing.

Application of manures and fertilizers

Under this technology the manurial patterns followed for hybrid and local varieties were not different since the fertilizer doses applied for both the types were found to be the same. The study revealed that farmers (29.59%) apply fertilizers only in partial level. Majority of farmers did not give any fertilizer at all. Maximum adoption was noticed in Stratum III (38%) followed by Stratum IV (32%). With regard to the number of applications of fertilizers only 2.96 per cent of the farmers applied fertilizers in split doses. While 26.6 per cent of the farmers applied fertilizers in single dose, 70.4 per cent of farmers did not give any fertilizers.

Considering the quantity of organic manure applied for coconut palms from second year onwards, the results have shown that the cultivators applied organic manure at the rate of 21.13 kg/palm/year. This indicates that the cultivators were applying organic manure in excess quantity than the recommended dose. In the stratum level, the quantity of organic manure varied from 15.7 kg in Stratum II to 30.56 kg in Stratum IV. In Stratum IV (holding size above 1.2 ha) cultivators applied maximum quantity of organic manure.

Regarding the application of nitrogenous fertilizers, the cultivators applied N at the rate of 178 g/palm in the aggregate level. In the stratum level the quantity applied varied from 158 g in Stratum II to 189 g in Stratum IV. The quantity of P applied was found to be at the rate of 188 g/palm. The minimum quantity was applied in Stratum II at the rate of 158 g and maximum in Stratum III at the rate of 200 g. The cultivators applied K at the rate of 320 g only. The variation noticed was from 296 g in Stratum IV to 366 g in Stratum II.

The general recommendation given in the package of practices for palms under good management is to apply N, P and K at the rate of 0.5, 0.32 and 1.2 kg/palm respectively. In general the farmers applied only 35.5 per cent of N, 58.75 per cent of P and 26.70 per cent of K recommended. At average management condition the percentages were 52, 111 and 47 respectively for N, P and K. The most important constraint responsbile for non-adoption of technology was found to be high cost of fertilizers (47.9 per cent). The other constraints noticed were lack of awareness of correct recommendation (20.16 per cent) and lack of conviction (15.9 per cent).

Green manure and cover crops

Only 2.96 per cent of farmers followed this technology. The maximum extent of adoption was noticed in Stratum III. Regarding the constraints the most important one restricting the adoption of technology was found to be the lack of interest of the farmers (40.24 per cent). The other constraints noticed were lack of awareness of recommendation (26.22%), non-availability of green manure seeds (12.8%) higher cost of labour, high cost of seeds etc.

Irrigation and moisture conservation

This practice was adopted only by 16.31 per cent of farmers, the maximum extent of adoption being noticed in Stratum II (holding size from 0.21 to 0.6 ha) to an extent of 34.78 per cent. The most important constraint was found to be lack of water source for irrigation (73.32 per cent). Another constraint identified was the high cost of labour for pot-watering.

Husk burial

The analysis has shown that this practice was not being followed by any of the farmer in the area. The lack of awareness of recommendation (26.6%), alternate use of husk for other purposes, high cost of labour and lack of conviction of benefits were the constraints noticed.

Intercropping

The results have shown that 4.1 per cent of the farmers grow perennials like cocoa, arecanut etc; 1.78 per cent grow pulses and oil seeds; 16.6 per cent grow tuber crops like sweet potato, tapioca and yams; 2.4 per cent grow banana and tubers; 7.1 per cent fruit crops like mango, jack, papaya, sapota etc; 8.3 per cent vegetables and 17.8 per cent plantains + vegetables. The most prominent intercrops followed by majority of farmers were plantains and vegetables followed by tuber crops.

The constraints for non-adoption of technology were found to be the lack of interest on the part of the farmers (60.56%), non-possibility of raising intercrops (23.9%) and a feeling among the cultivators that intercrop adversely affects coconut production (15.99%).

Plant protection

Only 3.6 per cent of the farmers

took some plant protection measures against pests and dieseases while 54.6 per cent of the farmers expressed the opinion that no severe pest and disease incidence was noticed. The important constraints observed were lack of awareness (26.9%), lack of conviction of benefits (13.4%), high cost of labour and high cost of chemicals.

The study has revealed that the extent of adoption of various improved technologies by the farmers is relatively low. The major constraints for this poor adoption were non-availability of planting materials of hybrid varieties in time and in sufficient numbers, lack of awareness of the recommendations, lack of conviction regarding benefits and higher cost.

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ECONOMICS OF COCONUT-BASED FARMING SYSTEMS

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Abstract: The interest for palm based farming systems has stemmed from both technical and economic grounds. Feasibility studies under rainfed situation involving different species and varieties of cereals, pulses, oilseeds, tubers and rhizomes revealed that under Kerala conditions the tubers and rhizomes are relatively more compatible and remunerative intercrops than that of other groups in coconut gardens of Kerala. The economic potential in terms of net profit in the case of coconut + elephant foot-yam system was estimated at Rs 18550/ha/year, while it was Rs 14350 in the case of coconut + ginger system and Rs 5150 in coconut sole crop system.

Among several feasible combinations under irrigation, one of the most promising systems is the integration of coconut + black pepper + cocoa + pineapple in an adult garden of above 20 years. The economic analysis suggests that this combination could generate a net return of Rs 33550/ha/year, while the net return realization from an irrigated middle aged coconut monocrop is estimated at Rs 23200/ha/year. The BCR in this system comes to 1.76, the IRR is higher than 20% and the annual NPW is Rs 32700.

In the case of coconut-based irrigated mixed farming system involving the production of fodder grass in the interspaces of palms, training pepper on coconut, maintaining cross-bred cows and rabbits and raising of subsidiary crops, it was observed that the net return from 1 ha coconut block of 60-70 year age group could be as high as Rs 29500 per annum.

While the annual employment generations in 1 ha rainfed coconut monocrop and irrigated coconut monocrop are assessed at 120 and 144 mandays, the same was estimated at 620 mandays in the case of rainfed coconut + ginger system, 335 mandays on coconut + pepper + coconut + pineapple mixed cropping system and 850 mandays in coconut based mixed farming system.

In the traditional homestead farmings in Kerala, the technical feasibility of coconut-based farming system is grossly misused, thus the opportunities to maximise the economic gains per unit area, input and time are lost.

INTRODUCTION

Coconut is quite an important crop for some parts of India and more so in the case of Kerala State as the economic destine of millions of small holders depends to a considerable extent on the prospects of this crop. It is grown in a predominantly subsistence economy. Under a typical socio-economic situation of Kerala where the average coconut holding size is only 0.222 ha and when many of the families have no other land to raise other crops or alternate sources of income to support them, the traditional practice of coconut farming has often not been sufficient to provide an incentive to improve the coconut productivity by using better management methods which are now available through research investment. On the other hand, the new production technologies which are labour intensive in nature do not find a favourable position in Kerala because of the very high cost of labour. The cost of production of coconut as well as copra in Kerala is relatively higher than that of the other coconut producing states in India because of lower productivity and higher factor costs.

has revealed that the scientifically planned farming system approach provides coconut growers with a sustainable high return (Nair, 1979; Nelliat, 1979; Gomez and Gomez, 1983). The economic prospects of some of the promising models have been highlighted here.

RAINFED SYSTEMS

The possibility of successfully raising semi-perennials or perennials, particularly those demanding water during the summer months, is very much restricted in rainfed coconut gardens; under such situations, the only choice is to raise seasonals or annuals in the interspaces of coconut palms.

Feasibility studies involving different species and varieties of cereals, pulses, oilseeds, tubers and rhizomes revealed that under Kerala condition the tubers and rhizomes are relatively more compatible and remunerative intercrops than that of other groups in coconut gardens. The economic potential in terms of net profit in the case of coconut + elephant-foot-yam system under the 1988 factor product market situations, was worked out as Rs 18550/ha/year. In the case of coconut + ginger system the same was estimated as Rs 14350/ha/year. Coconut sole crop under similar situation, however, gives a small net return of Rs 5150/ha/year.

IRRIGATED SYSTEMS

Among several feasible combinations under irrigation, one of the most successful systems is the integration of coconut + black pepper + cocoa + pineapple in an adult garden of above 20 years. In this system the vines of black pepper were trained on coconut palms, and cocoa and pineapple were raised in the interspaces of coconut palms in such a way that both root and canopy competitions could be avoided. The number of stands under each species in 1 ha plot was 175 coconuts, 175 black pepper, 400 cocoa and 10600 pineapple. The entire block was given irrigation during the dry months with perfo-spray.

An economic analysis of this system under the 1988 factor-product market situations suggests that this combination could generate a net return of Rs 33550/ha/year. The net return realization from an irrigated middle aged coconut sole crop is, however, estimated at Rs 23200/ha/year (Table 1). The cost benefit analysis of this system at 14% discounting factor reveals that the benefit cost ratio (BCR) in this system is 1.76 while the internal rate of return (IRR) is higher than 20% and the annual net present worth (ANPW) is Rs 32700 (Table 2).

MIXED FARMING

In this system, hybrid napier and other fodder grasses were raised in the interspaces of 60-70 year old coconut palms; black pepper was trained on palms; banana and vegetables were grown in the backyard of farm house; and 5 units of cross-bred cows and 30 units of rabbits were maintained on fodder produced from the 1 ha coconut block and supplemented with dry fodder and concentrated feed. Summer irrigation was provided to the field. The economics of this system when worked out at the factor-product price of 1988, the net return from 1 ha coconut block could be of the order of Rs 29500 per annum. On the other hand, an irrigated coconut garden of 60-70 year age group, when raised as a pure stand, may give at the most a net return of Rs 17000/ha/year provided it receives all other cultural energies at their optimum level without any sort of intervention (Table 3).

Table 3. Economics of coconut-based mixed farming (Rs/ha)

Particulars	Rainfed monocrop	Irrigated monocrop	Mixed farming system
Cost			
Labour wages Rs 28/day	3350	4050	23800
Organic manures Rs 100/t	450	450	
Fertilizers	1300	1300	2400
Plant protection	450	450	550
Cattle feed, dry fodder and concentrate			15660
Veterinary charges			560
Expenditure for rabbits			400
Contingencies	400	650	2430
Total variable cost	5950	6900	45800
Annuity value 14%	10800	16400	18400
Depreciation			2100
Gross cost	16750	23300	66300
Returns			
Coconut @ Rs 2.50/nut	26250	39400	38500
Pepper @ Rs 30/kg for 235 kg			7050
Milk @ Rs 5/l for 8760 l			43800
Rabbits (30 numbers)			1000
Subsidiary crops			4450
Byproducts	900	1000	1000
Gross return	17150	40400	95800
Net return	10400	17100	29500
Return from family labour	2900	3200	20500
Total return to family	13300	20300	50000

EMPLOYMENT GENERATION

These farming system models of CPCRI have conclusively proved that the scientifically designed coconut-based farming system is not only capable of generating higher income, but also employment potentials of small-holders. While the annual employment generations in 1 ha rainfed coconut monocrop and irrigated coconut monocrop are estimated at 120 and 144 mandays, the same were assessed as 620 mandays in the case of rainfed coconut + ginger system, 335 mandays in coconut + pepper + cocoa + pineapple mixed cropping system and 850 mandays in coconut-based mixed farming system.

DEMERITS OF TRADITIONAL HOMESTEAD FARMING

The traditional homestead farming is perhaps the most complex and widely followed mixed perennial-annual farming system in the densely populated humid tropics of Kerala. A variety of trees form the components of the homestead farming to provide food, fodder, fibre, fuel, fertilizer and timber. Coconut palms, however, form the single dominant species from socio-economic-cultural considerations (Das, 1986). But the homestead farming in its primitive way had resulted in yielding light and irregular crops. There are problems of soil, water and nutrient management, and the problem of disease, pest and weed management, besides the far reaching consequences to environment, with the increasing rate of complexity through extremely low land:man ratio, the homestead farmings in Kerala have become less and less rewarding. In other words, the technical feasibility of coconut-based farming system is grossly misused, thus the opportunities to maximise the economic gains per unit area, input and time are lost (Das, 1988).

LONG-TERM ADVANTAGES OF SCIENTIFIC FARMING SYSTEM

In a scientifically laid out coconut-based farming, unlike the traditional ones, the resource use efficiency gets considerably enhanced from crop interactions in the system. The interspecific plant interrelationship of certain crop combinations is either complementary or supplementary or even both. The yield of coconut, for instance goes with synergistic response from cocoa, when both are grown in close association. There could be several combinations of compatible plant species with coconut which encourage the proliferation of asymbiotic N_2 fixers and phosphate solubilisers (Thomas and Shantaram, 1984). Proliferation of the beneficial microbes such as associative N_2 fixing bacterium, *Azospirillum* and VA mycorrhizal fungi in coconut-based farming system has also been reported (Ghai and Thoms, 1988; Thomas, 1988). Increased N_2 fixation was also observed due to synergistic interaction of *Rhizobium* and VA mycorrhizal fungi in leguminous green manure crops suitable for cultivation in coconut gardens (Ghai and Thomas, 1987).

R & D EFFORTS IN FARMING SYSTEMS

Since a vast majority of the smallholders pin their hope to homestead farming, research in this area needs much better attention than what is given to it now, at least from the socio-economic considerations. In order to derive the maximum returns from the coconut-based farming system as in other crop based systems, several component technologies are required to be developed through serious research efforts.

There is an urgent need for evolving suitable varieties for the polyculture. Breeding for multiple resistant varieties could be the practical solution to the problems. Our understanding on the interaction fo crop, weed, soil and moisture should also increase to plan better farming system models. The emerging roles of slow release fertilizers and drip irrigation and their interactions in biomass production are another important areas of research investigation. Besides these, research on integrated pests, disease and nematode management in farming system research assumes priority. On-farm-research should also be the correct approach for the transfer of technology on farming system as the component technologies could be evaluated in the field and recommended for adoption by the coconut growers. It is however, often felt that much could be achieved by improving institutional credit supply position and guaranteeing remunerative prices for the agricultural commodities, including coconut products.

Table 1. Economics of coconut-based multistoreyed cropping system

Particulars	Coconut monocrop	Coconut + cocoa + pepper + pineapple
Costs	(Rs)	(Rs)
Labour wages @ Rs 28/day	4050	9400
Organic manure @ Rs 100/t	450	
Urea @ Rs 2.40/kg	920	1400
Superphosphate @ Rs 1/kg	700	950
Muriate of potash @ Rs 1.40/kg	980	1300
Plant protection	450	800
Contingencies	650	900
Total variable cost	8200	14750
Annuity value @ 14%	16400	20650
Gross cost	24600	35400
Returns		
Coconut @ Rs 2.50/nut	46800	46800
Byproducts	1000	1000
Mixed crops		17900
Gross return	47800	65700
Net return	23200	30300

Table 2. Cost-benefit analysis of coconut + cocoa (SH) + pepper + pineapple system

Age of coconut palm, years	Cost Rs/ha	Return Rs/ha	Incremental benefit Rs/ha	Discounted incremental benefit @ 14% DF (Rs)
25	33240	52000	18800	16500
26	31400	52000	20600	15800
27	32000	58300	26300	17750
28	33000	60400	27400	16200
29	31150	61800	30650	15900
30	31150	62500	31350	14300
31-40	31150	64600	33450	104400
			NPW	200850
			BCR	1.76
			IRR	>20
			ANPW	32700

has revealed that the scientifically planned farming system approach provides coconut growers with a sustainable high return (Nair, 1979; Nelliat, 1979; Gomez and Gomez, 1983). The economic prospects of some of the promising models have been highlighted here.

RAINFED SYSTEMS

The possibility of successfully raising semi-perennials or perennials, particularly those demanding water during the summer months, is very much restricted in rainfed coconut gardens; under such situations, the only choice is to raise seasonals or annuals in the interspaces of coconut palms.

Feasibility studies involving different species and varieties of cereals, pulses, oilseeds, tubers and rhizomes revealed that under Kerala condition the tubers and rhizomes are relatively more compatible and remunerative intercrops than that of other groups in coconut gardens. The economic potential in terms of net profit in the case of coconut + elephant-foot-yam system under the 1988 factor product market situations, was worked out as Rs 18550/ha/year. In the case of coconut + ginger system the same was estimated as Rs 14350/ha/year. Coconut sole crop under similar situation, however, gives a small net return of Rs 5150/ha/year.

IRRIGATED SYSTEMS

Among several feasible combinations under irrigation, one of the most successful systems is the integration of coconut + black pepper + cocoa + pineapple in an adult garden of above 20 years. In this system the vines of black pepper were trained on coconut palms, and cocoa and pineapple were raised in the interspaces of coconut palms in such a way that both root and canopy competitions could be avoided. The number of stands under each species in 1 ha plot was 175 coconuts, 175 black pepper, 400 cocoa and 10600 pineapple. The entire block was given irrigation during the dry months with perfo-spray.

An economic analysis of this system under the 1988 factor-product market situations suggests that this combination could generate a net return of Rs 33550/ha/year. The net return realization from an irrigated middle aged coconut sole crop is, however, estimated at Rs 23200/ha/year (Table 1). The cost benefit analysis of this system at 14% discounting factor reveals that the benefit cost ratio (BCR) in this system is 1.76 while the internal rate of return (IRR) is higher than 20% and the annual net present worth (ANPW) is Rs 32700 (Table 2).

MIXED FARMING

In this system, hybrid napier and other fodder grasses were raised in the interspaces of 60-70 year old coconut palms; black pepper was trained on palms; banana and vegetables were grown in the backyard of farm house; and 5 units of cross-bred cows and 30 units of rabbits were maintained on fodder produced from the 1 ha coconut block and supplemented with dry fodder and concentrated feed. Summer irrigation was provided to the field. The economics of this system when worked out at the factor-product price of 1988, the net return from 1 ha coconut block could be of the order of Rs 29500 per annum. On the other hand, an irrigated coconut garden of 60-70 year age group, when raised as a pure stand, may give at the most a net return of Rs 17000/ha/year provided it receives all other cultural energies at their optimum level without any sort of intervention (Table 3).

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IMPACT OF WEED CONTROL METHODS ON THE OCCURRENCE AND INTENSITY OF WEED FLORA AND MYCORRHIZAL ASSOCIATION IN COCONUT

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Abstract: In the coconut gardens of the reclaimed alluvial soils of the Regional Agricultural Research Station, Kumarakom, Kerala, chemical and mechanical methods of weed control alone and in combination were tried for four years from 1984 to 1988. The treatments had significant effect on the occurrence and intensity of various weed spp. and microflora. Perennial graminaceous weeds dominated in treatments receiving paraquat alone and in combination with 2,4-D sodium salt. Graminaceous weeds could be significantly controlled with dalapon application. The mechanical methods of weed control resulted in the recurrence of a number of weed spp. The mycorrhizal colonization studies indicate that the chemical weed control did not influence the VAM colonization. The incorporation of 2,4-D sodium salt stimulated the VAM intensity in the root and rhizosphere soil of weed plants and coconut. Weed control by cultural means generally reduced the VAM colonization in the weed plants and coconut.

INTRODUCTION

The very high fertility of the soil, unlimited supply of soil moisture and abundant sunshine make the reclaimed alluvial soils of Kuttanad (Kerala), very ideal for plant growth. Here weeds grow luxuriantly and deplete large quantities of soil nutrients. In coconut gardens of this area intercultivation is the conventional method of weed control. However, unlike in the other parts of the tropics, due to the unlimited supply of moisture the weeds attain the original stand in about a month or two after each intercultural operations. Mathai (1979) reported that two diggings were as good as clean surface removal of grass for increasing coconut yield. However, for controlling the weed growth two diggings are ineffective. The effect of different herbicides on control of weeds and their effect on micro and macroflora in coconut gardens have not been studied in detail. In this study an attempt is made to investigate the effect of cultural and chemical methods of weed control and their combination on the intensity and recurrence of weed spp. on mycorrhizal colonization with coconut and weed roots; and finally on yield of coconut.

MATERIALS AND METHODS

The experiment was laid out at the Regional Agricultural Research Station, Kumarakom, Kerala during May 1984 and continued for four years. There were eleven treatments replicated thrice. Each replication consisted of four palms of WCT variety. The treatments are : (T1) two digging in Aug-Sep and Dec-Jan, (T2) weed free control by regular digging and removal of weeds, (T3) sickle weeding once in three months (Mar/June/Sept/Dec), (T4) forming mounds in Sep-Oct and levelling in Dec-Jan, (T5) paraquat application @ 2.5 l/ha during March/June/Oct, (T6) application of dalapon @ 3.75 kg/ha in March and paraquat @ 2.5 l/ha in April/June/Oct, (T7) paraquat @ 2.5 l/ha + 2,4-D sodium salt @ 1.25 kg/ha in Mar/June/Oct, (T8) paraquat application @ 2.5 l/ha in Mar/June/Oct + one digging in Dec-Jan, (T9) application of dalapon @ 2.5 l/ha in April/June/Oct. + one digging in Dec-Jan, (T10) sickle weeding in March and August and paraquat @ 2.5 l/ha in April and September and (T11) unweeded control.

Monthly observations on the fresh and dry weight of weeds per unit area (g/m^2), occurrence of various weed spp. and their relative dominance were recorded. The effect of the herbicides on the mycorrhizal association with coconut and weed roots was studied by taking root samples from the experiment area, one month after the application of these herbicides. These root samples were made into small (1 cm size) bits and subjected to trypan blue staining (Philips and Hayman, 1970). Stained root bits were scanned under a microscope for the presence of mycorrhizal association. Fifty root bits were examined in each samples for infection and root infection was worked out on percentage basis. The yield of nut was recorded at monthly intervals.

RESULTS AND DISCUSSION

Effect on recurrence of weeds

The methods of weed control had a tremendous influence on the weed spp. observed in August 1987 and six months later. The treatment receiving two diggings in August-September and December-January (T1) revealed to have the maximum weed spp. There were 30 spp. during the first sampling. None of the spp. revealed to have dominance over the others. During the subsequent sampling the number of spp. observed decreased to twelve. In the treatment receiving sickle weeding once in three months (T3), during the first sampling, *Digitaria ciliaris* (35%) and *Brachiaria mutica* (17%) were observed to be the dominant spp. During the second sampling, *Brachiaria mutica* (33%) and *Peuraria phaseoloides* (25%) were the dominant weeds. In treatment receiving mound forming and levelling (T4) *Peuraria phaseoloides* (32%) and *Brachiaria mutica* (17%) were the dominant weeds. During the second sampling *Leucas aspera* (28%), *Panicum repens* (20%) were found to be the dominant spp. In T5 consisting of paraquat application at the rate of 2.5 l/ha in March, June and October, *Ischaemum muticum* (65%) and *Brachiaria mutica* (30%) dominated in both samplings. In dalapon + paraquat treatment (T6), *Ischaemum rugosum* (25%) was the dominant spp. during the August sampling. Compared to T5 the number of spp. especially broad leaved weeds were more in this treatment. During the subsequent sampling it is seen that the *Peuraria phaseoloides* (60%) became the dominant spp. In T7 (Paraquat + 2, 4-D sodium salt thrice) gramineae weeds viz., *Ischaemum muticum* (35%) and *Brachiaria mutica* (60%) were the only major spp. during both the samplings. The treatment receiving paraquat application followed by digging (T8) observed to have the combined effect of both the methods of weed control. During the August sampling, when the chemical means of weed control is in progress *Brachiaria mutica, Panicum repens, Digitaria ciliaris, Leucas aspera* and *Spermacoce ocymoides* were the important weeds. During the second sampling, after the digging operation the number of spp. increased from five to ten. *Leucas aspera* (80%) observed to be the dominant weed. T9 involving dalapon followed by paraquat application and one digging revealed to have a weed composition dominated by *Peuraria phaseoloides* (30%) during first sampling. During the subsequent sampling the number of spp. increased to twelve.

Gramineae weeds viz., *Brachiaria mutica* (42%), *Panicum repens* (28%), *Digitaria ciliaris* (6%), *Ischaemum muticum* (4%) and *Cyanodon dactylon* (3%), were seen during the first sampling in T10

Table 1. Effect of weed control methods on dry weight of weeds (g/m^2)

Treatments	1985	1986	1987	Pooled mean
T_1	392.6	1727.0	517.3	879.8
T_2	0.0	8.0	0.0	2.7
T_3	329.8	1481.0	509.3	773.3
T_4	458.5	112.0	524.7	701.6
T_5	267.3	1687.0	790.0	914.7
T_6	251.8	1347.0	528.7	709.3
T_7	244.0	2032.0	908.0	1061.2
T_8	182.3	994.0	687.3	621.3
T_9	173.3	1012.0	426.0	537.2
T_{10}	390.4	2088.0	624.7	1034.5
T_{11}	786.2	3617.0	1365.0	1922.8
Mean	316.0	1555.9	625.6	

CD (0.05) for treatment = 269.4

CD (0.05) for season = 235.5

Table 2. Effect of weed control methods on infection per cent and spore count of vesicular-arbuscular mycorrhiza

Treatments	Coconut roots (%)	Weed roots (%)	Spore count per 25 ml soil
T_1	9.26	16.33	45
T_2	8.00	13.45	38
T_3	12.80	18.00	56
T_4	6.33	15.28	44
T_5	10.40	18.33	62
T_6	14.00	12.66	58
T_7	18.20	23.40	84
T_8	11.30	16.00	57
T_9	12.00	19.50	49
T_{10}	10.66	18.24	66
T_{11}	12.20	16.86	78

Table 3. Yield of coconut (nuts/palm) and cost of weed control (Rs/ha) as influenced by different methods

Treatments	Pre-treatment yield	Post-treatment yield	Per cent increase	Cost of weed control
T_1	28.6	33.2	15.6	2125
T_2	33.1	37.5	12.0	6375
T_3	34.6	36.6	6.3	3300
T_4	34.1	39.6	15.8	2125
T_5	39.1	44.2	12.8	1400
T_6	38.1	35.1	-7.9	2050
T_7	33.9	39.4	16.2	1650
T_8	42.5	42.8	0.6	2500
T_9	39.9	41.5	3.0	3125
T_{10}	36.0	38.1	5.6	2600
T_{11}	34.4	32.7	-5.3	..

(sickle weeding in March and August and paraquat application in April and September). During the subsequent sampling *Peuraria phaseoloides* and *Leucas aspera* were also seen in addition to the above weeds.

In the unweeded control treatment (T11) the gramineae weeds viz. *Brachiaria mutica* (33%) and *Ischaemum muticum* (40%) were dominant during the August sampling. *Peuraria phaseoloides* (13%) and *Centrosema pubescens* (5%) were the weeds of secondary importance. During the subsequent sampling the creepers viz., *Peuraria phaseoloides* (30%) and *Mikania micrantha* (10%) could compete well with *Ischaemum muticum* (32%) and *Brachiaria mutica* (20%).

The chemical means of weed control with paraquat alone and in combination with 2,4-D sodium salt resulted in the dominance of gramineae weeds especially *Brachiaria mutica* and *Ischaemum muticum*. Chemical control with dalapon effectively controlled gramineae weeds. Dalapon application resulted in the recurrence of a number of broad leaved weeds, while disturbing the soil by way of digging resulted in the recurrence of a large number of weed spp. belonging to grasses, sedges and broad leaved categories. The unweeded control and combination of sickle weeding and paraquat application resulted in the dominance of gramineae weeds viz., *Brachiaria mutica* and *Ischaemum muticum* and creepers viz., *Peuraria phaseoloides* and *Mikania micrantha*.

Effect on dry weight of weeds

Notwithstanding the fact that the minimum dry weight of weeds was observed in the weed free control, compared to the other treatments, T9 (dalapon + paraquat + digging) recorded the minimum dry weight of weeds (Table 1). T8 receiving mound forming and levelling; T6 receiving dalapon in March and paraquat during April, June and October; and T3 receiving sickle weeding once in three months are at par as far as the dry weights of weeds are concerned.

A close perusal of the data reveals that the combination of cultural and chemical methods of weed control is more effective than chemical and cultural methods alone in controlling the weeds. Application of paraquat alone and in combination with 2,4-D sodium salt is ineffective in controlling weeds. Inclusion of dalapon in the treatment could invariably control the weeds more effectively than the other chemicals. The efficiency of dalapon in controlling the dominant gramineae weeds viz., *Ischaemum muticum* and *Brachiaria mutica* may be the reason for the low dry weight of weeds in the dalapon included treatments.

Effect on mycorrhizal association

The infection per cent of mycorrhiza on coconut and weed roots and the VAM intensity in the rhizosphere soil as shown by the spore count are less in the weed free control(Table 2). The infection per cent and the spore count are the maximum in T7 receiving combined application of paraquat and 2,4-D sodium salt. The VAM association with weed roots is 100 per cent more in this treatment compared to the treatment receiving paraquat alone. Association of VAM with coconut roots and the spore count is also more in this treatment. The 2,4-D sodium salt application may have stimulated the VAM association with coconut and weed roots. Compared to cultural methods of weed control the VAM association in coconut and weed roots and spore count are not less in the chemical weed control treatments. This points out the fact that these chemical means of weed control do not adversely affect the mycorrhizal association with host plants.

Effect on yield of coconut

Table 3 presents the pretreatment yield, mean post-treatment yield after four years and per cent change as influenced by the weed control methods. The unweeded control registered a decline in yield of 5.32 per cent compared to pretreatment yield. The treatment receiving dalapon followed by paraquat also gave a negative trend. The maximum increase in yield of 16.2 per cent is given by the treatments receiving the combined application of paraquat and 2,4-D sodium salt (T7). The increase is 12.83 per cent in the case of the treatment receiving paraquat alone. The cultural methods of weed control viz., two diggings in a year (T1) and forming mounds and levelling (T4) gave increased nut yields comparable to T7. Ramanathan *et al.* (1984) could get increased nut yield to the tune of 21.2 per cent by ploughing the entire field twice a year. Mathai (1979) reported that two diggings in a year is as good as clean surface removal of weeds, as far as the yield of coconut is concerned. The results of the present experiment, however, indicated that application of the paraquat thrice a year alone and in combination with 2,4-D sodium salt is as good as the cultural methods of weed control, as far as the yield is concerned The chemical means of weed control is lucrative from the economic point also (Table 3). The treatment consisting of paraquat alone requires Rs 1400 for weed control and for the combined application with 2,4-D Rs 1650 per ha. The corresponding figure for digging twice a year and for forming mounds and levelling is Rs 2125 per ha.

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NUTRITION OF HYBRID COCONUT

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Abstract: Comparatively, removal of NPK and other nutrient elements by hybrid varieties appears to be lesser than that of the tall varieties of coconut as revealed by the analysis of components. This is supported by the results of 15 year old manurial trial with WCT and three hybrids at CPCRI, Kasaragod. These results have shown that theoretically (M-B model) just to realize 50 per cent of maximum yields COD x WCT and WCT x COD require only 75:75:150 and 144:144:288 g N, P_2O_5 and K_2O respectively and to obtain 87.5 per cent of the maximum yield, the fertilizer application can be tailored to two third quantity.

Nutrient relationship to yield of coconut has shown good indications. Nitrogen content of all the leaf ranks (except 6) significantly related to yield in which leaf No.1 was showing highest correlation. The K values of all the leaves (except No.1) are significantly related to yield. The study on chemical potential in the palm and their relationship to the yield has indicated positive correlation of leaf K and Mg with coconut yield.

The D x T among the available hybrids was registered to be efficient user of nutrients in the cellular fractions of the constituents.

In coconut scattered information is available regarding reproducibility and dependability of tissue analysis with that of yield. Correlation coefficients were worked out between the nutrient contents of different ranks of leaves (1,6,11,14,16,21) and yield from samples collected from the field at CPCRI Kasaragod. Nitrogen content of all the leaves studied (except No.6) was observed to be significantly related to yield in which leaf No.1 was showing the highest correlation (0.647**). In the case of potassium, the K values of all leaves are significantly related with yield, barring leaf No.1. It was also recorded that the strength of coefficient of correlation between nutrient content and yield decreased with age of the leaf and the correlation between leaf K and yield increased with age of the leaf.

When the multiple correlations were worked out between yield and NPK content in different ranks of leaf, the predictability (R^2) was found to improve over single nutrient correlations.

Studies on diurnal variation of plant bio-elements were carried out to understand their dynamics during the day as a guide to leaf sampling for diagnostic purpose from 7.00 a.m.to 5.00 p.m. A slight increase in the mid-day and a gradual decrease thereafter for N, a decrease from 9.00 a.m. to 5.00 p.m. for K, and an uniform trend for P were observed. Calcium content of the leaf was uniform up to 11.00 a.m. and decreased thereafter while Mg content was constant throughout the day.

The pooled DRIS norms for NPK were 0.486, 0.107 and -0.594 respectively showing the order of requirement as KPN to achieve the yield of 88.8 nuts per palm/year. The optimum NP, NK and KP ratio was found to be 17.2, 1.6 and 10.8 respectively.

Chemical potential in the plant: It is now believed that cationic and anionic balances are independent of each other in the plant system. Wahid *et al.* (1974) from their studies on root CEC and its relationship with certain cations claimed that the coconut palms always tended to maintain an equilibrium level between monovalent and divalent cations irrespective of their productivity. An attempt has been made at CPCRI Kasaragod to evaluate the total ionic balance and free energy change of all nutrients in three coconut genotypes (WCT, D x T and T x D). The estimated data for nutrients converted into ionic strength (anionic and cationic) were correlated with the yield of coconut.

Sub-cellular nutrients: Any change in yield potential as indicated by the earlier work is the reflection of efficient utilization of absorbed nutrients in the cellular and sub-cellular fractions of the plant. In this direction studies have been carried out in WCT, T x D, D x T, T x GB, LO x GB and LO x CDO genotypes. The data revealed that D x T was found to be superior in incorporating the nutrients into its various functional cellular constituents compared to other genotypes. It is also in high yield potential of the genotypes. Nutrient content in certain cell fractions gave positive correlation with yield and this can be used as an index for prediction of yield in coconut.

Soil-plant integration models: Fertilizer applications tailored to the needs of optimal production is the current strategy in crop management. In evaluating crop responses in relation to soil tests Mitscherlich-Bray equation is used for phosphorus and potassium and further extended to nitrogen by Mackay *et. al.* (1963) and Biddappa and Patnaik (1977). In view of this, a study was conducted by Khan *et al.* (1986) on coconut. A fifteen year old field experiment conducted with three coconut varieties viz., West Coast Tall (WCT), Chowghat Dwarf Orange (COD) x WCT and WCT x COD with three levels of fertilizers. The response function for yield was found to be linear for WCT and curvilinear for COD x WCT and WCT x COD in the limits of fertilizer levels tried. The attainable maximum yield (A) was determined by plotting log yields against the reciprocal of dose of nutrients and extrapolating to $1/X \cdots\cdots\cdots \rightarrow 0$. Baule equivalents of soil and fertilizer form of nutrients were calculated by dividing the Mitscherlich efficiency constant of 0.301 by respective efficiency factors. Baule units were obtained by dividing the soil test values by Baule equivalent of soil form of nutrients. Normally for the production of 93.75 per cent of maximum yield, four Baule units of soil nutrient (NPK) are considered essential. The calculated Baule units range from 0.23 to 0.46 for soil NPK. Under the frame work of the results obtained in this experiment just to realize 50 per cent of maximum yields, COD x WCT and WCT x COD require only 75:75:150 and 144:144:288 g N, P_2O_5 and K_2O respectively per palm per year as shown in Table 1. To obtain 87.5 per cent of maximum yield, the fertilizer application can be tailored to two thirds of the M_1 dose for COD x WCT.

System approach: In the intensive cropping system and high density cropping system, the difference between nutrient enrichment and depletion is expected to give the nutrient balance which may be positive, negative or equal. In a perennial based system, the nutrient balance can be studied at equilibrium stage after 4-5 years of reproduction phase of 75 per cent crop communities concerned and at a stage when the system is fully mature. Based on the nutrient balance model suggested by Biddappa *et. al.* (1987), the nutrient profile in the system was determined in a coconut-based high density multispecies cropping system. While there was no build up of N and Mg, the levels of P and K doubled by the third year. Consequently there was a depletion in

Table 1. Fertilizer recommendation based on Mitscherlich-Bray equation

Cultivar	Nutrient	Baule units Fertilizer to be applied per palm/year			
		1 *(50%)	2 (75%)	3 (87.5%)	4 (93.75%)
WCT	N	370	851	1332	1813
	P_2O_5	370	851	1332	1813
	K_2O	741	1703	2665	3636
COD x WCT	N	75	214	352	490
	P_2O_5	75	214	352	490
	K_2O	150	427	754	980
WCT x COD	N	144	333	521	710
	P_2O_5	144	333	521	710
	K_2O	288	666	1043	1420

* Per cent of the maximum yield

the N and Mg balance. Application of higher doses of fertilizers appears to reduce the rate of N depletion. The depletion of Mg is uniform irrespective of the levels of fertilizer used. If the N depletion trend continues affecting yields and biomass production, necessary corrective measures will have to be undertaken in respect of this nutrient. On the other hand, P and K build up in the system strongly suggests the adequacy of one third dose for maximum productivity.

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MANAGEMENT OF HYBRID COCONUT PALMS

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Abstract: Recently, hybrids Chandrasankara (COD x WCT) and Chandralaksha (LO x COD) from CPCRI, Kasaragod, Lakshaganga (LO x GB) and Anandaganga (AO x GB) from the Kerala Agricultural University and VHC 1 (ECT x OGD) and VHC 2 (ECT x MYD) from the Tamil Nadu Agricultural University have been released for cultivation. Hybrids Chandralaksha and Lakshaganga were found tolerant to drought. Chandrasankara appeared to be susceptible to drought. However, in sandy loam soil under rainfed conditions at Kasaragod, this hybrid has outyielded the hybrid WCT x COD and the local cv WCT. Under rainfed conditions of Kasaragod with the fertilizer level of 500 g N + 500 g P_2O_5 + 1000 g k_2O/palm/year, hybrid Chandrasankara produced 92 nuts/palm/year as against 79 and 67 nuts respectively in WCT x COD and WCT. With 20 mm irrigation through perfo-sprinkler, hybrids Chandrasankara and WCT x COD yielded 147 and 135 nuts/palm/year respectively, compared to 126 nuts by WCT. Hybrid Chandrasankara showed higher efficiency in utilizing native fertility and attained earlier bearing than WCT x COD and WCT.

Planting of hybrid coconuts makes sense only if they are grown in a congenial environment and supplied with adequate nutrients and water and optimum plant protection measures are adopted to enable the palms to express their full yield potential. Most of the hybrids have been released for cultivation only recently and only limited information is available regarding their management. Though there is no basic difference in the management of cultivars and hybrids of coconut, hybrids do differ from local cultivars. Management practices for optimising the productivity of hybrid coconuts are discussed in this paper in the light of recent research findings. The hybrids COD x WCT (Chandrasankara) and LO x COD (Chandralaksha) of CPCRI and LO x GB (Lakshaganga) and AO x GB (Anandaganga) of KAU have been recommended for cultivation in Kerala. Similarly TNAU has released the hybrids VHC 1 (ECT x OGD) and VHC 2 (ECT x MYD) for cultivation in Tamil Nadu. The performance of the released hybrids vis-a-vis the local cultivars is summarised in Table 1.

The productivity of hybrids varies under different agro-ecological conditions. Among the released hybrids, COD x WCT was observed to be more susceptible to drought. The yield of COD x WCT palms showed large year to year variations and it recorded very poor yields during 1982, 1984 and 1986 as a result of the pronounced drought which occurred during the previous years. Hybrids involving LO (LO x GB and LO x COD), however showed greater tolerance to drought and recorded only smaller fluctuations in their annual yield. The increased susceptibility of COD x WCT hybrid to drought was also brought out by the physiological traits. Lower stomatal resistance, less epicuticular wax content and higher transpiration rate compared to its reciprocal hybrid, WCT x COD and the local cultivar WCT, make COD x WCT the most susceptible to drought. Therefore, this hybrid is not suited to drought-prone areas under rainfed conditions.

During 1981-83 hybrid COD x WCT produced significantly higher yield (77.6 nuts/palm/year) than WCT (61.6 nuts/palm) and hybrid WCT x COD (62.0 nuts/palm). During this period both the

Table 1. Performance of coconut hybrids released for cultivation

Location	Hybrid/ cultivar	Yield (nuts/ palm/ year)	Copra/ nut (g)	Copra yield (kg/palm/ year)
[1] CPCRI, Kasaragod	WCT	68	176	12.0
	COD x WCT	78	208	16.3
	LO x COD	78	195	15.2
[2] Regional Agrl. Res. Stn. (KAU), Pilicode	LO x GB	108	195	21.6
	AO x GB	95	216	20.6
[3] Coconut Research Station (TNAU) Veppankulam	VHC 1	112	162	18.1
	VHC 2	126	161	20.3
	ECT	105	134	14.1

Sources : [1]Bavappa (1986); [2] Balakrishnan *et al.* (1988); [3] AICRPP (1988)

Table 2. Response of coconut genotypes to fertilizer levels under rainfed conditions at CPCRI Kasaragod

Genotype	Yield during 1981-83 (nuts/palm/year)			
	m_0	m_1	m_2	Mean
WCT	33.7	66.9	84.4	61.6
COD x WCT	45.9	92.2	94.7	77.6
WCT x COD	26.4	79.2	80.4	62.0
Mean	35.3	79.4	86.5	

CD (0.05) for genotypes is 12.0; and for fertilizer levels is 12.0

hybrids have shown response up to m_1 level only. Thus the optimum dose for both the hybrids is 500 g N + 500 g P_2O_5 + 1000 g K_2O/palm/year. The hybrid COD x WCT produced 45.9 nuts/palm/year at m_0 level which was 36 and 74 per cent higher than the yields of WCT and WCT x COD at m_0 level. At m_1 level COD x WCT yielded 38 and 16 per cent nuts, respectively than WCT and WCT x COD hybrids (Table 2)

From 1984 onwards, the response of the three genotypes to fertilizer levels was evaluated under both rainfed and irrigated conditions. The data presented in Table 3 reveal that under irrigated condition, the hybrid COD x WCT responded up to m_1 level of fertilizer. The production was 166.4 nuts/palm/year under rainfed condition. Regarding the WCT x COD hybrid, the nut yield increased up to m_2 level of fertilizer application with irrigation, but decreased at m_2 dose under rainfed condition.

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Table 3. Performance of coconut genotypes under rainfed and irrigated conditions (1986-88)

Treatment		Yield of nuts/palm/year		
		Rainfed	Irrigated	Mean
WCT	m0	81.2	99.4	90.3
	m1	108.3	134.0	121.1
	m2	128.9	144.3	136.6
	mean	106.1	125.9	116.0
COD x WCT	m0	69.3	104.8	87.0
	m1	148.8	166.4	157.6
	m2	148.6	168.4	158.5
	mean	122.2	146.5	139.3
WCT x COD	m0	65.5	105.5	85.5
	m1	137.9	140.9	139.4
	m2	117.1	157.6	137.4
	mean	106.8	134.7	120.8
Means for	m0	72.0	103.2	87.6
	m1	131.7	147.1	139.4
	m2	131.5	156.8	144.1

m0 = No fertilizer; m1 = 500 g N + 500 g P_2O_5 + 1000 g K2O/palm/year; m2 = 1000 g N + 1000 g P_2O_5 + 2000 g K_2O/palm/year

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EFFECTS OF DIFFERENT LEVELS OF NPK AND THEIR ECONOMICS ON COCONUT VARIETIES UNDER SOUTH GUJARAT CONDITIONS

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Abstract: An experiment on coconut was conducted at the Department of Horticulture, Gujarat Agricultural University, Navsari Campus, Navsari during the period from 1972 to 1986. Uniform plants of two varieties of coconut (T x D hybrid and West Coast Tall) in the main plot and six treatments of NPK fertilizers viz., two levels of nitrogen (750 and 1500 g N/palm) and three levels of potash (750, 1500 and 2250 g K_2O/palm) and 750 g P_2O_5/palm were applied evenly in the subplot. The yield performance of different treatments was evaluated after obtaining stable yield from 1983 to 1986. Among the varieties, the T x D hybrid gave significantly higher yield than the West Coast Tall variety of coconut. The application of 1500 g N + 750 g P_2O_5 + 1500 g K_2O per palm gave significantly higher yield in both the varieties (12782 and 8729 nuts/ha) and it was the most economical dose which gave a net ICBR of 1:16.8 and 1:11.3 in T x D hybrid and West Coast Tall respectively, under South Gujarat conditions.

A field experiment was laid out in split-plot design with four replications at the orchard of the Gujarat Agricultural University, Navsari during 1972. The soil of the experimental field was black clayey with pH 7.5 and EC 0.15 dS/m. The treatments comprised of two varieties (hybrid Tall x Dwarf and West Coast Tall) of coconut in the main plot and six NPK treatments in the subplot. The fertilizer treatments (NPK combinations) were (1) 750:750:750, (2) 750:750:1500, (3) 750:750:2250, (4) 1500:750:750, (5) 1500:750:1500 and (6) 1500:750:2250 of N:P_2O_5:K_2O g/palm/year. The planting was done at a spacing of 7.5 m x 7.5 m having four palms in each subplot and 24 palms in each plot. The fertilizers were applied in two equal split doses, half the quantity in June and the remaining half in October, in ring of 30 cm wide and 15 cm deep and 1 m away from the trunk. The yield of nuts was recorded after 1983 onwards. The yield data for four years (1983-86) are considered in this study. The incremental cost benefit ratio was calculated to examine the benefit obtained through increased production due to the increased fertilizer doses.

Data on nut yield per palm (Table 1) revealed that the variety Tx D produced significantly higher number of nuts (59.7) per palm than West Coast Tall (40.4), which was about 41 per cent

Table 1. Average number of nuts per palm (1983 to 1986)

Variety	1983	1984	1985	1986	Mean
T x D	56.4	56.2	38.0	88.1	59.7
WCT	20.6	42.9	33.3	64.8	40.4
	38.5	49.5	35.6	74.4	50.05

SEm ± 2.27, CD (0.05) = 10.21

Table 2. Average number of nuts per palm per year as influenced by NPK treatments (1983-1986)

Treatments	1983	1984	1985	1986	Mean
T x D hybrid					
750:750:750	46.6	55.7	31.8	86.0	55.0
750:750:1500	50.0	50.0	33.1	92.1	56.3
750:750:2250	53.9	46.0	36.0	79.5	53.8
1500:750:750	56.0	50.8	28.4	85.7	55.2
1500:750:1500	73.9	72.0	47.2	94.5	71.9
1500:750:2250	58.2	62.9	51.6	90.5	65.8
Mean	56.4	56.2	38.0	88.0	59.7
West Coast Tall					
750:750:750	10.4	39.7	29.3	52.4	32.9
750:750:1500	10.4	36.7	25.9	70.0	35.7
750:750:2250	26.7	54.7	32.6	62.8	44.1
1500:750:750	17.9	43.8	33.2	55.6	37.6
1500:750:1500	34.2	41.5	41.5	79.3	49.1
1500:750:2250	23.7	41.1	37.6	68.7	42.8
Mean	20.5	42.9	33.3	64.8	40.4

CD (0.05) for variety, fertilizer, year and variety x year are 10.21, 9.71, 6.64, and 9.40 respectively

Table 3. ICBR with reference to the previous lower level of fertilizer for the mean nut yeild of coconut (1983 to 1986)

Fertilizer treatment No.	Mean yield of nut /ha	Additional yield of nut/ha	Mean expenditure Rs/ha	Incremental		ICBR	
				Cost Rs/ha	Benefit Rs/ha	Gross	Net
T x D hybrid							
	9775	-	1893	-	-	-	-
	10006	231	2227	334	462	1:1.38	1:0.38
	9565	-	2560	-	-	-	-
	9813	248	2560	-	496	-	-
	12782	2969	2893	333	5938	1:17.83	1:16.83
	11698	-	3227	334	-	-	-
West Coat Tall							
	5849	-	1893	-	-	-	-
	6347	498	2227	334	996	1:2.98	1:1.98
	7840	1493	2560	333	2986	1:8.97	1:7.97
	6684	-	2560	-	-	-	-
	8729	2045	2893	333	4090	1:12.28	1:11.28
	7609	-	3227	334	-	-	-

Selling price of coconut @ Rs 2/nut; cost of N in form of urea @ Rs 5/kg; cost of P_2O_5 in the form of single superphosphate @ Rs 6.70/kg; and cost of K_2O in the form of muriate of potash @ Rs 2.50/kg higher. The T x D hybrid of coconut started flowering and fruiting from 6th year of planting and gave progressively higher yield than West Coast Tall. The nut yield varied significantly due to the application of different levels of fertilizers (Table 2). Application of 1500 g N + 750 g P_2O_5 + 1500 g K_2O per palm gave the highest nut yield of 71.9 and 49.1 nuts per palm with T x D and West Coast Tall, respectively and it was significantly superior to all other fertilizer treatments. Obviously, the higher amount of N applied favoured better nutrient availability of the palm resulting in greater photosynthetic activity and increased yield. The data further revealed that interactions of variety x fertilizer, fertilizer x year, and variety x fertilizer x year were not significant. But the interaction between variety and year was found to be significant. The inconsistent yield performance was observed in both the varieties of coconut, probably due to climatic factors, shedding of buttons, failure in fertilization and attack of pests and diseases.

The incremental cost benefit ratio (Table 3) revealed that the application of 1500 g N + 750 g P_2O_5 + 1500 g K_2O per palm gave the highest net return in both the varieties of coconut. This treatment gave the highest nut production to the extent of 12782 and 8729 nuts per ha by T x D and West Coast Tall respectively. T x D hybrid was found more economical than the West Coast Tall. An additional investment of every rupee, gave the highest net return of Rs 16.83 and 11.28 for T x D and West Coast Tall respectively. Abeywardena (1975) observed that from fertilizer application the return per unit investment was found to be 107 per cent more after the first year which increased progressively to 447 per cent in about 10th year. Thus application of NPK at the rate of 1500:750:1500 g/palm/year proved to be the best among the fertilizer treatments tried both on total yield and economic considerations.

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STANDARDIZATION OF NURSERY TECHNIQUES IN COCONUT

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Abstract: Investigations involving seednuts floating vertically upright in water (V1); floating horizontally in water (V2); no husking (control) (H1); partial husking over half of the broader side towards stalk end (H2); complete half husking towards stalk end (H3); seednuts sown vertically upright (M1) and horizontally with the widest of three segments facing upward (M2) were tried during 1986-87 at the Horticultural Research Station, Assam Agricultural University, Kahikuchi. The treatments were replicated three fold in a 3 x 2 x 2 factorial experiment. The parameters employed to standardize the nursery technique in coconut were height, girth and number of leaves. The seednuts which floated vertically upright in water produced strong and robust seedlings than those sown vertically. Vigorous and stout seedlings were also obtained when nuts were husked partially during sowing.

In a perennial crop like coconut which exhibits considerable genetic variations and is being propagated only through seeds, the selection and use of planting materials of higher intrinsic value assume much importance. The floating habit for selection of seednuts from selected mother palm (Marar and Shambhu, 1961); husking (Whitehead and Thompson, 1966); and position of seednuts during sowing at nursery (Muhammed *et al.* 1971 and Shanthappa and Viswanathan, 1972) are some of the important factors considered for obtaining good seedling materials.

An experiment was conducted (factorial with three replications) at the Horticultural Research Station, Assam Agricultural University, Kahikuchi during 1986-87 in a sandy loam soil under non-irrigated condition in order to standardize nursery techniques for coconut. Uniform sized nuts were collected during October to November 1986 from selected mother palms. The treatments included two floating habits viz., floating vertically upright in water (V1) and floating horizontally in water (V2); three methods of husking viz., control, no husking (H1), partial husking over half of the broader side towards stalk end (H2) and complete half husking towards stalk end (H3); and two methods of sowing seednuts at the nursery bed viz., vertically upright (M1) and horizontally with widest side of the three segments facing upward (M2).

Maximum height (145.27 cm), girth (13.13 cm) and number of leaves (6.57) were observed (Table 1) when seednuts were sown horizontally (M2). The strong and stout seedlings obtained in this case were due to early germination of nuts and less exposure to drought. Since the most viable and dominant eye was present in the widest segment of the nut, sowing seednuts in this position might be more favourable for rapid germination as well as vigorous growth of the seedlings. Similar observations were made by Marar and Kunhiraman (1963), Joseph (1963), Viswanathan *et al.* (1966), Gopalakrishnan *et al.* (1969) and Muhammed *et al.* (1971).

The floating habit had significant influence on growth characters of the seedlings, namely, girth and number of leaves except height. The maximum of all these growth factors was observed when seednuts that floated vertically upright were selected and sown in the

Table 1 Effect of different sowing methods on height, girth and number of leaves of coconut seedlings

Method	Height cm	Girth cm	Number of leaves
Position of seednut			
M_1	145.27	13.13	6.57
M_2	138.33	12.21	6.34
CD (0.05)	4.024	0.022	0.022
Floating habit			
V_1	143.05	13.02	6.62
V_2	140.55	12.32	6.30
CD (0.05)	NS	0.022	0.022
Husking			
H_1	138.92	11.68	5.52
H_2	146.33	13.80	7.40
H_3	140.17	12.52	6.45
CD (0.05)	6.037	0.033	0.033

nursery. Thus, seednuts floating vertically upright in water were more vigorous than those floating horizontally. This is in agreement with the observations of Marar and Shambhu (1961).

Partial removal of husk recorded the maximum height (146.33 cm), girth (13.80 cm) and number of leaves (7.40) followed by complete removal of husk and control. Partial husking gave stout and strong seedlings which might be due to quick and maximum absorption of water, thus permitting the nuts to germinate earlier. The completely husked nuts might also absorb water quickly but not to that extent which could directly influence germination.

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INFLUENCE OF IRRIGATION AND FERTILIZER LEVELS ON FLOWERING BEHAVIOUR OF T x GB COCONUT HYBRIDS

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Abstract: The effect of three irrigation levels at IW/CPE ratios of 0.5, 0.75 and 1.00 and four fertilizer levels, viz., (1) 0.5 : 0.5 : 1.5, (2) 0.5 : 0.5 : 2.0, (3) 0.5 : 1.0 : 2.0 and (4) 1.0 : 0.5 : 2.0 kg N, P_2O_5 and K_2O per palm per year on the percentage of flowering in West Cost Tall x Gangabondam hybrids was studied during 1984-1987. Irrigation at IW/CPE ratio of 1.00 and fertilizer level of 0.5 : 0.5 : 1.5 kg N, P_2O_5 and K_2O per palm per year were significantly superior to other treatments. Based on the early flowering nature of T x GB progenies, the male and female parent trees for making future crosses have been identified.

Several workers have stressed the importance of irrigation and manuring in coconut cultivation (Wardlaw and Mason, 1936; Marar, 1963 ; Mathew, 1972; Shanmugham, 1973 ; Venkitesan, 1973; Bhaskaran and Leela, 1977). Most of the studies are confined to the tall group of palms. When basin irrigation was given once in 7 days for the West Coast Tall palm grown in sandy loam soil, there was increased female flower production (28.8%), fruit set (39.8%) and yield (43-85%). In the littoral sand, basin irrigation once in 5 days resulted in increased leaf production (51.6%), flowering (90%) and yield (514%). The irrigation requirement of West Coast Tall palm has been arbitrarily fixed at the rate of 1000 litres of water per palm given once in 5-7 days at 10 cm depth in basins of 1.75 m radius (Bhaskaran and Leela, 1977). The influence of irrigation in combination with fertilizer application on West Coast Tall was studied by Nelliat *et al.* (1976). The nut yield was 47 in palms receiving 60 mm irrigation with NPK and Mg while it was only 9 in palms receiving 60 mm irrigation alone and 12 in palms receiving fertilizer alone. The response of WCT x Gangabondam hybrids to irrigation cum manuring has not been studied. The present investigation was therefore undertaken to study the influence of irrigation and fertilizer levels on growth and percentage of flowering in West Coast Tall x Gangabondam hybrids.

An irrigation-cum-fertilizer trial on West Coast Tall x Gangabondam hybrids was laid out during 1980 at the Regional Agricultural Research Station, Pilicode. The three irrigation levels were given at IW/CPE ratios of (I_1) 0.5, (I_2) 0.75 and (I_3) 1.00 at the rate of 30 mm water per irrigation in a basin area of 2.0 m radius. The four fertilizer levels were (F_1) 0.5:0.5:1.5, (F_2) 0.5:0.5:2.0, (F_3) 0.5:1.0:2.0 and (F_4) 1.0:0.5:2.0 kg $N:P_2O_5:K_2O$ per palm per year applied in four splits. Observations on growth characters and date of flowering were recorded during 1984-1987 period. The percentage of young palms flowered with reference to the best male parent (Gangabondam) was worked out.

With regard to the collar girth, irrigation at IW/CPE ratio of 1.00 was significantly superior to irrigations at IW/CPE ratios of 0.75 and 0.50. Fertilizer levels F_1, F_2 and F_3 were on par and significantly superior to F_4. The interaction effect was not significant.

Irrigation at IW/CPE ratio of 1.00 with F_1 level of NPK (0.5:0.5:1.5 kg/palm/year) recorded maximum collar

Table 1. Effect of irrigation and fertilizer levels on growth of T x GB hybrids during 1987

(a) Collar girth, m

Irrigation	Fertilizer treatment				Mean
	F_1	F_2	F_3	F_4	
I_1	1.2	1.1	1.1	0.89	1.06
I_2	1.1	1.1	1.1	0.98	1.07
I_3	1.2	1.2	1.2	1.1	1.17
Mean	1.17	1.13	1.13	0.99	

CD (0.05) for I and F = 0.09

(b) Number of functional leaves

	F_1	F_2	F_3	F_4	Mean
I_1	16.7	16.0	16.8	11.5	15.3
I_2	16.9	14.9	16.3	13.9	15.5
I_3	17.2	17.9	18.9	16.9	17.7
Mean	16.9	16.2	17.4	14.1	

CD (0.05) for I = 0.8 and for F = 0.97

(c) Total No. of leaves on the crown

	F_1	F_2	F_3	F_4	Mean
I_1	53.4	53.1	53.3	47.3	51.5
I_2	54.8	51.8	54.4	50.3	52.2
I_3	56.1	57.5	57.1	53.4	55.8
Mean	54.8	54.2	54.9	50.3	

CD (0.05) for I = 2.1 and for F = 2.4

Table 2. Effect of irrigation and fertilizer levels on the percentage of flowering in T x GB hybrids during 1984-1987

Irrigation	Fertilizer treatment				Mean
	F_1	F_2	F_3	F_4	
I_1	60.3	36.6	55.2	38.3	47.6
I_2	65.7	55.1	55.2	34.8	52.7
I_3	63.9	68.9	60.2	55.1	62.0
Mean	63.3	53.3	56.9	42.7	

CD (0.05) for I = 6.6 and F = 7.7

girth (Table 1). When irrigation was given at IW/CPE ratio of 1.00, there was significant increase in the number of functional leaves. Even though fertilizer level F_3 recorded more number of functional leaves, it was on par with F_1. The interaction was not significant. When the total number of leaves retained on the crown was considered, irrigation at IW/CPE ratio of 1.00 and fertilizer level F_1 were significantly superior to other levels of I and F respectively. The interaction was not significant.

The effect of different levels of irrigation and fertilizer on the percentage of flowering (Table 2) showed that irrigation at IW/CPE ratio of 1.00 recorded the maximum percentage of flowering and it was significantly superior to I_1 and I_2. Among fertilizer levels, NPK 0.5:0.5:1.5 kg/palm/year (F_1) was significantly superior to F_2 and F_4 but it was on par with F_3. The percentage of flowering was correlated with collar girth (r=0.64**), number of functional leaves (0.42*) and total number of leaves on the crown (0.48**).

With a view to know whether the early flowering nature is carried over to the progenies, the percentage of flowered palms with respect to the male parent (Gangabondam) was worked out. Palm N3/145 when used as pollen parent, the progenies flowered early, followed by 8/10 and N3/89 (Table 3).

Gangabondam is a semitall variety of coconut from Andhra Pradesh which takes 4-7 years for flowering under average management conditions. The West Coast Tall palm, on the other hand, takes 7-10 years for flowering even under good management. Therefore, it is expected that West Coast Tall x Gangabondam cross takes more years for flowering than crosses like West Coast Tall x Chowghat Dwarf Orange, West Coast Tall x Chowghat Dwarf

Table 3. Influence of male parent (Gangabondam) on flowering behaviour of T x GB hybrids, 1984-1987

Palm No.	Age at first flowering (years)	Percentage of flowered progenies	Average yield for 10 years
8/10	4	75.0	45.3
N3/89	5	68.2	69.3
N3/117	5	67.7	83.0
N3/131	5	61.7	51.6
N3/132	4	56.8	81.6
N3/145	5	79.1	77.6

Green and West Coast Tall x Malayan Dwarf Yellow. Under rainfed conditions at Pilicode, when T x GB took 70.4 months for flowering, it was 66.8, 56.8 and 64.0 months in the case of T x CDO, T x CDG and T x MDY respectively (Anon., 1982).

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IRRIGATION REQUIREMENT OF COCONUT UNDER DRIP METHOD

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Abstract: For quantifying irrigation requirement of coconut under drip method, an experiment was conducted in randomised block design in the command area of Kuttiyadi Irrigation Project for a period of three years from 1985 to 1987. There were five treatments viz., drip irrigation at 15, 30 and 45 l/day/palm, basin irrigation at 600 l/week/palm and control (unirrigated), with four replications. Observations on yield of nuts were recorded for the period 1985-87. The results showed that treatment effects were significantly different from control at 5% level of significance. Yield of nuts for drip method at 30 and 45 l/day/palm was on par with basin irrigation at 600 l/day/palm, while treatment with drip at 15 l/day/palm was on par with control. From the results of the study, it may be concluded that irrigation at 30 l/day/palm is sufficient for coconut under the drip method.

Under the conditions of water scarcity existing in Kerala, the conventional/traditional irrigation methods practised for coconut offer limitations to the farmer due to wastage of water through seepage, evaporation, percolation, uptake by weeds etc. In addition to wastage, uneven topography of coconut holdings create problems in the adoption of these irrigation methods. Under these situations, microirrigation systems, particularly drip irrigation, seem to be suitable and viable alternative. In this system of irrigation, water is applied at a low rate in mulched pits near the crop root zone at frequent intervals, thereby maintaining a high matric potential in the root zone and minimising losses due to evaporation, percolation, weed uptake etc. Since loss of water is comparatively less, irrigation requirement under this method will also be considerably lower when compared to the conventional/traditional methods.

Published work on yield response of coconut to drip irrigation in India is limited. Bravan (1976) has reported that with the use of drip-irrigation system, crop yields have increased as much as 120% and water consumption reduced up to 85%. Griffin (1977) has reported 25 to 50% saving in water, 25% higher yield and better quality of crop under drip irrigation as compared to sprinkler system. Sivanappan and Padmakumari (1978) observed 13 to 55% increase in yield and 60 to 84% savings in water under drip in vegetables as compared to flood irrigation. From a three year trial on coconut in Tamil Nadu, Raveendran (1983) concluded that drip irrigation was the best water management system and was also more efficient in terms of energy consumption.

To quantify the irrigation requirement of coconut under drip method, an experiment was conducted in the command area of Kuttiyadi irrigation project for a period of three years in randomised block design with five treatments and four replications. Treatments included three levels of drip irrigation @ 15, 30, 45 l/day/palm, basin irrigation @ 600 l/week/palm and control (unirrigated). The set up of drip irrigation unit included a water storage tank at a height of 2 m from the ground level. The main pipe line (25 mm dia HDPE) was connected to this tank and to this main line were connected lateral lines (12 mm dia LDPE pipe). The laterals were laid along the crop rows. From the laterals,

Table 1. Mean yield of coconut under different treatments (nuts/palm/year)

Treatment	Year			Mean for 1985-87
	1985	1986	1987	
Drip method at 15 l/day/palm	40.2	68.7	54.7	54.5
Drip method at 30 l/day/palm	81.5	92.5	88.2	87.4
Drip method at 45 l/day/palm	64.2	65.7	71.2	67.0
Basin method at 600 l/week/palm	68.0	69.5	103.0	80.2
Control	53.2	48.7	76.2	59.4
CD (0.05)	NS	NS	29.7	14.8

four plastic microtubes (1.5 mm internal dia) were taken near each palm to reach four pits of dimension 50 x 50 x 50 cm each. The pits were dug at a distance of 1.8 m away from the palm and filled up in layers with coconut husk, dry leaves and soil on top. Irrigation was carried out through the microtubes into these mulched pits. The flow in the microtubes was controlled with screws for predetermined rates of application. For the basin method, circular basins of 1.8 m radius were formed around the palm and irrigation was done in the entire basin by surface method at 600 l/week/palm. The treatments were effected from Jan 1985 to May '87. Observations on coconut yield (nuts/palm/year) were recorded from 1985 to 1987.

The yield of coconut was significantly influenced in the third year of study (1987) and the pooled observations (1985, 86, 87) also showed significant difference between treatments (Table 1). During the year 1987, yield of nuts under drip method at 30 l/day/palm was on par with basin irrigation at 600 l/week/palm. Drip method at 30 and 45 l/day/palm was on par with basin irrigation, while drip at 15 l/day/palm was on par with unirrigated control.

It may be concluded that for the drip method of irrigation in coconut, an irrigation rate of 30 l/day/palm is sufficient since it is comparable in yield to 600 l/week/palm through the basin method of irrigation.

The authors are extremely grateful to the Executive Director, CWRDM and Head, Water Management (Agri) Division, CWRDM for extending the necessary facilities, guidance and encouragement for carrying out the experiments on micro-irrigation techniques. We wish to acknowledge the Central Board of Irrigation and Power (CBIP), New Delhi for the financial assistance provided for running the research project on Integrated Water Management in the Command Area of Kuttiyadi Irrigation Project.

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VARIETAL AND SEASONAL VARIATIONS IN OIL CONTENT OF COCONUT

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Abstract: The monthly percentage oil content of five coconut cultivars viz., West Coast Tall (WCT), Laccadive Ordinary (LO), Gangabondam (GB), Chowghat Dwarf Orange (CDO) and Laccadive Dwarf (LD) and their hybrids was studied from 1985 to 1987 at the Regional Agricultural Research Station, Pilicode. Of the three female parents WCT, LO and CDO, LO showed the maximum (73.0%) oil content and the minimum by CDO (66.0%). Among the male parents, WCT recorded the maximum (70.8%) oil content, followed by LD (68.4%) and GB (67.3%). The oil contents of the five hybrids were 70.4 per cent for LO x GB, 69.7 per cent for WCT x GB, 68.7 per cent for WCT x LD, 67.2 per cent for CDO x WCT and 66.7 per cent for WCT x CDO. The percentage oil content of the hybrids was intermediary.

The seasonal variations during the study period showed that the maximum (72.8%) oil content was recorded during the post-monsoon (October and November), followed by the winter (December to February) (71.3 %) and the minimum (66.6 %) during the summer (March to May). A gradual decline in the percentage oil content was also noticed from May 1987 onwards in all the palms studied. During the south west monsoon (June to September), the year 1985 recorded higher percentage of oil content than that of 1986 and 1987.

Earlier studies (Patel, 1938; Pillai and Satyabalan, 1960; Satyabalan and Mathew, 1984; and Rao and Nair, 1986) on varietal and seasonal variations in yield, nut characters, copra and oil revealed that there was a definite variation in the said characters among the varieties and seasons. Pillai and Satyabalan (1960) reported that the effect of season is not the same in all the varieties. In contrast, Rao and Nair (1986) observed that all the three hybrids viz., CDO x WCT, WCT x CDO and CDO x LO showed higher nut weight and copra content in the summer (March - May), followed by the winter (December - February) and conspicuously lower in the south west monsoon (June - September) and post-monsoon (October - November) seasons. On the variation in the percentage of oil, Patel (1938) pointed out that the percentage of oil is rather high during the cold season (November to February) when the production of copra is rather low. Also, it was concluded that the season has not markedly affected the yield of either copra or oil. However, such studies on different coconut hybrids and their parents are lacking. Keeping this in view, an attempt has been made to study the varietal and seasonal influence on copra weight and oil content per nut of different hybrid progenies and their parents. Five hybrid progenies viz., West Coast Tall x Chowghat Dwarf Orange (WCT x CDO), Chowghat Dwarf Orange x West Coast Tall (CDO x WCT), West Coast Tall x Gangabondam (WCT x GB), West Coast Tall x Laccadive Dwarf (WCT x LD) and Laccadive Ordinary x Gangabondam (LO x GB) and their parents West Coast Tall (WCT), Laccadive Ordinary (LO), Chowghat Dwarf Orange (CDO), Gangabondam (GB) and Laccadive Dwarf grown in laterite soils under the rainfed conditions at the Regional Agricultural Research Station, Pilicode were the material for this study. A total of 42 palms belonging to these hybrids and varieties were made use of. Two coconuts from each palm were collected monthly from July 1985 to December 1987. The weight of copra per nut, percentage of oil in copra and oil content

Table 1. Varietal variations in copra weight, percentage of oil and oil content per nut of different coconut hybrids and their parents during the period from July 1985 to December 1987

Hybrid/variety	Copra weight (g/nut)	Oil in copra (%)	Oil content (g/nut)
CDO x WCT	168.6	66.8	112.6
WCT x CDO	168.3	66.4	111.8
WCT x GB	169.6	69.1	117.2
LO x GB	119.5	69.9	83.5
WCT x LD	158.4	68.3	108.2
WCT	160.9	70.1	112.8
LO	102.4	73.3	75.1
CDO	142.5	66.0	94.1
GB	121.1	67.1	81.3
LD	135.5	64.5	87.4

per nut were recorded. The oil content was estimated using the cold percolation method (Kartha and Sethi, 1957).

The weight of copra per nut of WCT x CDO, CDO x WCT and WCT x GB was around 169 g (Table 1) while LO x GB recorded the lowest (119.5 g/nut). Among the parents, WCT recorded the maximum (160.9 g/nut) copra, followed by CDO (142.5 g/nut) and the minimum (102.4 g/nut) by LO. Interestingly, LO recorded the maximum (73.3) percentage of oil content, followed by WCT (70.1) among the parents and their hybrid progenies studied. Out of the five coconut hybrids, LO x GB recorded the maximum percentage of oil (69.9) followed by WCT x GB (69.1%) and the minimum (66.4%) by WCT x CDO. However, the oil content per nut of all the hybrids was more than their parents except WCT. The oil content per nut of different coconut hybrids and their parents followed the same trend as that of copra weight. It was also noted that the percentage of oil of all the hybrids was intermediary to that of parents.

Table 2 gives the seasonal variations in copra weight, percentage of oil and oil per nut of different coconut hybrids and their parents from July 1985 to December 1987. The mean weight of copra of different hybrids and their parents was maximum (181.8 g/nut) during the summer (March - May), followed by the winter (152.9 g/nut) and the minimum (119.1 g/nut) in the post-monsoon (October - November) while the percentage of oil was minimum (66.8) in summer and maximum (71.2) in winter. As regards the variety x season interaction, in the case of copra per nut, all the five hybrids and their parents followed the same trend i.e., copra per nut was maximum in summer followed by winter and minimum in the post-monsoon period. However, WCT and GB differed as they showed slight variations in the south west monsoon season. All the hybrids and their parents recorded the maximum percentage of oil content during the winter (December - February) except CDO.

The effect of season on copra weight clearly showed that all the coconut hybrids and their parents exhibited the same trend for different seasons. The variations in copra weight during different seasons may be due to the influence of varying weather parameters during the process of nut development which extends to twelve months after fertilization. According to Nambiar *et al.* (1969) any abnormal weather factor, coinciding with the initial phase of development (4-7 months after fertilization) adversely affected the rate of growth and final size of the nut and copra content. The second phase of nut development of all the varieties was seen influenced very much by the heat unit which was dependent on air

Table 2. Seasonal variations in copra weight, percentage of oil and oil content per nut of different coconut hybrids and their parents from July 1985 to December 1987

Hybrid/variety	Summer (March-May)			SW monsoon (June-Sep)			Postmonsoon (Oct-Nov)			Winter (Dec-Feb)		
	Copra (g/nut)	Oil in copra (%)	Oil (g/nut)	Copra (g/nut)	Oil in copra (%)	Oil (g/nut)	Copra (g/nut)	Oil in copra (%)	Oil (g/nut)	Copra (g/nut)	Oil in copra (%)	Oil (g/nut)
CDO x WCT	205	64.9	133	141	62.7	88.2	120	65.6	78.7	203	72.1	146
WCT x CDO	215	65.8	141	147	67.7	99.5	142	65.6	93.3	169	68.4	116
WCT x GB	214	67.3	144	160	69.1	110.7	143	69.6	99.5	170	73.3	125
LO x GB	152	67.9	103	111	70.6	78.4	96	69.9	66.9	130	72.1	94
WCT x LD	213	67.7	144	139	69.0	96.0	125	67.9	84.9	179	70.2	126
WCT	177	69.8	123	164	70.0	114.9	147	71.0	104.7	152	74.4	113
LO	118	69.6	82	98	74.5	72.6	85	74.8	63.6	100	75.4	75
CDO	182	63.8	116	130	66.0	85.6	119	68.4	81.3	150	67.9	102
GB	189	65.6	124	146	67.7	98.5	102	67.3	68.9	135	70.2	95
LD	155	65.6	101	129	59.5	76.5	111	64.4	71.7	141	67.9	96
Mean	182	66.8	121	136	67.7	92.1	119	68.5	81.4	153	71.2	109

temperature according to Rao and Nair (1986). Though the copra content was more during the summer, the percentage of oil content was less. This was probably due to the effect of the higher maximum temperature which prevailed during the final stage of nut development.

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Technical Session 5

PROCESSING TECHNOLOGY, PRODUCT DEVELOPMENT AND MANAGEMENT

COCONUT AND COIR PRODUCTS

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Abstract: The chief peculiarity of coconut fibre is its elasticity as well as breaking strength. The sound absorption properties of chip boards made of coir pith were evaluated. The properties are comparable with that of paddy straw board. Acoustic and other properties of coir pith chip board were determined. Coconut shell can be used as fuel and for charcoal, activated carbon and shell oil. The optimised operational parameters for gasification of coconut shell have been standardized. Pith obtained during extraction of coir fibre constitutes 70 per cent of the husk. Mixing pith with additives improves burning characteristics. The density can be improved by briquetting. Coir pith when treated with *Pleurotus sajor-caju* and urea resulted in drastic reduction in lignin content from 30 per cent to 4.8 per cent within a period of 30 days. Coir pith briquettes with cowdung and clay as binding materials and saw dust as additive yield solid fuel. Coir pith is also studied for its utility for the production of building materials, fillers, polymers, chemicals, biogas etc.

INTRODUCTION

Coconut yields food, fibre, fuel and shelter material. One of the non-edible applications of coconut oil is in improving the quality of soap. Similarly, useful chemical derivatives of coconut oil are methyl esters, fatty alcohols, detergent intermediates in the ethoxylated and sulphated forms. Future of coconut products lies in the promotion of coconut based agro-industries. Coconut water, coconut cream, coconut milk and coconut flour are the possibilities of cottage industries which will improve the lot of coconut growers. Copra based byproducts like oil cake render itself as an ideal feed-stock for animals while coconut shells on distillation and pyrolysis yield crude pyroligneous acid and activated carbon respectively. Coconut fibre has already picked up its role in rural development through coir industries whereas coir pith, even now, is a waste product.

Coconut is an important source of protein. Coconut is used for domestic purposes, oil extraction and as tender coconuts. Oil can be extracted at desired level up to 65 per cent of the total oil in dried coconut gratings. One kilogram of dried coconut gratings yields about 400 g of oil and 600 g of partially defatted coconut gratings which still contains about 47 per cent fat.

The building materials are obtained in the form of particle board, insulation board and hard board.

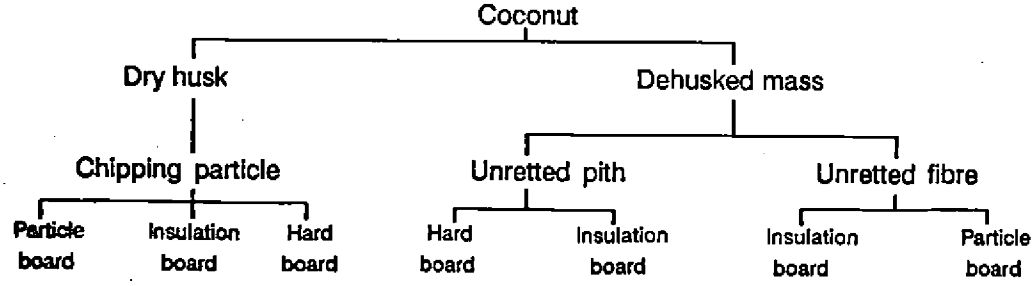

Table 1. Composition of coconut fruit, nut and kernel

	Constituents	Per cent
1	*Coconut fruit*	
	Husk	30.8 - 38.0
	Shell	11.9 - 12.7
	Meat	27.4 - 30.1
	Water	22.7 - 26.4
2	*Husked nut*	
	Shell	23.5 - 32.8
	Meat	48.2 - 62.0
	Water	8.2 - 25.1
3	*Kernels*	
	Oil (wet basis)	35.0 - 40.0
	Protein	4.0 - 5.0
	Moisture	40.0 - 50.0
	Carbohydrate	5.0 - 10.0
	Crude fibre	2.0 - 4.0
	Ash	1.0 - 1.5

Table 2. Composition of coconut oil cakes

	Expeller cake %	Solvent extracted meat %
Moisture	7.0	8.9
Fat	6.7	2.4
Protein (N x 6.25)	21.2	21.4
Nitrogen free extract	11.2	13.3
Mineral matter	6.5	6.6

Child (1974) has described the design of standard copra kiln and oil extraction unit operations to obtain 73.5 kg of clear coconut oil from 220 kg of grated fresh coconut (1000 Nos). The Department of Agricultural Processing of the Tamil Nadu Agricultural University has developed a copra dryer. Coconut can be dried by solar dryer as well. Milling of coconut is done for extraction of coconut oil for which units both animal drawn and power driven are used. Expellers available commercially extract 2 to 3 tonnes in 10 hours.

Solvent extraction of coconut oil is possible using benzene or hexane as solvents. Composition of coconut oil cake is given in Table 2.

HUSK, FIBRE AND PARTICLE BOARD

Retting, fibre extraction and grading are the major processes in dehusking. They involve:

a. Retting : Kolli, Malli bundles are floated in backwater.

b. Fibre extraction : Nanji process, Elod process, Thomas process, Rowell process, Van der jagt process, Hayes Gratzi process

c. Fibre grading : Bristle fibre, mattress fibre

The chief peculiarity of coir rope is its elasticity as well as breaking strength even though its fibre dimensions are smaller than the other materials (Table 3 and 4).

Chip boards are made of coir pith at the Tamil Nadu Agricultural University and its properties are evaluated. The sound absorption properties of chip boards at different sound frequencies are given in Table 5.

The properties are comparable with that of paddy straw board. Transmission loss and attenuation factors of coir pith chip board are given in Table 6.

Dampening factor of the coir pith chip board was found to be 0.019 at natural frequency of 490 Hz and amplitude of 3.8 mV. Similarly, dynamic and loss modulii of particle board made of coir pith were determined as 3.04×10^3 kg cm^{-2} and 57.1 kg cm^{-2} respectively. Table 7 summarises the longitudinal velocity, shear modulus, acoustic resistance etc. of chip board of density 0.30 g cm^{-3}.

Table 3. Breaking strength of coir and other fibres (kg)

Particulars	Coir	Jute	*Sanse-vieria zeyla-nica*	*Crota-laria juncea*	*Agave ameri-cana*
When fresh	39	30-31	54	31	50
After 116 days in water	24	18-22	13	decayed	decayed

Table 4. Dimensions of coir and other fibres

Particulars	Coir	Hemp	Jute	Flax
Length, mm	0.7	28.0	1.9	20.0
Diameter, mm	20.0	20.0	17.5	25.0

Table 5. Absorption coefficient of coir pith chip board

Frequency, Hz	125	250	500	1000	2000	NRC
Absorption coefficient	0.23	0.40	0.58	0.60	0.43	0.50

NRC = Noise reduction coefficient (mean at 125 - 2000 Hz)

Table 6. Transmission loss and attenuation factor (Board thickness 1.6 cm)

Frequency Hz	Transmission loss db	Attenuation factor db cm^{-1}
125	23.8	14.9
250	14.0	8.7
500	6.1	3.8
1000	1.9	1.2
2000	2.4	1.5

Table 7. Acoustic and other properties of coir pith chip board

Properties	Values of board made of	
	Coir pith	Paddy straw
Longitudinal velocity cm s^{-1} x 10^5	1.21	1.21
Shear modulus, kg cm^{-2} x 10^3	1.19	0.80
Acoustic resistance, kg cm^{-2} s^{-1} x 10^3	34.40	22.89
Bulk modulus, kg cm^{-2} x 10^3	2.30	1.55
Modulus of elasticity, kg cm^{-2} x 10^3	2.82	1.88
Modulus of rupture, kg cm^{-2} x 10^3	58.30	48.80
Impact strength, g cm	2700.00	2000.00
Tensile strength, kg cm^{-2}	52.20	31.00
Screw withdrawal force, kg	46.20	21.00
Nail withdrawal force, kg	3.90	5.90
Water absorption after 2 h, %	43.40	46.20
Swelling after 2 h, %	19.00	17.00
Thermal conductivity, kcal cm^{-1} s^{-1} $^{\circ}C^{-1}$ x 10^{-4}	2.07	1.51
Thermal diffusivity, cm^2s^{-1} x 10^{-4}	38.23	44.46

Using paraformaldehyde as adhesive, particle boards made of coconut husks show a density of 250-1070 kg m^{-3} with a modulus of rupture of 22-373 kg cm^{-3} and water absorption of 23.6-113.5 per cent in 24 hours. Coir pith bricks have been developed at the Regional Engineering Research Laboratory at Trivandrum. Brick of cement-sand-pith mix of 2:3:6 (by volume)is developed by the Regional Engineering College, Calicut and is reported to have a crushing strength of 13.5 kg cm^{-2}.

COCONUT SHELL

Cocunut shells can be used as a fuel and for charcoal and activated carbon besides for extraction of shell oil. Applications of granular activated carbon from coconut shell charcoal are: (a) protection against toxic gases, (b) air purification, (c) filter for war gases/nuclear fall outs, (d) recovery of solvents, (e) separation of hydrocarbons, (f) purification of fermentation carbon-dioxide, (g) carbon battery, (h) pollution control; and (i) water purification. Coconut shell consists of 29.4% lignin, 26.6% cellulose and 27.7% pentosan. Distillation of this yeilds 35% charcoal, 38.2 % pyroligneous acid and 5.6% settled material, which contains 30% phenols. Pyroligneous acid contains 13.9% acetic acid and 2.9% of wood spirit.

Activation processes are divided into two groups (a) steam activation and (b) chemical activation (phosphoric acid, zinc chloride). The methods of production of coconut shell charcoal are: (a) pit method, (b) drum method and (c) kiln method. Some of the solvents and other vapours recovered by activated carbon from coconut shell charcoal are (a) hydrocarbons (hexane, benzene, toluene, xylene) (b) halogenated hydrocarbons (methyl chloride, chloroform, tri/penta chloroethylene, carbon tetrachloride), (c) alcohol (ethyl and methyl), (d) ethers (ethyl ether, tetrahydrofuran), (e) ketones (acetone, methyl ethyl ketone), (f) esters (methyl acetate, butyl acetate, amyl acetate), and (g) sulfides (carbon sulfides). Coconut shell has been studied at the Tamil Nadu Agricultural University as a feed-stock for gasifiers. Table 8 summarises the optimised operational parameters in coconut shell gasification.

Table 8. Optimised operational parameters for gasification of coconut shell

Particulars	Optimised value	
	Coconut shell	Wood chips
Mass, kg	20	30
Air flow rate, m^3 min^{-1}	0.98	0.48
Depth of charcoal, cm	20	20
Reynolds no. x 10^3	20.3	7.0
Calorific value, kcal m^{-3}	1176	1195
Residence time, s	0.39	0.82
Gas produced, m^{-3}	58.5	33.1

Calorific values of coconut fibre dust and coconut shell have been reported to be 20.05 and 19.04 MJ/kg. Coconut shells are used as (a) hookah shell, (b) shell bottles, (c) shell charcoal and (d) shell oil. Destructive distillation begins at 300°C and volatiles are removed between 600-700°C and on condensing pyroligneous acid containing acetate, methanol, acetic acid etc. are obtained.

COCONUT CREAM AND DESICCATED MEAT

The coconut cream must be emulsified and stabilized to prevent segregation or phase separation. The protein of coconut is a good emulsifier. Other stabilisers are vegetable lecithin, mono/di-glycerides, sorbitol esters, al-

Table 9. Composition of desiccated coconut, per cent

Constituent	Plain DC	Sweetened	Toasted
Moisture	2.50	11.50	0.50
Fat	66.00	39.00	46.50
Solids-not-fat	31.50	20.00	22.50
Added sugar	27.00	30.00	
Propylene glycol		2.00	
Salt		0.50	0.50

Table 10. Coir pith degradation by *Pleurotus sajor-caju*

Constituents	Raw coir pith %	Coir pith + *Pleurotus* sp + urea after 30 days %
Lignin	30.00	4.80
Cellulose	26.52	10.10
Organic carbon	29.00	24.90
Nitrogen	0.26	1.06
Phosphorus	0.01	0.06
Potassium	0.78	1.20
Calcium	0.40	0.50
Magnesium	0.36	0.48

ginates, carregenin, carboxy methyl cellulose, hydrated cellulose and glycerinated triglycerides. High temperature short time (HTST) process of sterilisation of cream requires 80°C for at least 30 seconds; ultra-high temperature (UHT) process for coconut cream requires 150°C for 3 seconds. The dried meat is produced by size reduction in hammer mill after grating. The moisture content is reduced from 50 per cent to less than 2 per cent. Secondary size reduction is obtained by passing it through a mechanised grinder and is dried under suspension. The composition of desiccated coconut is given in Table 9.

COIR PITH

Pith is a waste product obtained during extraction of coir fibre from retted, partially retted or unretted husk and constitutes up to 70 per cent of the husk. Pith has a calorific value of 4000-4500 kcal kg^{-1}. As pith itself does not burn well, mixing it with additives tends to improve its burning characteristics. The purpose of briquetting is mainly to increase the density of mixture and make it easy for transportation. As pith has not been carbonised, there will be an emission of smoke. The constituents of coarse coir pith are (a) moisture (12.67%), (b) ash (21.86%), (c) cellulose (22.44%), (d) pentosan(9.48%) and (e) nitrogen (0.45%). Coir pith (1 t) when treated with *Pleurotus sajor-caju* mother spawn (5 bottles) together with 5 kg of urea renders drastic reduction in lignin content from 30 per cent to 4.8 per cent over a period of 30 days (Table 10). Volume was reduced from 1 m^3 to 0.52 m^3 with a corresponding reduction of C/N ratio from 112.1 to 24.1 within 30 days. Coir pith briquettes with cowdung

Table 11. Calorific value and thermal efficiency of briquettes made of coir pith with cowdung and clay at various proportions

Ratio	Calorific value kcal kg^{-1}	Thermal efficiency, %
1. *Coir pith : Cowdung*		
1:1	3365	20.99
2:1	3250	20.74
4:1	3210	19.65
6:1	3090	19.54
2. *Coir pith : Clay*		
1:1	2850	17.59
2:1	2870	17.85
4:1	2885	18.12
6:1	2930	18.95
3. Fire wood	3600	19.77

The coir pith briquettes were burnt with equal quantity of wood

and clay as binding materials together with saw dust as additive yield solid fuel (Table 11).

Coir dust is not as fertile as cattle manure. Coir pith is studied for its utility for the production of building materials, expansion joint fillers, light weight porous bricks, light-weight polymers and for chemical degradation to yield monomers like phenol, furfural, biogas etc. Coir pith can be used as an absorbent for absorption of moisture at half cycles of less than 9 min and is more effective than even silica gel.

FUTURE LINES OF WORK

The analysis of the potentials of coconut and coir products raises the following issues : (a) Coconut kernel, shell, coir pith and sweet water have not undergone the process of value-addition and technology transfer; (b) Precise and exact feasibility studies on treatment of tender coconut water, its preservation and packaging, meat, cream and desiccated powder production have to be initiated; (c) Linkage between the coir pith waste availability and its gainful disposal for fuel, manure and building construction materials is to be examined; (d) There are lack of identification of market channels for coconut shell activated carbon, baby food from coconut milk and particle boards; (e) Measures should be taken immediatly to place the coconut based industries on sound footing so as to generate sustained domestic and international wealth; (f) The gaps in the technology have to be identified so as to make the know-how viable and socially acceptable.

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UTILIZATION OF COCONUT PRODUCTS

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Abstract: The most valuable part of the coconut palm is the coconut, because this can give excellent products having industrial applications. Each and every part of coconut is useful to man in one way or the other. The tender coconut water is a delicacy and recommended even for patients, as a popular, refreshing and satisfying beverage. The fibre from the husk is used in the manufacture of coir ropes, mats and mattings. The oil from the dried copra is used for edible purposes and has several industrial applications. The residual cake, after solvent extraction or as such is a valuable cattle feed. The meal can be processed to obtain useful proteins. The coconut shell is carbonised and then activated to obtain active carbon useful for adsorption of gases especially for making gas masks, bleaching of vegetable oils, sugar, glycerin and recovery of solvent vapours.

By the aqueous processing of premium grade coconut kernels one can obtain edible oil with superior flavour, coconut water, coconut milk, coconut protein, syrup etc. with nutritive properties. The paper discusses the various aspects of obtaining and utilization of products from coconut. There is a good potential market in India for diversified products from coconuts, when large quantities of coconuts are available at reasonable prices.

INTRODUCTION

Coconut gives us food, drink, health and nutrition, housing and shelter and hundreds of other vital necessities of life. India ranks third in the world in coconut production. More than half the quantity is utilized for food uses, while the rest is converted into copra for the production of coconut oil, which is about 7 per cent of total vegetable oils produced in the country. The progress of post-harvest processing of coconuts has been slow in India due to lack of research and development support, but national laboratories like the Regional Research Laboratory at Trivandrum has made know-how available recently. The main reason for unstable coconut economy in India is the fluctuating price trend of a single major item, namely coconut oil. On the other hand, foreign countries like Philippines, Malaysia and Thailand have advanced to a large extent due to lower prices.

TENDER COCONUT

The tender coconut is a delicacy as a popular, refreshing and satisfying beverage. It is fully sterile and in Sri Lanka it is often used in hospitals for injections and for saline drips. The coconut water can be bottled, sterilized and marketed as a beverage. Fresh coconut water can be used as a substitute for the high priced dextrose. Coconut water used as an oral rehydration solution has an advantage over expensive import-based alternatives, because coconut water comes from natural source and is rich in minerals and vitamins.

COPRA

The copra is the important product from coconut. In India, copra could be broadly classified into two categories, namely one for edible purposes and the second for milling purposes. The former group comprises of high class copra fit for edible purposes, while the later group finds an outlet mainly for the production of coconut oil, both for edible and non-edible purposes. The details of processing copra and industrial applications of coconut oil have been discussed elsewhere (Bhat, 1984). The conventional method of expelling copra to produce coconut oil and oil cake is cumbersome, costly and liable to spoilage due to rancidity and microbial infection. It is reported that over 25 per cent of all coconuts produced in the world is thereby wasted or rendered unsuitable as a non-edible waste product.

DESICCATED COCONUT

The demand for desiccated coconut has risen and the world's largest importer, the USA, has increased her purchase from only 36462 tonnes in 1986 to 46007 tonnes in 1987. India can export only if prices are comeptitive compared to prices in other countries. The desiccated coconut is a simple product in which water content is reduced to two per cent or less from about 50 per cent. It is used in home and hotel cookery, bakeries, pastries, confectioneries etc. in many forms and shapes like chips, curls, gratings, powder, bits etc. as also plain or sweetened or spiced.

WET PROCESSING

The ECAFE conference held in Manila during 1968 recommended the wet-processing of fresh coconuts, which gives coconut oil with its natural flavour and light colour, while the protein concentrate is a good source of human food. A large scale plant known as coconut complex was put up in Edapal, Kerala State, for the first time during 1978 using the wet "Solvol Process" for maximising the utility and income from coconuts (Nambiar, 1978). There is scope to adopt this process here and more and more plants are likely to come in existence in the future adopting this technique.

COCONUT MILK POWDER AND HONEY

The Malaysian Agricultural Research Institute and a local food processing company are to manufacture powdered coconut milk on commercial scale. The new product does not contain preservatives and has a shelf life of 8 months without refrigeration and the production envisaged is of the order of 2200 tonnes of powder per year. A byproduct of coconut processing is a thick sweet syrup called "coconut honey" possessing medicinal properties (Thyagarajan, 1987). This is obtained by evaporation of coconut water. The defatted "coconut protein" containing all the essential amino acids is an excellent material for baby foods, weaning foods, convalescent food-drinks etc.

COCONUT SHELL

Another important byproduct of coconut processing is the coconut shell, which is mostly used for fuel purposes and some quantities used as filler in plastics. The coconut shell on destructive distillation is a good source of chemicals like acetic acid, acetate of lime, phenols, creosote oil etc. The shells on burning give carbon which could be activated for use in gas-mask, bleaching of sugar, glycerin, vegetable oils etc. In India, large scale activated coconut shell carbon plants are not yet installed due to competition from other countries which can produce economic grades due to large scale of operations. However, there is scope to look into this aspect to meet more and more demand for activated carbon from coconut shells needed for controlling pollution. The technique of fluidized bed pyrolysis can give better yield and quality of activated carbon at reasonable prices. This technique can be operated on both small as well as large scale of operations.

The fibre from the husk of coconut has several applications. These are being discussed in a few papers presented at this symposium.

COCONUT OIL

The last but not the least important and valuable product of the coconut is the coconut oil, which is premium priced on account of its wide use for both edible and non-edible purposes. The coconut oil and its derivatives have been discussed in detail elsewhere (Bhat, 1987). The characteristic flavour and light colour of coconut oil make it a favourable salad oil, as also used for frying purposes. The refined and deodorised oil finds a place in hair oils, shampoos and liquid soaps. The hydrogenated coconut oil is preferred as coating for cookies, candies and as confectionery butter due to its resistance to the development of rancidity. Coconut oil has maximum glycerin content compared to other vegetable oils and as such one can recover maximum glycerin by high-pressure splitting of coconut oil or by converting the oil into methyl esters, which can be fractionated at lower temperatures and transported easily compared to fatty acids which are corrosive. The short-chain fatty acids can be converted into value-added products like artificial fruit flavours, perfumes, chemical intermediates and plasticizers. The major component of coconut oil is the lauric acid which can be hydrogenated under high pressure using suitable catalyst to obtain lauryl alcohol which is the basic raw material for synthetic detergents and cosmetics. Coconut oil being a rich source of myristic acid, one can esterify this into iso-propyl myristate, a good binder and emollient for cosmetics.

The major industrial application of coconut oil is in soaps due to its high foaming power. The high cost of coconut oil has compelled the soap manufacturers to reduce its percentage to minimum and have even switched over to substitutes like alpha olefin sulphonate, which is cheaper due to its manufacture from petroleum sources. The synthetic surfactant foams in hard water with lime-soap dispersing action, which is lacking with coconut oil soap.

The fluctuating and high price of coconut oil has forced consumers even in Kerala to substitute edible coconut oil with palm-olein, which is available at half the price. Thus, in India the coconut oil is in surplus as both edible and non-edible users have switched over to cheaper substitutes due to fluctuating high price of coconut oil. If India's production of coconut oil increases one has to find new outlets for its use.

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POST-HARVEST TECHNOLOGY OF COCONUT

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Abstract: India ranks third in the world in coconut production, producing 6000 million nuts per year. It is a small holder's crop with an average land holding of only 0.1 ha per house-hold. Half of the production is processed in the form of copra, at farmers level and at rural industries. The unit operations involved in processing coconut are seasoning, husking, drying, storage of copra, and oil extraction. Among these, drying is an important operation which dictates the quality of final product i.e., copra, its storage and also the quality of oil extracted from it. The research efforts have been mainly concentrated on developing a package of technology from seasoning to storage of copra to suit all the categories of processors and producers. At CPCRI, three different types of prototypes of dehusking machine and four types of copra dryers have been developed and their suitability has been tested. The demand for large number of dryers shows that, given the appropriate type of equipment the adoption of technology by users is not that difficult. Other important aspect is preservation of wet kernel from spoilage if unfavourable weather condition is faced during drying. Many research workers have tried various chemicals and a few from them such as glacial acetic acid and propionic acid were found effective. However, this technology needs extension efforts and easy availability of these chemicals at rural level.

The paper describes unit operations in coconut processing and their level of technology. Other types of processing i.e., desiccated coconut, wet processing and other potential products from coconut have been discussed in brief. The recommendations and suggestions for future work have also been given.

INTRODUCTION

Coconut is an important source of vegetable oil used for both edible and industrial applications. it is estimated that nearly 50% of coconuts in India are consumed raw, while the remaining quantity is converted to copra to obtain coconut oil.

Coconut meat (kernel), the endosperm of the fruit contains carbohydrate 20%, fat 36% and protein 4% at moisture content of 50%. Coconut oil can be extracted either from fresh kernel or from dried kernel known as copra. The flow diagrams for dry processing and wet processing are shown in Fig 1 and Fig 2.

A number of products are derived from coconut and copra, the dried kernel is the major one. When milled, copra yields coconut oil, used extensively as both an edible and a technical oil and copra cake, a valuable animal feed. The kernel of coconut, shredded and dried under hygienic condition yields desiccated coconut widely used in bakery and confectionery trade.

The coconut meat in the fruit begins to form after about 160 days, when it is at its full size. After 220 days shell begins to harden and the meat gets fully formed after 300 days. However, for full maturity 360 days are required. At this stage the husk, shell, meat and water constitute about 35, 12, 28, and 25 per cent respectively.

STORING AND SEASONING

It is a common practice to store or season harvested nuts before they are further processed. The advantages of this procedure have been reported as (i) decrease in moisture content, (ii) in-

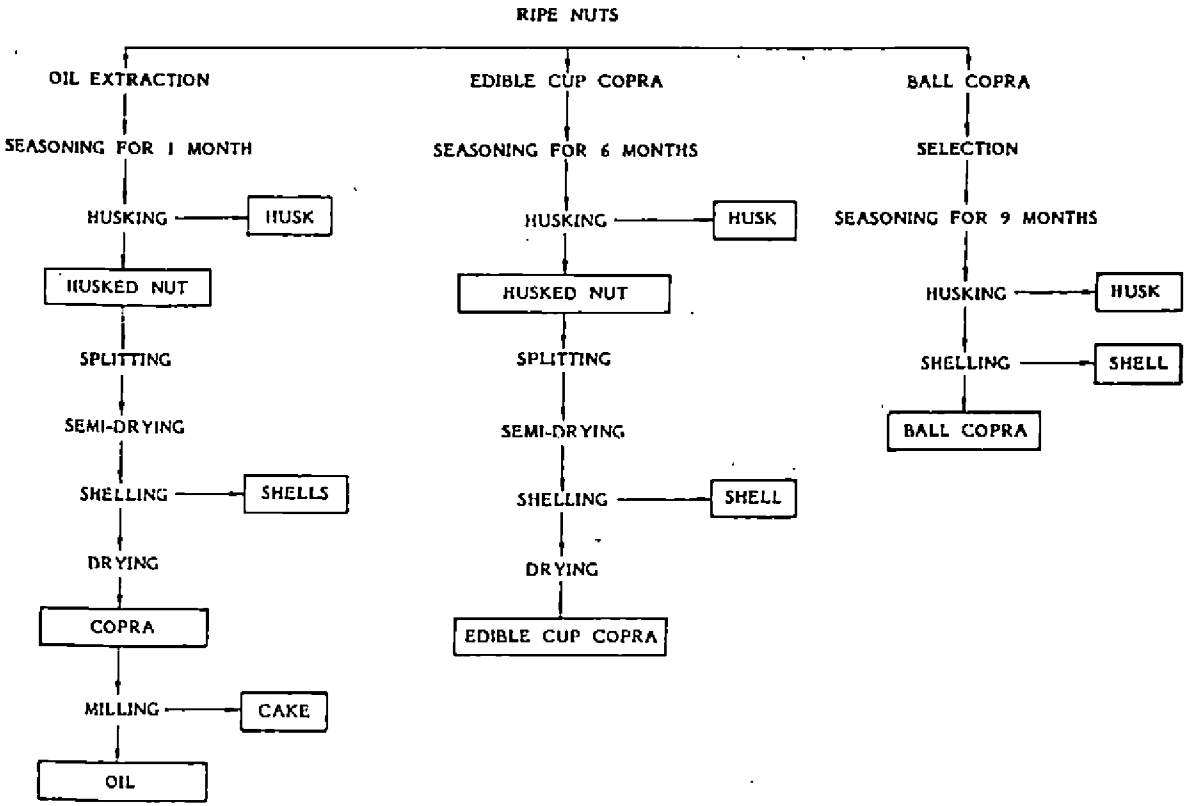

Fig 1. Flow diagram for dry processing of coconut

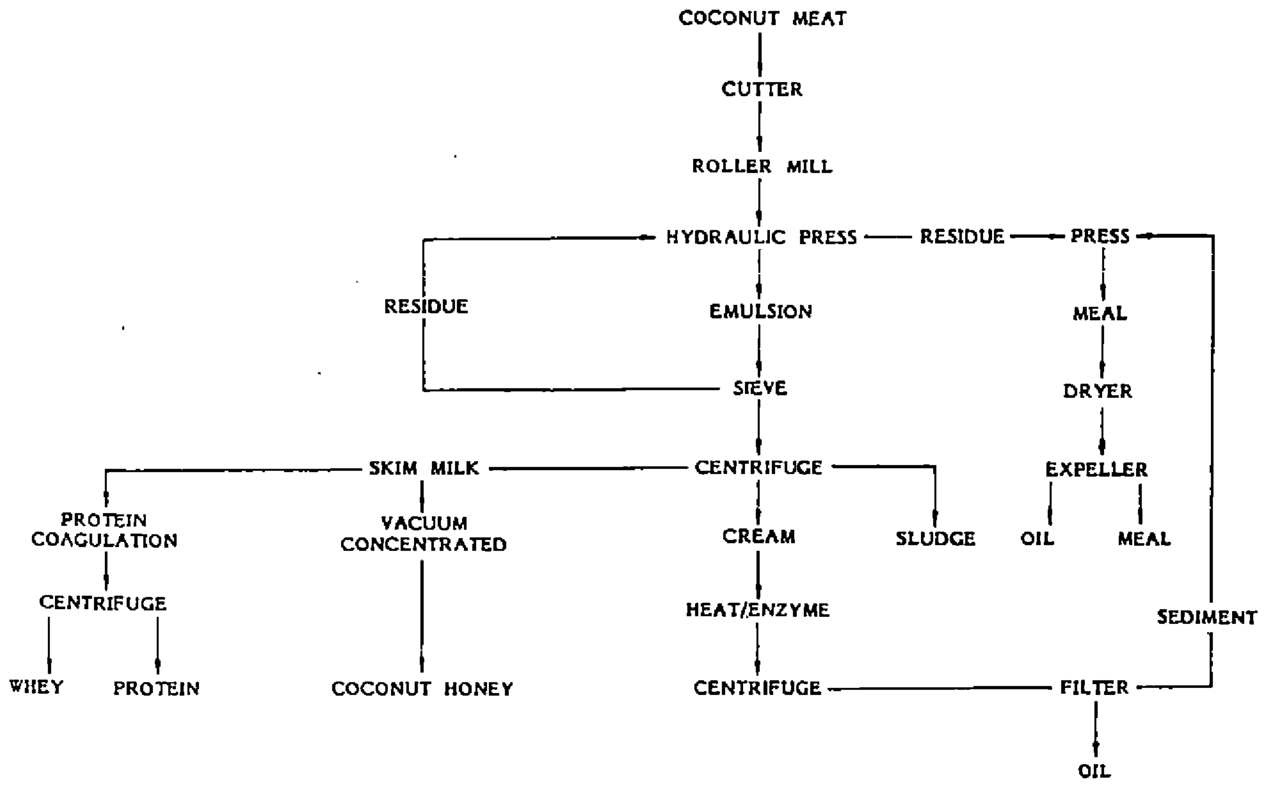

Fig 2. Wet processing of coconut, KM/CFTRI process

crease in thickness of copra, (iii) increase in oil content, (iv) greater meat resistance to bacterial sliming while sundrying, (v) easier husking, (vi) shelling cleaner and easier and (vii) uniform quality of copra. The studies conducted at CPCRI on storage of fully mature (12 month old) nuts of West Coast Tall variety (Table 1) indicated that whole nut gets dried fully within 2 months and so dehusking operation is easier. Gradual decrease in water content was observed during storage. At the end of the 6th, 7th, 8th and 9th months, ball formation was 10, 33, 70 and 100% respectively. The testa of the copra turned dark brown after 6 months storage which is a desirable property for edible quality copra. However, there was no change in copra content during storage as the nuts were fully matured (Patil, 1984). If the nuts are not fully mature, the seasoning or storage causes increase in copra content as reported by Nair (1984).

HUSKING

The first stage in processing is the removal of husk. Traditionally it is done manually by skilled labourers with the aid of a spike driven to the ground. The work calls for considerable skill and is strenuous. There has been a long felt need for developing mechanical devices for dehusking coconut which should work as an aid to the operator so that dehusking can be done even by unskilled persons with least efforts. Many attempts have been made to develop a suitable machine for husking of coconut (Grimwood, 1975) but none of the machine devised proved entirely satisfactory.

More recent efforts in this direction were at CPCRI, Kasaragod. An experimental prototype for husking coconut developed by Singh (1981) comprised of a set of three spring loaded blades which could be moved up and down on a frame by a telescopic lever which was hand operative. Another set of blades was fixed on a platform which also moved up and down by the linkages and lever. The coconut was placed upright between the two sets of blades. By pressing down hand lever the spring loaded blades pierced into husk and by presssing further, the blades moved out in horizontal plane removing the husk. The bottom blades also simultaneously pierced into husk which helped in holding the nut. The loosened husk could be easily removed by hand. Though the device helped in reducing the drudgery of work the out-turn was low and breakage was to the extent of 5 per cent. Moreover, it was not possible to dehusk the nuts of all shapes and sizes by this prototype.

This prototype was further improved by replacing the spring loaded top blades to accommodate all shapes and sizes of nuts. These top blades were fixed on a frame which rotated freely in the shaft. By this, breakage was reduced to 1 per cent. However, the number of movements required was more and out-turn was further lowered. When one unskilled labour was employed, the output was 500 nuts/day and device was difficult to be operated by one man. The out-turn was reported to be 1600 and 3000 nuts per day when two and three persons were employed respectively. In many cases one segment was found to remain attached to the shell which required to be detached later (Patil and Annamalai, 1984).

The device was further modified at CPCRI to make it a table or chest height model. The modification was that the lifting of nut was foot operated with a lever. The nut was placed on three blades fixed to bottom frame and lifted by foot operated lever so that it got pressed between lower and upper set of

Table 1. Effect of storage period on coconut components

Month of storage	Average wt of coconut, g	Wt of water husk,g	Wt. of copra g	Wt of copra g	Ball copra-formation %
1	1255	625	147	193	0.0
2	942	343	114	184	0.0
3	912	349	93	189	0.0
4	891	-	89	192	6.7
5	903	347	-	193	6.7
6	866	-	670	198	10.0
7	836	328	335	201	33.3
8	780	310	102	198	70.3
9	662	289	-	199	100.0

blades. After complete piercing of the blades the bottom plate with blades was rotated with hand lever. The capacity of this unit was reported as 980 nuts/day. Broken nuts were only 1.35% and only 4.9% nuts required further husk separation by hand. The cost of the machine has been reported as Rs 1100 (CPCRI, 1986).

However, in all these units feeding and proper placement of nuts consume a lot of time and hence capacity did not match with conventional labour. The efforts therefore should be to design a device with suitable automatic feeding arrangement at least for a batch of 10 nuts.

COPRA DRYING AND DRYING SYSTEMS

Fresh coconut meat contains between 50 to 55 per cent moisture most of which is removed during the drying process, to yield a product containing less than 7% moisture. Drying must be carried out within 4 hours of splitting, since coconut meat deteriorates very rapidly due to growth of moulds and bacteria. Within 4 hours microbial activity in the form of slime is seen if temperature is 30°C and relative humidity around 80 per cent. The surface slime continues to develop and within 48 h penetrating mould makes its appearance. Microbial activity is reported to be more above 20 per cent moisture content (Nair, 1984). The mould attack on copra cup while drying reduces its oil content. The oil content levels of 40.2%, 35.1%, 20.1% and 0.6% have been reported in white, brown, black and green copra respectively (Nair, 1984).

The methods generally used for drying of copra are (1) solar drying, (ii) smoke drying or kiln drying and (iii) indirect hot air drying.

Solar drying

Open sundrying

The conventional system of copra drying is by spreading the cups on any open surface for sundrying. This operation is laborious and time consuming requiring more than 7 days. The loss is also caused by birds and rodents and quality deterioration due to deposition of dirt and dust on wet meat is nearly unavoidable.

The recommended drying practice during sundrying requires reduction of moisture from 55% to 35% within the first 24 hours, during subsequent 24 hours it should be reduced to about 20%

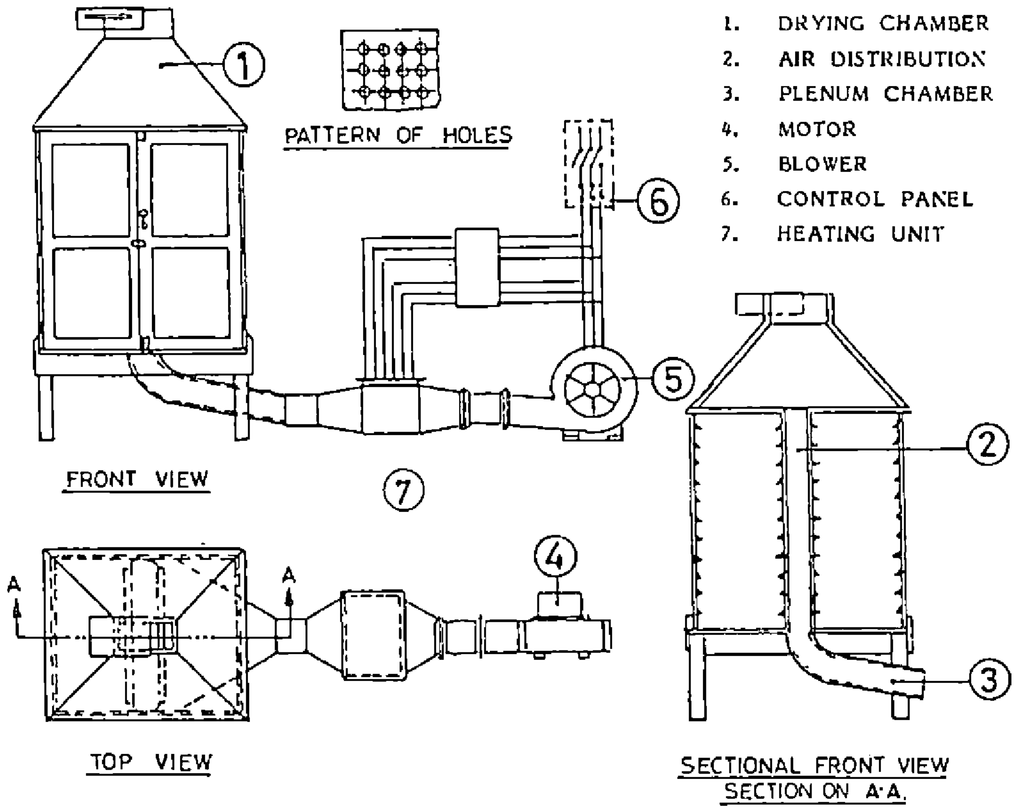

Fig 3. Mechanical copra dryer for 1000 nuts developed at CPCRI (Patil and Singh, 1983)

Table 2. Comparison of different indirect natural convection dryers with CPCRI small holders copra dryer

Name of dryer	Batch capacity, nuts	Platform area, m^2	Spreading density of nuts/m^2	Fuel used	Arrangement of cups	Land area reqd. m^2	Removal of shell	Cost of dryer Rs
WESTEC Village dryer (W. Samoa)	2000	6.7	300	Shell and husk	Random fingerlines	15	Before	6000
Kumkum dryer (Solomon islands)	1000	6.7	150	Shell and husk	Random fingerlines	28	Before	6200
PCA dryer (Philippines)	1000	6.7	150	Shell and husk	Bottom layer up	24	After one day	6200
NIST dryer (Philippines)	2000	5.0	400	NA	NA	17	NA	6800
CPCRI dryer (India)	400	1.10	364	Shell and husk	Bottom two layers up	3	After one day	1000

and in next 24 hours to 5-6%. That means, due to quicker drying the exposure to atmosphere is minimised, which improves the quality of copra (Nathaneal, 1968).

To reduce open sundrying time a low cost improvement in existing sundrying practice was suggested (Patil and Nambiar, 1982). The cup spreading surface/floor of black painted palmyra mat was found to lower the drying time by 20% compared to concrete floor. Here the known property of black surface to absorb more light energy and to convert the same into heat energy was utilized.

Low cost solar dryer

To utilize the energy conversion property of black surface more effectively a low cost (Rs 50) dryer was developed. The drying surface was black painted palmyra mat and over that MS bar and GI wire frame were put to support the 200 gauge polyethylene cover. Perforations were provided on the front, at bottom and rear top of the cover for air inlet and outlet. The top surface of transparent cover was kept inclined at 27° to get maximum penetration of light. The temperature inside the dryer was observed on an average 6°C above the ambient. This dryer could accommodate 1.5 times the open drying capacity/m^2 (i.e. 60 nuts/m^2) and drying time was reduced to 6 days. The performance index of this dryer worked out to 2.2 compared to open drying (Patil, 1984).

Solar cabinet dryer

The coconut stands are inter or mixed-cropped with crops such as pepper and cocoa which also need drying as primary processing operation. Hence an efficient time saving and low cost solar dryer will be an useful asset for a plantation crop farmer. A batch type solar copra dryer for 150 nuts was developed at CPCRI (Singh *et al.*, 1982). It was having 2 m^2 drying surface area, air inlet and exhaust. The drying time required was 5.4 days compared to 9.7 days in open drying. The dryer was stationary and was required to be kept facing south.

It was observed that a surface inclined at an angle equal to that of the local latitude and kept facing south receives about 14% more solar radiation compared to horizontal surface. When the surface is inclined and kept facing sun throughout the day by frequently changing the position, it receives about 23% more solar radiation compared to horizontal surface. Taking advantage of this phenomenon, a small solar cabinet dryer with drying area of 1 m^2 was developed. The drying area of black painted corrugated GI sheet was kept inclined equal to the angle of the latitude. The transparent cover was made of window glass on sides and acrylic plastic at the top. For air movement, wiremesh covered inlet and exhaust were provided. Castor wheels were provided for manual sun tracking and transportation to short distances. On three sides commercial grade aluminium foil reflectors were also provided. The average temperature and relative humidity in the dryer was found to be 17° above and 22% less than ambient conditions respectively. The dryer accommodated 80-100 nuts depending on the size, and the drying time was reduced to 4 days. The performance index of the dryer was 4.5 compared to open drying (Patil, 1984).

Kiln drying

It is a direct type copra dryer made from locally avaibale raw material. The fuel used is mainly husk and shell, although for good quality copra dry coconut shells are necessary, as they burn with a smokeless flame. Kiln processing requires continuous attention and supervision, as oil contained in copra is highly inflammable and serious damage can be caused by fires.

Verghese and Thomas (1952) had constructed a copra kiln based on the design of cooke type kilns in use in Malaysia. The main components of the kiln were drying chamber, roofing, grill, heat spreader, fire container and fuel tunnel. The optimum economic load of this kiln was 200 nuts arranged on four grills and temperature could be maintained at 54 to 60°C .

Indirect drying

In these dryers the coconut meat does not come in contact with fuel gases and smoke. The copra obtained is usually of very high quality.

Due to considerable capital investment and high rate of fuel used, it was considered that indirect dryers were economical only on relatively large scale. Hence, the earlier reported indirect dryers were all building type and having large capacity such as Samoa dryer, Comoro dryer, New College copra dryer, iron hot table dryer, inclined chamber dryer, Tonga hot air dryer (Grimwood, 1975). One such dryer based on Samoa type was experimentally tested at RRL, Trivandrum (Satyavathy *et al.*, 1984). The capacity of the dryer was 250 nuts and the temperature was in the range of 71-75°C. However, a lot of variation in the temperature and drying time was reported at various points in the dryer. The drying time required was reported as 16 hours. However, the economics and size of the dryer compared to its capcity look very high and not feasible to be constructed under Indian socio-economic conditions.

Keeping in view the above points, an indirect type copra dryer of 400 nuts per batch capacity and using agricultural waste as fuel was developed at CPCRI, Kasaragod. The components of the dryer were drying chamber, plenum chamber, burning-cum-heat exchanging unit and butterfly valves to control the rate of combustion and also the drying air temperature. The dryer was fabricated using MS angles and flats, asbestos sheet, GI sheets and wiremesh tray. The over all dimensions of the dryer were 122 x 90 x 117 cm and its present cost is only Rs 2200. The drying time required per batch was about 38 hours, spread over 4 days. This dryer required only 3 m^2 area for housing and could be carried by 2-3 persons (Patil, 1982). So far more than 30 units of this dryer have been sold to various copra makers and they are satisfied with its performance.

A mechanical mixed flow-dryer was also developed at CPCRI (Patil and Singh, 1983) to dry 1000 coconuts per batch. This dryer had drying chamber, plenum chamber, air distribution unit, heating unit and blower. Heating unit consisted of twenty 400 watts air heaters. Ten trays of welded wiremesh were kept on aluminium angle runners on either side of the air distribution unit. This dryer accommodated 50 nuts per tray and drying time required was 30 hours spread over 2.5 days. The cost of the dryer was Rs 12000 and required only 6 m^2 area for housing (Fig 3).

The small-holders' dryer using agricultural waste developed at CPCRI was compared with other 4 types of indirect natural convection copra dryers being used in other countries. The cost computation was made as per the prevailing rates of raw materials in India (Patil, 1984). The details such as batch capacity, platform area, spreading density, loading weight etc. are given in Table 2. It was found that CPCRI dryer

Table 3. Standard copra grades in order of market value

Sl. No.	Grade	Specification
1	F.m.g.w.s.	Fair, merchantable, good white, sundried
2	i) F.m.s,	Fair, merchantable, sundried
	ii) F.m.s. standard	
	iii) F.m.s. trade	
3	i) F.m.	Fair, merchantable, little kiln dried
	ii) F.m. mixed	
	iii) F.m. kiln dried	

had many advantages over these dryers, namely i) suitable for small farmers, ii) low cost and less space requirement, iii) precise temperature control and iv) portable.

This dryer was further scaled up at CPCRI to raise its capacity to 1000-2000 nuts per batch. Here, platform area was 3 m^2 and burning cum heat exchanging unit was having 45 cm dia. The over all dimensions of the dryer were 2.7 m x 1.2 m x 1.75 m. The copra drying temperature was 60-70°C. The drying time required was average 37 hours to reduce moisture from 50 % to 5-6%. The capacity in terms of copra was 153 kg/batch. More than 80% of the copra dried in the dryer was of very good quality (CPCRI, 1985).

Chemical treatment to wet kernel of copra

Preservation of fresh kernel becomes essential when drying is delayed due to uncertainty of weather condition. Many chemicals have been tested for this purpose and their suitability was assessed.

Subramonian (1966) in Philippines reported that copra treated with solution of H_2SO_4,(combined glacial acetic acid and H_2SO_4) and with soda ash of 1.250 specific gravity yielded increased copra and about 10 to 20%-more oil recovery. Sreemulanathan *et al.* (1979), also confirmed that application of thin coat of glacial acetic acid prevented microbial growth during open sundrying.

A chemical treatment of dipping fresh kernels in 1000 ppm propionic acid for 60 min to preserve it up to 49 days without further drying had been developed at CPCRI. This was found to be a useful and simple method to overcome the spoilage of kernel due to sudden onset of inclement weather (Patil, 1980).

Copra grading

The copra is graded in order of its market value. As drying system is a very important factor which dictates the quality of the final product, the standards are also evolved based on it as given in Table 3. Since moisture is a principal agent of deterioration it is clear

Table 4. Grading of copra as per moisture content

Sl.No.	Description	Apprx. moisture content, %
1	Wet coconut meat, fresh coconut kernel	50
2	Wet or half-dried copra	20-30
3	Mixed copra, underdried copra	10-20
4	Fairly dry copra	8-10
5	Commercially dry copra	6-8
6	Well dried copra	5-7
7	Warehouse dried copra	5-8

that grading by quality should take into account the percentage of moisture also. For this reason the grade specifications suggested on the basis of moisture are given in Table 4.

The Indian Central Coconut Committee had prepared standards for grading copra. The grading was mainly based on moisture content, the foreign matter and black copra . The maximum limits for them were 10%, 2% and 5% respectively. However, the good quality copra lot should have following requirements i.e., moisture 6%, oil content 71%, acid value 2.5%, foreign matter 0.5%, mouldy cups 5%, wrinkled cup 5% (free), chips 5% (free) and black copra 1% (free) (Anon., 1950).

COPRA STORAGE

Due to its hygroscopic nature, the safe moisture level cannot be maintained in copra if stored under the conditions of high relative humidity and wide fluctuating temperature. The wet copra should not be mixed with dry copra and storage structure should be such that there is minimum fluctuation in temperature compared to ambient to avoid moisture migration effects in the structure. Painting of upper surface of roof with mat white reflective paint has been reported to reduce temperature fluctuations within 10°C, thus preventing serious condensation effect. The walls also should be shaded from direct sunlight and should be provided with sufficient number of adjustable ventilators. The floor of the structure should be water proof, smooth and easy for cleaning. The cracks and crevices in the structure must be regularly cleaned out and filled in with mortar so as to eliminate residual population of insects. If the commodity is bagged, it should never be stored directly against the wall, and should be provided with proper dunnage. Wooden bins for storage of bulk copra may be avoided. Marar and Padmanabhan (1960) reported that copra could be safely stored in plastic lined gunny bags even during rainy season. However, the cost of plastic lined gunny bag was double than that of ordinary bag.

The suitability of multiwall paper sacks for copra storage was reported by

Mathen *et al.* (1968). They found that multiwall paper bags could keep copra free from insects up to 3 months and those treated with pybuthrin could keep up to 9 months. The scientific storage of copra is essential because presence of aflatoxin-B above the critical level of 1 ppm during March - August has been reported by Philip and Menon (1983).

EXTRACTION OF OIL FROM COPRA

In the rural areas and villages copra is crushed in the primitive 'chakku' driven by bullocks. The power driven chakkus or rotaries are used in larger establishments and are driven by steam, diesel or electricity. In the organised sector, copra is crushed by expellers. A double crushing unit gives better extraction; hence, series of expellers are preferred. The clean copra is passed to disintegrator, where it is converted into a coarse meal. The meal is heated in the cooker by steam up to 88°C. The pulped copra is fed continuously to the expeller from which the oil and the cake are forced from different streams. The first expeller gives 50% extraction and the second extracts the remaining leaving about 10% oil in the cake compared to 70% in copra. The oil can further be extracted from cake with hydraulic pressing but these presses have gone out of business due to higher cost of maintenance. For removing this oil the solvent extraction method with hexane is followed or the cake as such is used as cattle feed.

DESICCATED COCONUT

Desiccated coconut is the dried, disintegrated white kernel of coconut processed under strict hygienic condition for human consumption. It is produced in four standard grades; extra fine, fine, medium and coarse. The manufacture of desiccated coconut is a relatively straight forward and simple process of crushing, shelling, removing testa, washing, sterilizing, disintegrating, drying, sieving and packaging (Rajasekharan *et al.*, 1962). For manufacture of desiccated coconut, it is necessary to select nuts on the basis of yeild and quality. Husking is usually carried out in field to reduce the bulk and weight to be transported. On arrival at the factory, nuts are carefully inspected to ensure that only the best ones are processed. The nuts are seasoned for easy removal of shell. The shell of nuts is removed by hand with hatchet or knife, without damaging the wholeness of kernel. Paring is the next operation of removing the testa from kernel with a special knife. The parings on extraction yield second grade oil. The kernel is then sliced to release coconut water.

After washing, the coconut pieces are sterilized to make it free from microorganisms. The pieces of kernel are then shredded. The moisture content of the material at this stage is around 55 per cent, which is then reduced to 3 per cent during drying process. The continuous conveyor dryers are best suited for drying of desiccated coconut. In this type of dryer, a continuous fine mesh conveyor belt carrying the wet disintegrated meat at a depth of 7-8 cm passes through a tunnel at a constant rate. Hot air of a uniform velocity, is circulated uniformly through the bed of coconut. Around half way through the tunnel, the coconut is usually transferred by a tumbling action into a second conveyor belt situated beneath the first. In this type of dryer, the first stage of drying is done at 115°C and at the second stage it is reduced to 105°C.

After drying the coconut particles are allowed to cool and are then graded by size in series of screen sieves. The individual grades are packed into 45 kg five-ply craft sacks lined with 75 micron polyethylene film. Desiccated coconut should be stored in a clean, dry and well ventilated room, out of influence of direct sunlight. The best temperature and relative humidity for storage is 18°C and 50% respectively.

WET PROCESSING OF COCONUT

Though dry processing of coconut to get oil from dried coconut kernel is a simple process, the losses and disadvantages also cannot be overlooked. The losses due to microbial spoilage have been reported and losses also take place due to attack of rodents during drying, storage and transportation. About 6 to 10 per cent of oil goes with cake after extraction. Due to decentralised operation the FFA level in the coconut oil rises quite high which leads in considerable losses while refining.

To avoid these problems efforts have been made to develop a process to extract oil from fresh coconut meat. The major wet processes reported are the Chayan or impulse rendering process, Roblendano-luzuriage process, Krauss-Maffei/ CFTRI process, Roxas process and Sugerman process (Grimwood, 1975). The process developed in India was at CFTRI by Bhatia(1963) as given in Fig 2. Hagenmaier (1976) conducted cost analysis of wet process and found that optimum plant size would process about 270000 nuts daily. The rate of return was estimated about 37% before paying taxes. Only transportation cost was found to be lower in this process compared to copra processing. Yield of oil up to 95% of the theoretical maximum was reported. The other advantages were natural oil with FFA as low as 0.0028%, less colour and more oxidative stability, with yeild of other byproducts such as skim powder, protein, dried coconut milk, pressed meat and coconut flour (Hagenmaier, 1979).

OTHER POTENTIAL PRODUCTS FROM COCONUT

Toasted coconut

It is mainly a desiccated coconut which is mixed in surcose, dextrose and salt, then toasted in a continuous conveyor oven to a moisture content of 0.5 per cent . It is used as a topping and as a nutment in doughs. The ball copra can also be processed after cutting into chips and can be consumed as snack.

Sweetened coconut

It is prepared by mixing desiccated coconut, powdered sucrose, salt, a trace of calcium phosphate and water in a tumbling type mixer. Sweetened coconut is usually used in the confectionery and baking industries.

Creamed coconut

It is prepared by milling desiccated coconut until most of the oil has been released from the cells. It is then chilled and treated with nitrogen to a shortening like consistency. It is used in sandwich fillings, to which a relatively small quantity imparts a pronounced coconut flavour.

Coconut flour

In Philippines a process to obtain coconut flour after defatting desiccated coconut under mild expelling conditions was developed (Grimwood, 1975). From this process a high quality white oil and a residual flour are obtained, where flour can be used directly into breads and also in other food items, wherever coconut is used.

At RRL Trivandrum (Satyavathy *et*

al., 1984), a process to produce defatted edible gratings has been developed which can be used in many common food preparations like chutney, curries and sweets where wet disintegrated meat was used. The process as in desiccated coconut consists of shelling, disintegrating, drying and defatting the dried white gratings. The partially defatted gratings are packed in polyethylene bags.

COCONUT WATER

At present water from ripe coconut is a waste of copra making industry. At RRL Trivandrum, a process has been developed to properly utilize the coconut water by bottling. The coconut water soon after breaking of coconut is filtered and processed for upgrading and preservation. This water with or without carbonating is filled in bottle. It is likely to be a very attractive industry as it can be marketed to northern parts of the country where coconut water is a rarity.

FUTURE WORK

The dehusking operation needs to be mechanised so that one can do this job with ease and simplicity.The extension agencies should educate the farmers on the use of appropriate type of drying system to get good quality copra for extraction. The indirect type small-holders copra dryer is an efficient and low cost device for this purpose. Wet processing looking to its high capacity limitation and centralised nature will be of limited feasibility under Indian conditions; but the plant at cottage industry levels to prepare partially defatted coconut gratings can be feasible. The process has been developed at RRL; however, the studies for feasiblity of small plants to make it a decentralised operation are necessary. Because, if this product can substitute even partially the use of fresh coconut in coconut growing region, it would have great impact on availability of coconut oil in the country as about 45% of production is consumed for culinary purposes.

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TECHNOLOGY OF COCONUT - CURRENT STATUS AND FUTURE REQUIREMENT

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Abstract: A variety of non-traditional products from fresh coconut can be made on commercial scale as a result of newer technological advancement. They include coconut cream, cream powder, beverages, desiccated coconut and coconut flour. Different aspects of manufacture of coconut cream and cream powder have been discussed. After several laboratory and pilot plant trials a flow sheet has been developed for the manufacture of coconut cream at the RRL, Trivandrum. The flow sheet has the built-in flexibility for the production of other products like coconut cream powder, bottled coconut water etc. with a little modification. Other coconut based products developed at RRL Trivandrum are bottled coconut water (BCW) and partially defatted coconut grating (PDC) and both are released through NRDC for commercial exploitation. The raw material for BCW is mature coconut water, a waste in copra and desiccated coconut industry. PDC is manufactured by extracting oil from the dried gratings and therefore has less fat and more protein and carbohydrates with better shelf life and functional properties. Future reasearch and development requirements for integrated coconut processing have been suggested.

INTRODUCTION

Coconut palm is one of the most versatile trees known to mankind for its myriad uses as source of food,drink and shelter. However, potential of coconut has not been exploited due to lack of adequate research and development support. Therefore, major coconut producing countries in the world, export only the primary products such as copra (0.2 million tonnes) and coconut oil (2 million tonnes). Less than 10% of the coconut production is converted to value-added product like desiccated coconut.

In the recent past, there have been attempts to develop value-added products. As a result, products such as coconut cream, coconut cream powder etc. were developed in the Philippines, Malaysia and Singapore, primarily to cater the export market.

Activated carbon and shell flour have also been now commercially produced from coconut shell and exported from Philippines and Sri Lanka.

India ranks third in the world in coconut production, the demand being more than the supply. Nearly 60% of the production is utilized for food uses and the rest is converted into copra for subsequent oil extrction. For this reason coconut is valued more as food crop rather than oil seed crop. Nevertheless coconut oil comprises 7% (2 lakh tonnes) of the total oil produced in the country. Though coconut cultivation and coconut based industry sustain millions of people in gainful employment in the country, the pace of modernisation in the post-harvest processing sector had been very slow in the past mainly due to inadequate R & D support. Consequently, other than the traditional activities such as copra making, oil milling and coir processing no progress has taken place in the application of modern technology for the fuller utilization of the different coconut products. Product diversification and byproduct utilization have hitherto been neglected areas in the R & D programmes. As a result, coconut based economy continues to be unstable because of total dependence on the fluctuating price trend of a single product, i.e. coconut oil. It is therefore, highly essential to promote R & D efforts in the area of product diversification and byproduct utilization with an integrated approach to ensure stability to coconut based economy. A brief account of the advances made in other countries as against the R & D efforts that are underway in India particularly at RRL, Trivandrum is presented in the ensuing text.

NON-TRADITIONAL PRODUCTS FROM FRESH COCONUT

A mature husked nut yields 50% kernel, 17% coconut water and 33% shell; the edible part being more than two third by weight. The fresh kernel contains 45% water, 37% fat, 6% protein, 7% sugars, 3% fibre and 0.8% minerals with minor amounts of vitamins. Processing of the kernel for coconut oil is under-utilization of this valuable resource. A variety of new food products can be made on commercial scale as a result of newer technological advancement. Some of the industrially important products are coconut cream, cream powder and beverages based on these products and desiccated coconut and coconut flour.

Coconut cream

Manufacture of coconut cream has gone into commercial operation in the Philippines, Malaysia, Thailand and Singapore. The total production is estimated to be about 5000 t in 1983. The technology adopted for the production of coconut cream is more or less the same with slight variations. However, details are not published for obvious reasons. The Phillipine process (Fig 1) involves splitting, deshelling, paring, comminution and extraction using screw process. The gratings are mixed with two times the weight of water before extraction. The extracted milk is concentrated by centrifugation. The cream thus obtained is mixed with water and pasteurised at 75°C for 25 min followed by homogenization with additives. Cream is filled hot in cans and autoclaved for 45 to 70 min. In the Malaysian and Thailand processes the milk is concentrated by heating in steam jacketted kettles at 80°C for 4 hours, the other sequence being similar to the Philippine process. Sodium metabisulphite is added before canning.

Singapore is reported to have adopted the latest in liquid food processing technique called aseptic packing for coconut cream. In this process the milk is heated to ultra high temperture (140°C) for 2 seconds followed by rapid cooling, homogenization and filling in cartons (tetra pack or tetra brick) under aseptic conditions. This process does not warrant addition of preservatives. Detailed flow sheet, mass balance and cost analysis for these processes are not available. A critical evaluation of these processes would reveal that there is addition and removal of water in subsequent step which means more unit operations and added cost. All the processes involve either prolonged heating (4 hours in the case of Thailand and Malaysian processes) or autoclaving for more than an hour (Philippine process, Fig 1). Coconut cream is a delicate product and the coconut protein is highly susceptible to heat treatment. Prolonged and high temperature heating would result in curdling and cooked flavour. Analysis of the canned coconut cream made in Malaysia and Singapore revealed that the product is dilute (21% and 15% total solids), curdled and is devoid of coconut aroma. The product is separated into cream and water phase. It appears, therefore, that the technology for the commercial production of coconut cream has not been perfected.

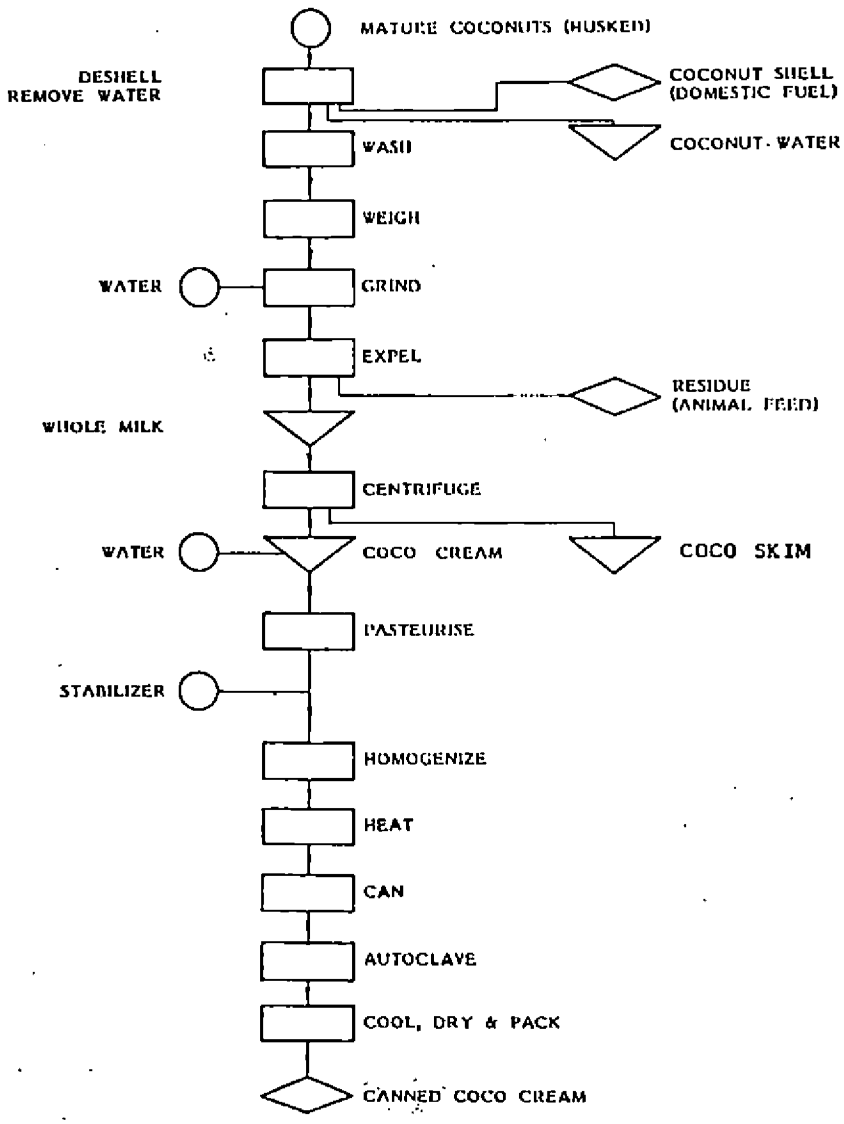

Fig 1. Manufacture of coconut cream (Philippine process)

Table 1. Composition of fresh coconut kernel

Constituents	Per cent
Moisture	45
Fat	37
Protein	4
Sugars	7
Fibre	3
Minerals	8
Vitamins	Trace

Table 2. Analytical data of coconut cream processed at the Regional Research Laboratory Trivandrum (RRLT)

Colour	White
Texture	Smooth
Flavour	Coconut
Appearence	Homogeneous
Consistency	Creamy
Fat globules	Uniform
Total solids	37%
Solids non-fat (SNF)	12%
Fat	25%
Protein	4.5%
Sugars	5.5%
Minerals	1.8%
Added gums	0.4%

COCONUT CREAM POWDER

Liquid processed food is vulnerable to deterioration due to various reasons. It requires, therefore, a high standard of process controls, packaging and storage to ensure reasonable shelf life and quality. Dehydration is a widely adopted technique in food industry for the preservation of processed foods. Coconut cream can be dehydrated by vacuum shelf drying, drum drying, freeze drying or spray drying methods. Vacuum shelf drying and drum drying would yield a poor quality product. Freeze drying can produce a superior product but is a very expensive technique. Spray drying, though sophisticated, is the method of choice. The unit operations for coconut cream and cream powder are common till extraction stage. However, process requirements differ as the cream route demands standardization of composition and special additive to obtain free flowing powder. A commercial sample of coconut cream powder made in Malaysia, after analysis in the laboratory showed that the product is spray dried free flowing powder packed in laminated foils. It also contained malto-dextrin and milk protein as additives. No other details are available. Philippines is also known to manufacture coconut cream powder for export. In the manufacture of cream powder in the Philippine process, skim milk is a byproduct, which is spray dried and this coconut skim milk powder is reported to be a good beverage baye.

STATUS OF POST-HARVEST TECHNOLOGY OF COCONUT IN INDIA

Until recently processing of coconut has not been given adequate attention. The major activities have been copra making and oil milling. With the establishment of RRL, post-harvest technology of coconut was taken up as a major activity considering its importance to the region. Of the annual coconut production of 6404 million nuts about 60% are consumed for food uses in the form of coconut paste, gratings or as coconut milk by the house-hold sector. Coconut processing at house-hold is cumbersome, labour intensive and inefficient with inherent wastage and underutilization. Because of the poor yield of milk at house-hold extraction, the residue may contain nearly 50% oil which is wasted. It is estimated that about 25000 tonnes of coconut oil may be wasted on this account alone. Processed coconut cream, if made available, could to some extent avoid wastage and also ease the house-hold drudgery. During the last three years the

Table 3. Composition of coconut gratings after milk extraction, per cent

Constituents	Coconut residue	Desiccated coconut
Moisture	3.0	3.0
Fat	48.0	66.0
Protein	8.0	8.5
Sugars	9.0	10.5
Fibre	15.0	4.3
Minerals	1.5	0.8

Table 4. Cost analysis of coconut cream process (tentative)

Cost of production	Rs	Returns	Rs
* 1 Raw material (10000 nuts, whole sale)	21000	(1) Coc. cream 2500 kg (Rs 25/kg)	62500
2. Overheads (Ex-factory)	21000	(2) Coc. residue of 500 kg	
		(a) Chutney/ curry powder of 1000 kg (Rs 25/kg)	25000
		*(b) Coc. oil of 200 kg	6000
		Total	
		(1) + (2a)	87500
		(1) + (2b)	68500
Total	42000	(3) Coc. water (5000 bott.)	10000
		(4) Shell	1000

* Whole sale price of coconut product at Cochin as on 10.1.1987

laboratory has been engaged in the optimisation of unit operations of extraction and processing of coconut cream and is being continued as sponsored programme funded by the Coconut Development Board. After several laboratory and pilot plant trials a flow sheet has been arrived at (Fig 2). In this (RRLT) process,only calculated amount of water is added to avoid the concentration step envisaged in the Philippine and Malaysian processes. Since excessive heat treatment is avoided in the RRLT process the quality of the end product is superior compared to the coconut cream available in Malaysia or Singapore. Stability, texture, and over all appearance of the cream by RRLT process is superior as modern technique like pressure homogenization is employed in presence of certain additives to enhance the functional properties of the cream. The gratings obtained after the extraction of cream has retained enough nutrients so that it can be used for ready to use food formulations like chutney powder. The flow sheet has the built-in flexibility for the production

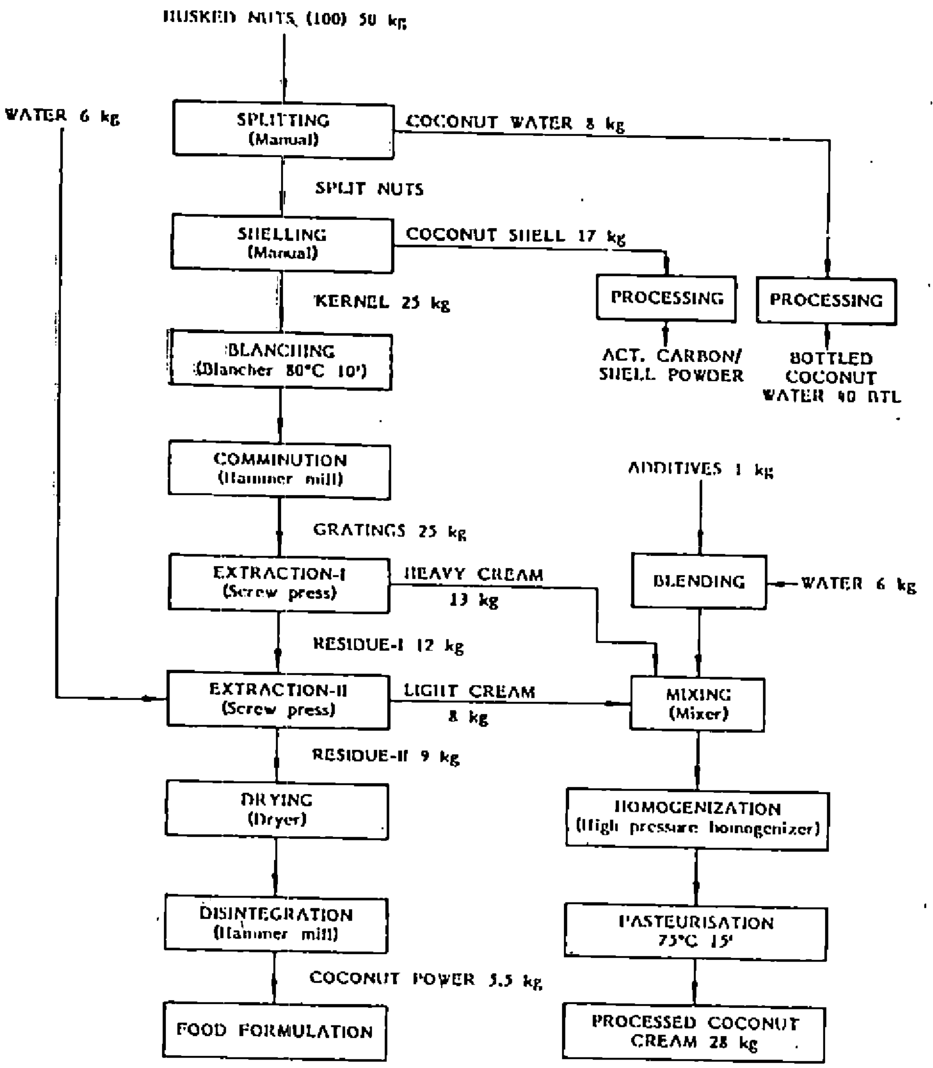

Fig 2. Flow sheet and mass balance for coconut cream (RRLT process)

colour of the exposed surface. To estimate the moisture content in a scientific and accurate way, the CPCRI has developed a moisture meter which works on the principle of electrical conductivity. It can read moisture content from 40% to 5% so that the moisture can be found out at different stages of drying. After the initial calibration of the meter, the percentage of moisture in copra can be read directly by inserting its probe into the coconut kernel (Madhavan, 1986).

WET PROCESSING

Wet processing comprises (1) aqueous processing and (2) preparation of desiccated coconut.

Aqueous processing

The advantage of aqueous process is that the protein present in coconut is not lost in the cake. The suitability of this processing method for India requires in-depth study as it will release the existing dry milling rotaries and expellers.

Desiccated coconut

It is the dried disintegrated coconut meat having demand all over the world in confectionery and other food industries. The flow diagram for the preparation of desiccated coconut is shown below

Husking → Shelling → Paring → Disintegrating
↓
Packing ← Sieving ← drying

The disintegrated coconut meat is to be dried at a temperature of 77°to 82°C to bring down the moisture content to 2-2.5 per cent. The CPCRI electrical dryer is suitable for this purpose.

PARTIALLY DEFATTED COCONUT GRATINGS

The Regional Research Laboratory, Trivandrum has developed a technology by which partially defatted coconut grating can be produced for food use after a part of the oil is recovered. The oil thus recovered is of superior quality ('water white') with fresh coconut aroma and very low FFA (Satyavathi, 1987). This technology was released through NRDC.

BOTTLING OF COCONUT WATER

Large quantity of coconut water is being wasted in the copra and desiccated coconut processing units in Kerala and Karnataka because of poor storage quality. Due to biochemical changes including flavour and taste during maturation, the mature coconut water is not as palatable as tender coconut water. The Regional Reseach Laboratory, Trivandrum has developed techniques to upgrade the mature coconut water to a product, very close to tender coconut water in taste and flavour and to bottle and preserve it for 45 to 60 days. This technology was also released through NRDC (Satyavathi, 1987).

COCONUT SHELL

The coconut shells are mainly used as fuel and to some extent in the manufacture of activated carbon. It has been reported that coconut shell can be used as a building material in cellular building blocks for load bearing and partition wall construction and in sandwich panels for wall cum roof construction.

CONCLUSION

The post-harvest processing of coconut is mainly confined to copra making for edible oil milling purposes and for coir processing. For diversification of its uses entrepreneurs are to be encouraged to start industries for the commercial utilization of coconut products and byproducts. The farmers and the processors have not fully accepted the modern technologies either due to its high cost or due to their lethargy to go away from conventional ways. Research should be activated to modify certain labour oriented operations. For example, coconut dehusker and a mechanical palm climbing device are long felt needs. A small scale simple oil mill for house-hold may also have to be developed. Above all, the achievements in the field of research should reach the farmers and they must be able to adopt it.

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of other products, coconut cream powder, bottled coconut water etc. with a little modification. Further work in the processing of coconut cream includes improvements on the stability, setting up of a demonstration unit, sensory evaluation etc. The technology for the processing of coconut cream is expected to be ready for technology transfer within one year.

Other coconut based products developed at RRLT are bottled coconut water (BCW) and partially defatted coconut gratings (PDC) and both are released through NRDC for commercial exploitation. The raw material for BCW is mature coconut water, a waste in copra and desiccated coconut industry. The mature water that is bland in taste and normally not acceptable as a beverage has been upgraded with certain additives and processed under utmost hygiene and sanitation. On test marketing BCW has been found to be acceptable as a soft drink. Availability of mature coconut water is estimated to be 250 million litres per annum from Kerala alone.

PDC is manufactured by extracting oil from the dried gratings at 70%, 60% and 45% levels. PDC therefore has less fat and more protein and carbohydrates with better shelf life and functional properties. This has been aimed to conserve coconut oil by controlling the level of the oil of the coconut consumed as food.

FUTURE R & D REQUIREMENTS FOR COCONUT

Of the 2 lakhs tonnes of coconut oil produced per annum in India, 125000 tonnes are used for toiletary and industrial uses, mainly in soap industry. The remaining is used for edible purposes. Because of the violent fluctuations in price, coconut oil is being substituted by other cheaper oil thereby destablizing coconut industry. The problem is compounded by the fact that coconut industry in India depends mainly on single commodity, i.e., coconut oil. Future emphasis, therefore, should be on the development of diverse products to utilize the full potential of this valuable commodity. Other than coconut cream, spray dried coconut cream powder will have good market potential. Products based on coconut shell, and coconut water should also be developed leading to the integrated processing of coconut products.

Coconut cream powder

The flow sheet for coconut cream (Fig 1) could be easily adopted for the manufacture of cream powder by the addition of two unit operations; cream separation and spray drying. Cream powder has several advantages such as reduction in the cost of packaging and transportation, better shelf life and flexibility in its end use. However, its development requires rigorous standardization to obtain a quality free flowing powder.

Integrated coconut processing

Dehusked coconut as the starting material yields three distinct but valuable raw materials (50% kernel, 17% water and 33% shell) for further processing. Kernel may be processed for coconut cream, cream powder or desiccated coconut. Water can be bottled for marketing as soft drink. Shell may be converted to active carbon or shell flour. For the shell products, technology has been developed abroad but not yet perfected in India. The flow chart (Fig 2) for coconut cream can be adopted for the manufacture of desiccated coconut without any additional equipment. Cream powder requires only a spray dryer as a unit operation. Production can be shifted depending on the market demand for the product. For processing coconut water the additional requirement is only a filtration unit. Process and product integration of this nature would be highly cost effective. A demonstration unit integrating all these products will be a milestone in the activity of the future programme.

CONCLUSION

In India, according to the current pattern of consumption about 4000 million nuts are consumed for food uses and this figure is likely to reach 8000 million nuts by the turn of the century, keeping with the total production target of 12000 million nuts during the same period. If ten per cent of the nuts are processed into coconut cream, cream powder, desiccated coconut and other value-added products, it can sustain at least 10 medium sized units. Through better efficiency of processing and byproduct utilization at least 10000 tonnes of coconut oil could be conserved and released to the common vegetable oil pool per annum. Integrated processing of coconut product should be adopted to exploit the full potential of this commodity and to stabilize coconut-based economy. There is an urgent necessity to accelerate the R & D efforts to commercialise products like coconut cream and cream powder in view of the time bound programmes of national importance on oil seeds.

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RECENT DEVELOPMENTS IN THE HARVEST AND POST-HARVEST TECHNOLOGY OF COCONUT

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Abstract: The harvest and post-harvest practices, in general, determine the quality of the end product. Husking, drying and oil extraction are the major post-harvest operations in the dry processing of coconut. Wet processing, though costly, can be adopted for the preparation of a variety of food items like spray dried coconut milk, white soluble protein powder etc. The CPCRI machineries/devices like coconut dehusker, dryers and copra moisture meter are much useful to farmers and copra processors. The multipurpose dryer using agricultural waste as fuel developed by CPCRI has made possible to dry coconuts economically during rainy season also. The CPCRI copra moisture meter can estimate the moisture content from 40 per cent to 5 per cent so that the moisture content at different stages of drying can be found out. The technology developed by RRL, Trivandrum for bottling and preservation of coconut water and for preparation of partially defatted coconut gratings is another step in coconut processing. Commercial utilization of coconut shell in building construction as a primary structural material or as a filler material and coconut pith in the manufacture of hard boards, insulators, etc. could convert these waste materials into useful products.

INTRODUCTION

The harvest and post-harvest practices determine the quality of the end product and byproduct of coconut which directly influence the economy of the producer. Of late, considerable efforts are being put in for improving the age old practices in harvest and post-harvest processes and to develop new technology, thus obtaining valuable byproducts from waste material.

HARVESTING

In India, harvesting is commonly done by experienced climbers. It is a job of skill and experience. Nowadays climbers are rare and their wages are also very high. A mechanical device for climbing the palm has been a long felt need and many attempts were made. The climbing device developed by a farmer from Chemberi, Kerala is becoming popular although it needs improvements on ease of operation and safety of the climbers. Harvesting can also be done on palms which are not much taller with the help of a knife attached to a long bamboo pole. After the harvest, the usual practice is to store the nuts in heaps under shade. This type of storing is also known as seasoning.

HUSKING

The husk is generally removed manually with the aid of a spike fixed on the ground. This is a specialised job and requires skilled labourers. Attempts were made to develop a husking device with which any unskilled person can do the husking. The coconut dehusker developed by CPCRI can be operated by any unskilled person (Anon., 1985). The out-turn of this husker is 105-120 nuts per hour. Its cost is about Rs 1200 only. This device is economically viable for a farmer having 5 ha of coconut garden or for medium processing units.

The most important commercial utilization of husk is for the manufacture of coconut coir. Husks are also utilized as fuel, seedling pit mulch and soil moisture absorbent in coconut gardens. Pith, the waste product obtained during the extraction of coir fibre from retted, partially retted or unretted husk, constitutes 70% of the husk. It has a limited use as a surface mulch of top soils. Research is in progress to use coconut pith in building blocks, and for the manufacture of commercial products such as hard boards, insulators, etc.

COPRA DRYING

Fresh coconut kernel which has 45-55% moisture has to be dried to a moisture level of less than 6% for oil extraction. Drying determines the quality of copra and ultimately coconut oil. Copra may be made both in the form of cups and balls. Cup copra can be made either by sundrying or by using different types of dryers. During rainy season or with restricted sunshine, drying by artificial method is the only solution for processing plantation crop products. The direct type kiln dryers are not desirable for copra as the product becomes inferior in quality due to smoking and improper drying. Hence, the solar cabinet dryer, electrical dryers and the small-holders dryer using agricultural waste as fuel were developed by CPCRI, for copra drying.

(1) Solar cabinet dryer

This dryer is of chamber type (Patil,1982a) having direct heating and natural air convection arrangements. The capacity of the dryer is 90-100 nuts per batch. The drying time is 3.5 to 4 days thereby reducing the time by 50% as compared to the conventional method. The temperature and the relative humidity inside the dryer were found to be 17°C more and 22% less respectively, compared to the respective ambient factors. The dryer costs about Rs 2200 and the cost of drying is 85 paise per kg.

(2) Electrical dryer

It is a tray type dryer with mixed flow and forced hot air circulation designed (Patil and Singh, 1984) for drying 1000 coconuts (160 kg of copra). This can be used to dry other crops like cardamom, pepper, etc. by changing the weld mesh trays to wiremesh trays of suitable size. The dryer may cost approximately Rs 8000 and so is feasible to co-operatives and copra processing units.

(3) Small-holder's dryer for plantation crops using agricultural waste as fuel

This dryer is of 'batch type' having indirect heating and natural air convection arrangements (Patil, 1982b). Four hundred nuts per batch can be dried in this dryer in 36 hours. It is a multipurpose dryer and so other crops like cocoa and arecanut can also be dried in this. The cost of drying per kg of copra and cocoa is Rs 0.75 and Rs 1 respectively. Similar types of dryers of 1000 coconuts/batch and 3000 coconuts/batch capacity were also developed at CPCRI.

BALL COPRA

Ball copra is of superfine quality and commands a premium price in the market. It is prepared by storing fully matured nuts for 10 to 12 months, when kernel gets detached from the shell. Research is in progress at CPCRI to prepare ball copra in a shorter time by giving different heat treatments.

COPRA MOISTURE METER

In milling establishments, the moisture determination is done by experienced people who by breaking a piece of copra, assess the moisture content on the basis of the nature and

ECONOMICAL COIR REINFORCED FLOOR SLABS FOR CATTLE SHEDS

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Abstract: An intermediate technology has been developed to prefabricate floor slabs for cattle shed in place of expensive concrete flooring and to replace unhygienic mud flooring. Different mix ratios of white ash from paddy husk, lime and sand were tried to cast cubes and briquettes for asessing the compressive and tensile strength. The mix was optimised with further addition of ordinary portland cement (OPC) to attain desirable strength and binding ability. Of the various mix raios tried, 1:3:12 mix (OPC : white ash cement : sand) gave maximum cube compressive strength of 66.75 kg/cm^2 and briquette tensile strength of 18.2 kg/cm^2 which was 34 per cent more over mere white ash cement : sand mix in 1:3 ratio. Trials conducted on coconut coir reinforcement to improve modulus of elasticity and flexural strength showed that coconut coir at the rate of 400 g/m^2 is found to be optimum. A prefabricated slab flooring of 4.5 m^2 was constructed using the above optimum mix ingredients and found that there is absolutely no damage due to movement of cattle during the one year study period and it is 29.2 per cent cheaper than the conventional 1:5:10 cement concrete flooring.

INTRODUCTION

At present, cattle shed floor is normally constructed with cement or lime concrete or mud. The use of concrete enhances the cost of flooring though it is good from the hygienic point of view. The mud floor is neither favourable for healthiness of cattle nor for maintenance. Heavy and thick stone slabs are also used in certain parts of India which is uncomfortable for cattle due to uneven hard surface. Hence, the necessity of cheap flooring is felt for providing comfort to animals in cattle sheds.

The use of ash resulting from burning of agricultural wastes like rice husk as a cementitious binder in conjunction with lime has been receiving increasing attention in recent years. The need for such materials is clear as the conventional binder, portland cement, is expensive where its high strength and rapid setting properties are not of primary importance to the low-rise building or simple civil engineering works. Yet another agricultural byproduct, coconut coir is also within easy reach of the rural folk. Hence, a study was undertaken to develop prefabricated floor slabs using the above agricultural waste/byproducts at the Tamil Nadu Agricultural University.

MATERIALS AND METHODS

The essential raw materials for floor slabs were produced as detailed below.

Rice husk ash cement

Rice husk was burnt between 450-750°C under controlled conditions in a suitably designed kiln. Owing to the calorific value of husks, it was possible to obtain combustion in this range by igniting the husks with small amount of fuel. Ash produced in this way was light grey to white in colour. The ash along with lime in proportion of 1:1 by weight was ground and mixed well in a ball mill to form white ash cement.

This newly prepared cement has been identified as a substitute for partial replacement of OPC. The white ash containing 72-92 per cent silica can form a good pozzolanic material. The silicious and aluminous materials in a finely divided state and in the presence of moisture chemically react with lime at ordinary temperature to form compounds possessing cementitious properties.

Coconut coir

The lengthy and thick coconut fibres useful for rope making were adopted. The length varied from 6-20 cm and the diameter ranged from 0.4-1.0 mm.

Conventional materials used

For partial addition in proportioning, ordinary portland cement (OPC) of standard quality, well graded sand and water suitable for general building construction were used.

Experimental procedures

Step 1

The mix containing paddy husk white ash, lime and sand in the ratios of (1) 2:1:9, (2)1:1:6 and (3) 1:2:9 were tested for compressive strength and tensile strength by fabrication of 7 cm x 7 cm x 7 cm cubes and briquettes of standad size (cross-sectional area 6.25 cm^2). The average strengths of the 7 day old specimen tested as per ISS are furnished in Table 1

As there was no significant variation in strength between 1:1:6 and 1:2:9 ratios, the mix ratio 1:1:6 was selected for prefabricating the slab.

Step 2

Initially 30 x 30 x 4 cm size slabs were prefabricated by 'L' angle moulds, using 1:1:6 mix. Minute surface cracks were observed after a month and corners were found damaged after three month period.

Step 3

To improve the binding and stability, portland cement and white ash cement were mixed in the proportions of 1:3 and 1:4 and tested for compressive strength. For each test, sand was admixed three times the total quantity of ash cement plus OPC. Additional strength of 34 per cent was resulted in 1:3:12 mix compared to 19.5 per cent increase in 1:4:15 mix (over mere white ash cement and sand mix in 1:3 ratio).

Step 4

Different sizes of slabs viz., 30 x 30 cm, 60 x 30 cm, 90 x 60 cm and 90 x 90 cm were cast with 4 cm thickness using L angle moulds and tested for functional adoptability by handling and laying on the firm level ground. The 90 x 60 cm size was found to be the optimum with reference to easy handling and economical considerations.

Step 5

In order to improve tensile and flexural strength of the slabs, the coconut coir reinforcement at the rate of 100 g, 200 g, 400 g and 600 g for on 1 m^2 area was tried. A slab of size 1 m x 0.21 m x 0.04 m was cast *in situ* and the modulus of elasticity (E) and flexural strength were estimated using Macaulay's method. The results are summarised in Table 2. The coir reinforcement at the rate of 400 g/m^2 was found to be optimum to get the maximum strength. Further addition resulted fall in strength.

RESULTS AND DISCUSSION

The above experiments indicate that ordinary portland cement, white ash cement and sand in the proportion of 1:3:12 by weight is the optimum combination for prefabricated slab. The size of the slab has been optimised as 90 cm

Table 1. The compressive and tensile strength of cubes and briquettes fabricated

Mix ratio	Cube compressive strength (kg/cm^2)	Briquette tensile strength (kg/cm^2)
2:1:9	28.7	11.1
1:1:6	49.8	14.4
1:2:9	52.5	15.9

Table 2. Tensile and flexural strength of coir reinforced slabs

Quantity of coir reinforcement (g/m^2)	E rate (kg/cm^2)	Flexual strength (kg/cm^2)
100	0.81 x 10^5	102.70
200	0.92 x 10^5	138.89
400	1.36 x 10^5	211.11
600	1.10 x 10^5	190.97

Table 3. Material requirements and cost economics of coir reinforced slabs

Material description	Cost (Rs)
Ordinary cement 2.25 kg	3.40
White ash cement 6.75 kg	3.90
Coconut coir 0.20 kg	0.75
Sand 27.00 kg	1.35
Fabrication charges	1.00
Cost of fabrication of one slab	10.40
Cost of slab/m^2	19.25
Cost of pointing works and preparation of firm ground/m^2	2.00
Total cost/m^2	21.25
Cost of 1:5:10 cement concrete flooring for 10 cm thickness/m^2 (for comparison)	30.00

x 60 cm x 4 cm with reference to the strength and functional adoptability.

Cost economics

The material requirements and cost details are furnished in Table 3. There is 30 per cent saving in the cost of slab if coir reinforcing with OPC, white ash cement and sand mix is used for the fabrication of the slab. The cost of the slab per m^2 is only Rs 21.25.

Construction of cattle shed floor

An area of 4.5 m^2 was cleared,

bottom soil was mixed with little quantity of water and well rammed. During this process, a gentle slope was maintained to provide easy drainage in the stall. The prefabricated slabs were laid over the rammed surface with 1:3 ash mortar. The slab flooring so constructed was exposed to natural weather conditions for two years and it was found that there is no cracks developed. There is absolutely no damage due to the movement of cattle and men during the one year study period.

CONCLUSIONS

Coconut coir (reinforcement) and white ash from agricultural wastes like paddy husk along with a fixed proportion of OPC can be effectively used for prefabrication of floor slabs for farm buildings like cattle sheds. There is a cost saving of 25-30 per cent over the conventional cement concrete flooring and better hygienic conditon as compared to the mud flooring. The prefabricated coir reinforced floor slabs will definitely be an intermediate and appropriate technology suited for low cost farm structures like cattle shed.

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COCONUT COIR REINFORCED ROOFING SHEETS FOR FARM BUILDINGS

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Abstract: A technology for coconut coir reinforced corrugated cement roofing sheets was developed for farm buildings in place of corrugated asbestos, steel and aluminium roofing sheets. Trials were conducted to optimise the quantity of cement, coconut coir and dimensions of the sheet based upon the breaking strength. It is found that 1.5 m x 1.0 m is the optimum size for maximum breaking strength (3.5 kg/cm). The coefficient of thermal conductivity, weight of the sheet, water permeability, cost etc. were estimated and compared with the asbestos roofing sheet. A few model sheds have been constructed with coir-cement roofing and indoor climatic conditions have been evaluated with reference to poultry growth and yield performance. The results indicate that yield parameters like mean weight gain, egg weight, egg yield, water intake etc. are better under coir-cement roofing compared to those under asbestos sheet. The cost of 1 m^2 roofing works out to Rs 30 which is 50 per cent cheaper than the asbestos sheet roofing.

INTRODUCTION

A roof is an essential part of any building which provides the necessary protection from rain, sun, wind, heat and cold. The integrity of the roof is important for the structure of the building itself as well as the occupants and the goods stored within the building. The roofing must be leakproof, durable and perhaps satisfy other requirements such as being fire resistant, a good thermal insulator or high in thermal capacity. From a study conducted on cost components of farm buildings like farm houses, cattle sheds, poultry sheds etc. at the Department of Agricultural Structures, Tamil Nadu Agricultrual University, it was found that the roofing cost varied from 40-60 per cent of the total cost of shelter.

Thatch is a cheap common roofing material in rural areas. It has good thermal insulating qualities and helps to maintain rather uniform temperature within the building even when outside temperature varies considerably. Though the initial investment is low, it may harbour insects, pests and snakes and its durability is relatively poor. Galvanized corrugated steel (GCS) and corrugated aluminium sheets are also used in certain medium level farms. But the main disadvantage is the poor thermal properties and the noise caused by heavy rainfall and thermal movements.

The corrugated asbestos cement sheets have recently replaced GCS and aluminium sheets due to their relatively better thermal insulating values and less noise during heavy rain and attractive appearance. However, asbestos is seen as a cause of certain diseases including lung cancer. Hence, developed countries like the USA has recently imposed restrictions on the use of asbestos sheets.The cost of these asbestos sheets is also beyond the reach of the majority of the rural folk which constitutes around 80 per cent of .total population of India. Under these circumstances, the College of Agricultural Engineering, Tamil Nadu Agricultural University developed economical corrugated coir-cement roofing sheets and evaluated their behaviour under natural exposed weather conditions.

MATERIALS AND METHODS

Coconut coir is available in plenty in many parts of Tamil Nadu and Kerala. The first quality fibre which is thick, lengthy, and useful for making ropes is found to be suitable for making durable corrugated roofing sheets. It is due to its higher tensile strength and good bonding effect with cement compared to the second quality fibre which is shorter in length and used in making beds and packing materials.

General properties of coir fibre

The length of the coir fibre was 10-20 cm and the diameter ranged from 0.3 mm to 1.2 mm. The fibre was soaked in water for 24 hours after removal of pith dust and then tested for its tensile strength. The tensile strength of the single fibre was found to be around 300-400 g for 10 cm length. It is also observed that the coir fibre enables good bonding in cement matrix and is not easily affected by the free lime released during hydration of cement.

At a preliminary stage, a few fibres were identified as reinforcement in cement at the rate of 800 g/m^2 and the load test was conducted as per ISI standards. The average breaking load of the fibres tested in kg/cm is (1) manji fibre 0.4-0.60, (2) human hair cuttings 0.55-0.70, (3) polyester undrawn wastes 0.80-0.85 and (4) coconut coir 3.50-3.80. Even though human hair cuttings, manji fibre and polyester undrawn wastes possessed some strength, they were not able to develop good bonding with cement and accordingly they developed cracks in course of time, resulting in serious loss of strength within a period of two months. Hence, coconut coir was identified as the best suitable reinforcing material for making corrugated sheets.

Optimisation of coir and cement quantity

Trials were conducted to optimise the quantity of coconut coir and cement by maintaining the thickness of sheets as 0.7 cm to 1.0 cm (the minimum thickness that can be maintained in the manual moulding process). For obtaining this thickness, 1.50-1.75 kg of fibre was needed for an area of 1.5 m^2. Hence the four treatments were tried by keeping constant fibre content of 1.5 kg and varying levels of cement viz., (1) 10 kg (2) 15 kg (3) 20 kg and (4) 25 kg for an area of 1.5 m^2. The load tests were conducted as per IS code using 1.5 m^2 sheets and the values for mean breaking load in kg/cm for the treatments (1),(2),(3) and (4) were 2.9, 3.1, 3.6 and 3.2 respectively.

The sheets made from 1.5 kg coir + 25 kg cement showed more number of cracks on the surface. This may be due to the presence of excess cement above the optimum bonding requirement and hence in this case, a fall in strength was noticed. Hence, 20 kg of cement was found to be sufficient to make 1.5 m^2 of coir-cement sheets with maximum breaking strength.

Process of moulding

The following unit operations were optimised for making corrugated coir-cement roofing sheets. The coir fibre was soaked in potable water for 3-4 hours. Then the free water present in the fibre was drained off. Five kg of cement was sprinkled over the fibre and mixed well. The cement coated fibre was spread over the corrugated sheet mould lined with a polythene sheet. Ten kg of cement was mixed in 10 l of water and this paste was applied uniformly throughout the area. Over this, another polythene sheet was spread and the male mould was placed over this and using bolts and nuts, the mould was well tightened.

After 10 hours, the mould was declamped and allowed to dry under shade for 2 hours. Then, 5 kg of cement dissolved in 7 l of water was applied as a coat on both the sides. Curing of sheets was done in a water tank for two weeks. Trimming of sides and painting with a water repellent material like snocem and white paint were done.

The sheets were moulded using a corrugated MS sheet mould and the uniform thickness of 0.7 to 1.0 cm was maintained only by eye judgement. The mould consisted of corrugated female and male sheets. The size of the mould was 2 x 1 m and was made up of die-pressed 18 gauge MS sheet. Pitch and depth of the corrugation were 14 cm and 4 cm respectively. In both female and male moulds, angles of size 40 x 40 x 3 mm were welded to the valley of corrugation along its length to strengthen the mould. Six number of channels of 1.25 m length were provided with bolts and nuts for tightening the mould.

The sheets were made for length of 1.0 m, 1.5 m and 2.0 m, keeping width as 1.0 m in all cases and the thickness as 1.0 cm using the above mould. The average breaking loads in kg/cm were 3.9, 3.5 and 2.8 respectively. As the breaking load was very low for 2 m span compared to the conventional asbestos sheets (4 kg/cm), 1.5 m length was identified as optimum with reference to the comparable strength of AC sheets. Even though 1.0 m long sheets gave still more strength, they were given only secondary importance due to economical considerations viz., higher requirement of roof structure.

RESULTS AND DISCUSSION

Based upon the breaking strength criteria, the dimensions of the roofing sheet were optimised as 1.5 m x 1.0 m. The coefficient of thermal conductivity, weight of the sheet, water permeability etc. were estimated as per the standard procedures and were compared with that of asbestos sheets (Table 1).

Structures with corrugated coir-cement sheet roofing

A shed for housing machinery was constructed eight years ago, at the Tamil

Table 1. Properties of corrugated coir fibre sheets as compared to asbestos sheets

Property	Asbestos sheet	Corrugated coir fibre sheet
Pitch of corrugation, mm	146	140
Depth of corrugation, mm	48	40
Length of sheet, m	1.5 - 3.0	1.0 - 1.5
Breadth of sheet, m	1.0 - 1.05	1.0
Thickness of sheet, mm	6	7 - 10
Weight of sheet, kg/m^2	13.5	14
Water permeability	-	-
Breaking load, kg/cm		
1.5 m span	4.0	3.5
1.0 m span	5.0	3.9
0.5 m span	-	5.0
Fire resistance		Excellent
Thermal insulation, kcal/mh °C	0.24	0.05
Cost per sq. m, Rs	55.60	30

Nadu Agricultural University and is still serving satisfactorily. Three years ago, four lean-to roof sheds were erected for parking vehicles and they are now performing successfully. Two residential rooms for the poor were constructed two years ago, and the occupants feel them very comfortable for living. Two poultry sheds with these sheets were successfully completed and studies on the growth rate, behaviour and the performance of birds like egg yield, egg weight, feed conversion ratio etc. are underway with 20 poultry birds.

Table 2. Cost economics of corrugated coir fibre sheets as compared to asbestos sheets

Size of the sheet	1.5 m x 1.0 m
Weight of the coir fibre used	1.5 kg
Weight of cement used	20 kg
Cost of coir	Rs 4.80
Cost of cement	Rs 30.00
Moulding charges	Rs 10.00
Total cost	Rs 44.80
Cost per sq m	Rs 29.86
Saving in cost	50%

Indoor comfort in coir-cement roofing

Studies on temperature and relative humidity revealed that lower temperature values by 1 to 4°C are prevailing in the coir cement roofing than in asbestos sheet roofing at almost all points in the vertical direction at all recorded hours of the day (up to 4.00 pm). Relatively warmer condition is prevailing in the coir sheet roofing in evening with slightly higher temperature and

Table 3. Mean weight of poultry chicks under coir-cement roofing, kg

Type of roofing	Month				
	I	II	III	IV	V
Corrugated coir-cement sheet	0.640	0.820	1.071	1.299	1.346
Corrugated asbestos sheet	0.651	0.730	0.816	0.920	0.990

Table 4. Comparison of the performance of birds under coir-cement roofing and asbestos roofing

Parameter	Coir-cement roofing	Asbestos roofing
Mean weight gain in four months, %	110.31	52.07
Mean egg weight, g	50.55	40.45
Egg yield for 20 birds/day	18 to 20	15 to 17
Total feed intake kg/day	2.40	2.10
Water intake, l/day	1.80	3.10

low values of relative humidity. This may be due to the fact that the coefficient of thermal conductivity of coir-cement roofing is only one fourth of that of asbestos sheet.

Performance of poultry birds

The mean weight of 20 poultry chicks for four successive months from the start of rearing is given in Table 3.

From Table 3, it is clear that the mean weight of chicks is significantly higher under coir-cement sheet roofing compared to that under asbestos sheet roofing. Table 4 summarises the performance of the birds and growth rate behaviour in both sheds.

The above observations indicate that the poultry growth rate and yield performance are comparatively better in coir-cement roofing than in asbestos roofing due to the better indoor climatic conditions prevailing in the coir-cement roofing. As this study has been completed only for one season at Coimbatore the results have to be confirmed by repeated trials in the subsequent two or three seasons and at different places.

CONCLUSIONS

The corrugated coir-cement sheets developed can act as a better substitute for corrugated steel, aluminium or asbestos sheets for all types of farm buildings. The low cost corrugated coir-cement roofing provided better environmental control and comfort to occupant birds/animals. It can be used to provide cheap but comfortable shelter to the poor section of the society.

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PROCESS DEVELOPMENT OF MAKING BRIQUETTES FROM COIR PITH WASTE FOR FUEL PURPOSE

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Abstract: The coir pith as such does not burn well and cannot be used as a fuel and at present the coir industries are facing the problem of disposing it . An attempt has been made to make the coir pith into fuel briquettes with cowdung as a binding material. For this a continuous horizontal extrusion type briquetting machine was developed in the Tamil Nadu Agricultural University, Coimbatore. The machine consists mainly of an overhanging screw shaft, a barrel housing and an extruder die-pipe (6.5 cm dia). The screw shaft is coupled directly to a reduction gear unit (10:1) and is driven by a 5 hp electric motor. The coir pith has to be mixed with cowdung as a binding material in the ratio of 6:1 to form a dough material. The length of the hollow briquettes produced varies from 5 cm to 10 cm. The capacity of the machine is found to be 125 kg/h and the calorific value of briquettes is around 3000 kcal/kg. The approximate cost of the machine is Rs 10000 and the cost of production of hollow briquettes is Rs 180/tonne.

INTRODUCTION

The estimated production of agricultural wastes in India is over 200 million tonnes per year compared to about 130 million tonnes of wood. These agricultural wastes like saw dust, groundnut shell, bagasse, straw etc. are at present being burnt ineffectively giving only 10 per cent of useful energy. For the efficient use of the fuel they should be available in compact form. The compacts can be easily handled, stored and burnt on grates, boilers and domestic stoves more effectively. Compacting of wastes thus offers an alternative domestic fuel which is efficient, inexpensive and easily available. One of such waste materials viz. coir pith which is abundantly available, has no uses other than as fuel, can be properly utilized for burning purposes by compacting the mass as briquettes. The coir pith as such does not burn well and cannot be used as a fuel in a thermally efficient manner and at present the coir industries are facing the problem of disposing it. Therefore, these agricultural wastes like coir pith can be compacted to briquettes which may be utilized as a low cost energy source and it is easier for handling, storage and transportation.

Earlier study revealed that the saw dust briquette required a minimum of 10 per cent binding material with a pressure of 250 kg/cm^2, whereas the coir pith briquettes required a minimum of 15 per cent binding agent and 420 kg/cm^2 pressure. Considering the swelling property, the lignite powder plus waste oil combination binding agent was much superior to coal tar binding agent. The incremental load had better effect on the compaction of briquettes as well as arresting the swelling. Briquettes were made with coir pith and saw dust under different proportions by using the reciprocating mechanism of fly press with the help of ram and die arrangement. From this study it was revealed that as the die depth increased the density of the briquettes also increased. It was also inferred that as the proportion of coir pith was increased the density of the compacted mass was decreased so also was in the case of thermal property. Therefore it was concluded that for getting desirable briquetted mass the die depth has to be increased to the maximum permissible extent and the proportion of coir pith may be reduced to an optimum value. This experimental set up could produce briquettes only at the rate of 50 kg per hour and this rate is very low on economic point of view. Hence a continuous type briquetting machine with a screw press was thought off and accordingly a machine was developed.

This continuous type briquetting machine essentially consists of a thick cylindrical barrel of 15 cm diameter housed with a screw auger, a reduction gear unit and a lengthy extrusion die arrangement. The centre shaft along with the screw auger is directly coupled with a reduction gear unit through a flange coupling. The other end of the screw shaft is supported by an extrusion die plate which has six extrusion pipes of 2 cm dia and 15 cm length. The reduction gear used has a step down speed ratio of 10 : 1 and is driven by a 5 hp electric motor.

The raw material has to be made like a dough by adding about 10% water and then fed into the machine. The screw press provided inside the barrel of the machine presses the dough like material through the extrusion pipe and the pellets are formed due to the pressure heat developed. The pellets formed are of 2 cm dia. The length of the pellet varies from 2.5 cm to 4.0 cm depending upon the self weight of the material extruded from the die portion.

This horizontal extrusion type briquetting machine was tested with coir pith for making briquettes. The coir pith was mixed with cowdung in the ratio of 1:1, 2:1, 4:1 and 6:1 and briquetes were made. Similarly, the coir pith was mixed with red earth in the ratio of 1:1, 2:1, 4:1 and 6:1 and the briquettes were made. The thermal property viz., the calorific value of the briquettes and the burning performance were measured with the help of bomb calorimeter and actual burning of these briquettes.

The burning performance of the briquettes revealed that as the proportion of coir pith increased in the mixture of coir pith and cowdung, the calorific value of the briquettes reduced and hence the water evaporation capacity also. These briquettes required pre-heat arrangement for complete burning and hence equal quantity of fire wood also was added for burning purposes. The study revealed that the minimum quantity of cowdung as binding material required was in the range of 10 to 15 per cent to form stable pellets (Devadas and Palaniswamy, 1985).

While red earth was mixed with the coir pith as a binding agent to form stable pellets, the minimum quantity required was as low as one part of red earth with six part of coir pith. The amount of binding agents could be reduced further to form a stable pellet by increasing the extrusion pressure, which in turn required higher horse power to drive the unit.

These briquettes made with cowdung and red earth emitted a lot of smoke during burning. Hence the choola attached with a chimney was found to be better in burning with these briquettes.

MATERIALS AND METHODS

A new briquetting machine was designed and developed so as to produce tubular briquettes (Fig 1). The machine consists of a over-hanging type shaft with a screw press, a barrel housing and an extruder die pipe. The screw shaft is mounted at one end by two bearings and the other end is hanged.

The barrel assembly has been housed over the shaft and mounted on a stand. The free end of the shaft is coupled directly with a reduction gear unit (10:1) and is driven by a 5.0 hp electric motor.

The coir pith has to be proportionately mixed with the binding material either cowdung or clay to form a dough. Then, the dough has to be fed through the feed hopper of the briquetting machine. Due to the rotary motion of the screw shaft, the dough material will be pressed through the extruder pipe assembly. Since the other end of the screw press has a lengthy rod incentric to the pipe circumference the dough material extruded through the pipe will form a hollow briquette. The hollow briquettes formed are of 6.25 cm diameter. The length of the briquettes varied from 5 to 15 cm depending upon the self weight of the material extruded from the pipe. This new extrusion briquetting machine was tested for its performance. The coir pith was briquetted to a tubular shape by proportionately mixing with cowdung in the ratio of (coir pith : cowdung) of 1:1, 2:1, 4:1 and 6:1 and with the clay in the ratio (coir pith : clay) of 1:1, 2:1, 4:1 and 6:1. These briquettes were dried and burnt in the meccan choola to find out their burning performance. The calorific values of these briquettes were measured with the use of bomb calorimeter. The burning performance was also measured by evaporating a known quantity of water on the meccan choola and the thermal efficiency was calculated by the following formula.

$$\text{Thermal efficiency} = \frac{\text{Water evaporated (kg)} \times \text{latent heat} + \text{sensible heat}}{\text{Calorific value} \times \text{quantity burnt}}$$

RESULTS AND DISCUSSION

The horizontal type extrusion briquetting machine was tested with the coir pith for making solid briquettes. In order to make stable briquettes with less horse power, red earth and cowdung were mixed with the coir pith in different proportions. The study revealed that the minimim quantity of cowdung/red earth required was in the range of 10 to 15 per cent to form stable briquettes. These briquettes emitted a lot of smoke during burning. Hence an

Table 1. Burning performance of the tubular briquettes made of coir pith with cowdung and clay at various proportions

Ratio	* Water evaporated (kg)	Calorific value kcal/kg	Thermal efficiency %
Coir pith : cowdung			
1:1	0.395	3365	20.99
2:1	0.365	3250	20.74
4:1	0.325	3210	19.65
6:1	0.300	3090	19.54
Coir pith : cowdung			
1:1	0.205	2850	17.59
2:1	0.215	2870	17.85
4:1	0.225	2885	18.12
6:1	0.400	3600	19.77

* Weight of water taken = 2 kg; Initial temp. of water = 25°C; Final temp. of water = 95°C; Time taken for each trial = 1 h. In all cases 0.25 kg briquette was used with 0.25 kg wood in meccan choola.

Table 2. Cost analysis of the briquetting machine

Cost of the unit		Rs 10000
a. *Fixed cost*		
Depreciation @ 10% (10 year life period)	=	Rs 900/year
Interest @ 12% on capital	=	Rs 1200/year
Repairs, maintenance and housing charges @ 10%	=	Rs 1000/year
Total fixed cost	=	Rs 3100/year
Total fixed cost per hour (Assuming 3000 working hours/year)	=	Rs 1.33
b. *Variable cost*		
Labour cost per hour (5 men for cleaning, mixing and operating @ Rs 8 per day of 8 hours)	=	Rs 5
Electricity for 3.75 units @ Rs 0.20/h	=	Rs 0.75
Screw press wear and tear (replacement for every 50 hours of working)	=	Rs 1/h
Total variable cost per hour	=	Rs 6.75/h
Total cost of operation per hour (a+b)	=	Rs 8.08
Capacity of machine	=	125 kg/h
Time required for producing 1 t briquettes	=	8 h
Cost of operation for producing 1 t of briquettes	=	Rs 64.64
Raw material input cost		
Cost of coir pith for 850 kg @ Rs 100/t	=	Rs 85
Cost of cowdung for 150 kg @ Rs 200/t	=	Rs 30
Total cost for producing 1 t of hollow briquettes	=	Rs 180
Minimum selling price for 1 t of briquettes	=	Rs 250
Therefore, profit per tonne of briquette/day	=	Rs 70
Energy output input ratio for making 1000 kg of briquettes		
Electricity for running 5 hp motor for 8 hours duration	=	25000 kcal
Human labour (5 men for 8 hours)	=	2580 kcal
Calorific value of raw material, 1150 kg	=	3565000 kcal
Calorific value of briquetted mass, 1000 kg	=	3100000 kcal

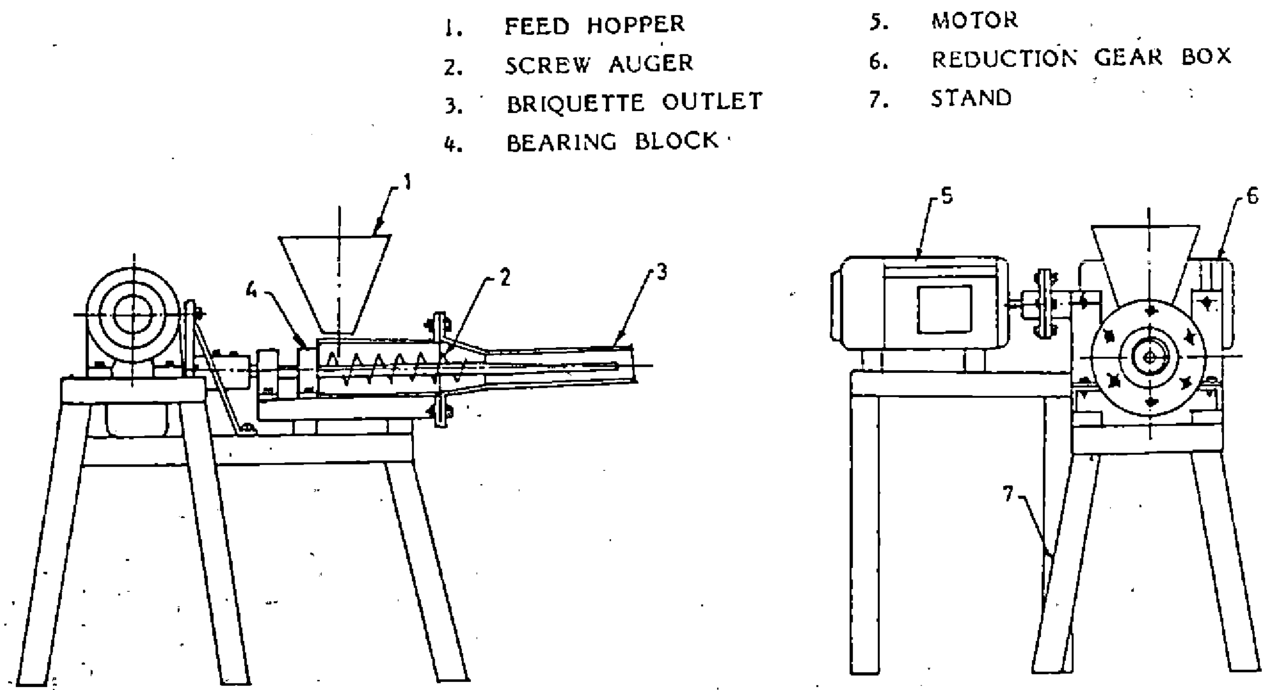

Fig 1. Briquetting machine (Tubular)

attempt was made to make hollow briquettes in order to minimise the smoke and to improve the burning characteristics. Accordingly, a new machine was developed and tested for producing briquettes. The briquettes made with this new machine were burnt in the meccan choola and their water evaporating capacity, calorific value and the thermal efficiencies are evaluated.

The briquettes need pre-heat arrangements for complete burning. Therefore, equal quantity of fire wood is used for burning these briquettes. These briquettes could be considered as supplement heat source and could not be used as a substitute for any solid fuel. The calorfic value and the water evaporation capacity of the briquette increased with increasing proportion of the cowdung mixed. In the case of clay mixed with coir pith, the calorific value and the water evaporation capacity decreased as the proportion of clay increased. Since the meccan choola is used for burning these briquettes, the complete heat energy evolved is used to the maximum possible extent by putting another vessel on the exhaust line. Therefore, the thermal efficiencies could be obtained in the range of 19.5 to 20.9 per cent in the case of coir pith + cowdung briquettes and 17.5 to 18.9 per cent in the case of coir pith + clay briquettes (Table 1).

Attempts were made to make stable briquettes by mixing the wood powder of different grades with the coir pith. These binding materials were consumed in the range of 15 to 20 per cent to form stable hollow briquettes. But this leads to a high cost input. Therefore the selection of binding material was restricted to cowdung or clay. To reduce the proportion of binding agent needed, higher horse power drive has to be given to this new machine. The cost economics of the machine is shown in Table 2. The cost of production of 1 t of briquettes by using cowdung as binding agent works out to Rs 180 including the cost of coir pith and cowdung and the briquettes can be sold at the rate of Rs 250/t. The cost of machine is approximately Rs 10000 and it has a capacity of producing 125 kg of briquettes in an hour. Therefore, a farmer can easily fetch a revenue of Rs 70 per day making use of the coir pith which is going otherwise as a waste.

CONCLUSION

For producing stable hollow briquettes out of coir pith, a continuous type briquetting machine has ben developed. The capacity of the machine is found to be 125 kg/hour and the approximate cost of the unit is Rs 10000. For making briquettes out of coir pith either cowdung or clay may be used as a binding agent. The burning performance revealed that a lower proportion of cowdung with the coir pith gave lesser heating effect than with a higher proportion of cowdung. Therefore, it is recommended that depending upon the availability of the cowdung the proportion may be increased so as to get a good burning effect. Meccan choola was found to be good in burning these types of poor calorific value solid fuels.

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MECHANICAL DRYING OF COPRA

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Abstract: Experiments were conducted in a laboratory model thin layer drying set-up for the determination of drying characteristics of copra at air flow rates of 19.57, 38.37 and 82.88 m^3/h and drying air temperature of 50, 65, 80 and 95°C. For reducing the moisture content of copra from 50% (w.b.) to 7% (w.b.) it took only 20 hours of drying in mechanical drying at an optium temperature of 65°C as compared to the duration of 7-10 days by sundrying.

A mechanical dryer with agricultural waste fuelled furnace has been developed for drying of copra. In this furnace hot air can be obtained by burning any agricultrual wastes like sugarcane baggase, stems, stalks, shells of crops etc. to any desired temperature up to 90°C at an air flow rate of 25 m^3/h.

Copra, the dried kernel of coconut is the richest source of vegetable oil, containing 65-70% oil. In India, the nuts produced are partly consumed as tender coconut, used as mature coconut in food preparations and converted into copra by drying from about 55% (w.b) moisture content to about 7% (w.b.) for oil extraction. This oil is used extensively for edible and industrial purposes and the cake is a valuable feed for cattle. Various drying methods, sundrying and primitive kiln methods to modern and sophisticated methods are available. However, traditional method of drying takes 7-9 days for complete drying which requires more space and labour, besides resulting in losses due to birds and rodents. Hence, this investigation was carried out to study the drying characteristics of copra by mechanical drying and to develop a suitable dryer with agricultural waste-fuelled furnace.

Mature coconuts of tall variety obtained from the Tamil Nadu Agricultural University Farm were used. To study the drying characteristics of copra, a laboratory model thin layer dryer was used. The laboratory model dryer (Fig 1) consists mainly of a centrifugal blower, powered by a 2 hp three phase electric motor rotating at 2880 rpm, electrical heaters and a metallic holding bin. The drying air temperature and flow rate were varied by using a thermostat and by varying the speed of the blower respectively. Three to five coconuts were split and dried during the experiments. The drying experiments were conducted at 19.57, 38.37 and 82.88 m^3 h air flow rates at 50, 65, 80 and 95°C hot air temperatures. After drying to about 35% (w.b) moisture content, scooping of kernel or meat from the shell was done. The drying continued at all air flow rates and temperatures to reach a final moisture content of 6-7% (w.b.). The weight lost during the experiment was recorded at three hour intervals. Moisture determination was done by drying 5 g of sample at 130 ± 1°C for 1 hour. Also, drying experiment was performed by sundrying as control.

Based on the drying studies conducted, a mechanical dryer with agricultrual waste-fuelled furnace was developed. The dryer consists mainly of a rectangular metal bin with perforated bottom connected to the furnace by a duct. The furnace is a fire tube indirect heating type, consisting of a burning chamber, flue gas chamber, chimney, casings and centrifugal blower as shown in Fig 2. By burning any agricultrual waste in the burning chamber, the burning chamber and flue cham-

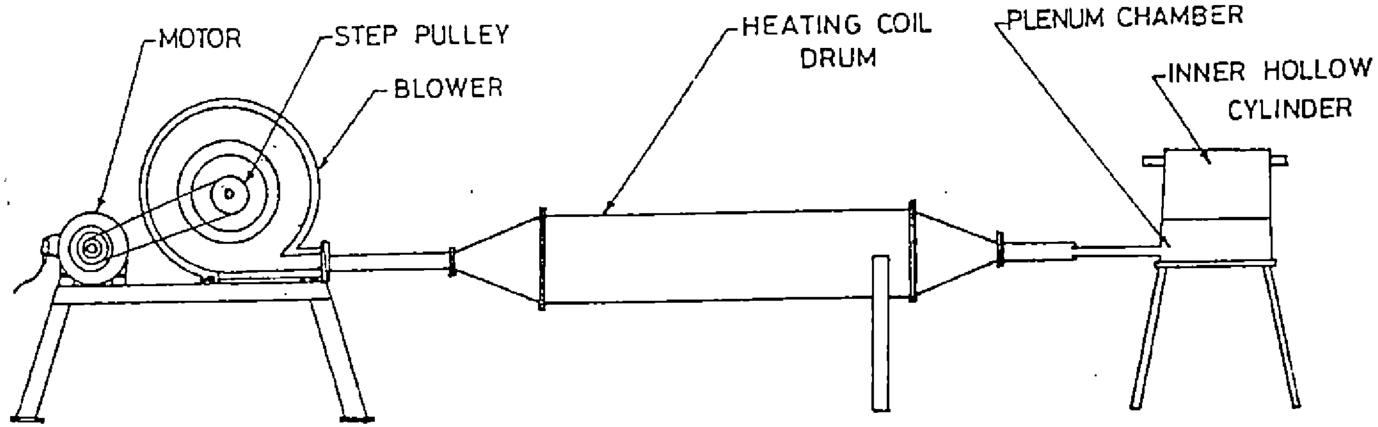

Fig I. Laboratory model thin layer dryer

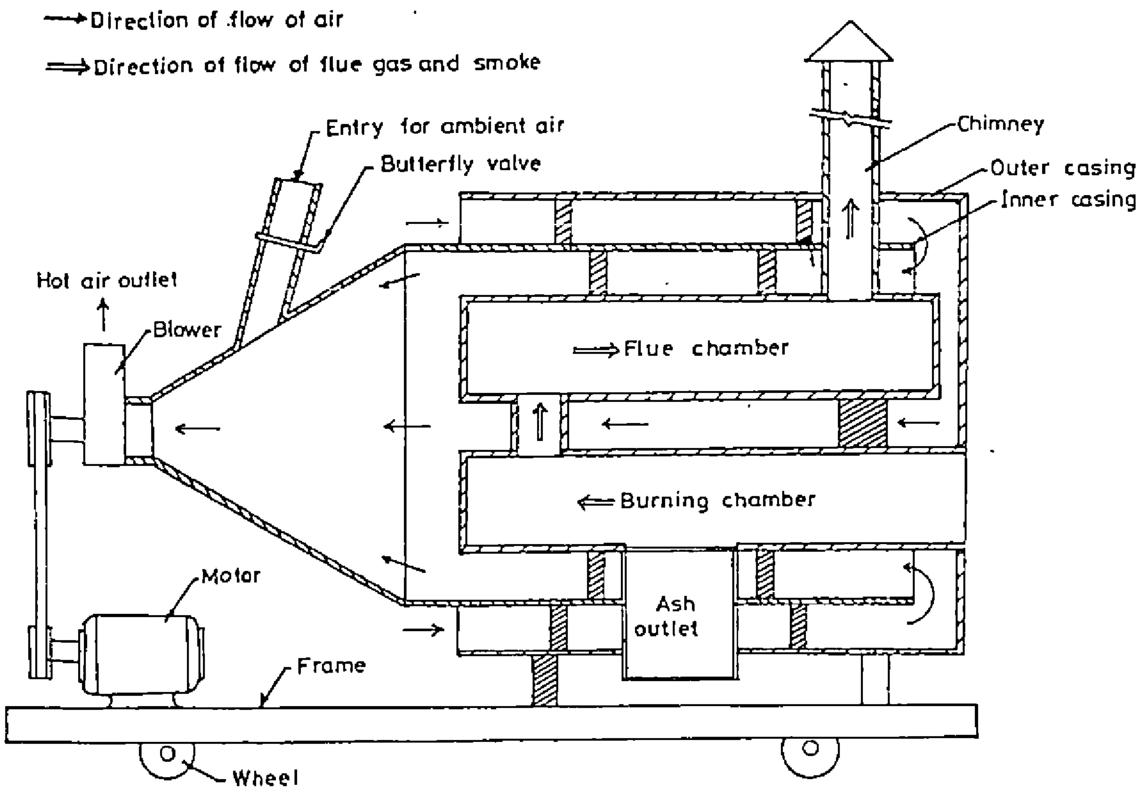

Fig 2. Schematic diagram of waste-fuelled furnace showing the principle of operation

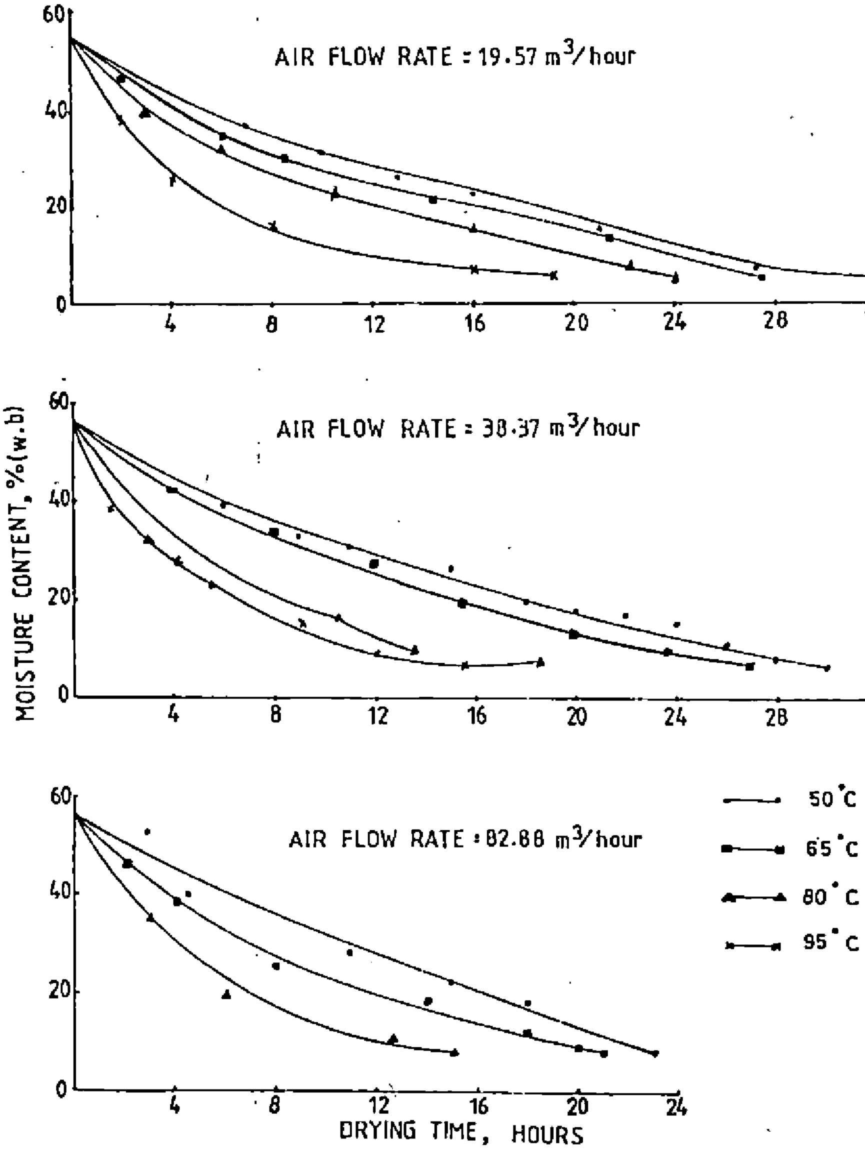

Fig 3. Effect of temperature and air flow rate on drying copra

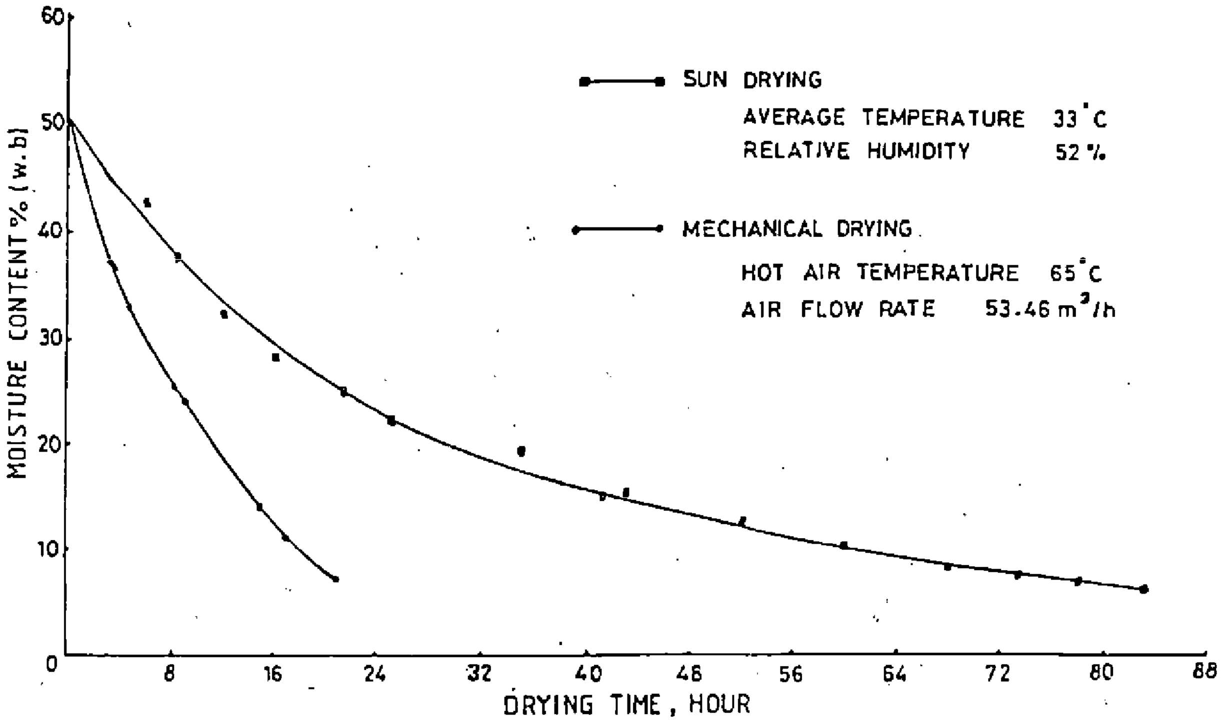

Fig 4. Drying characteristics of copra by mechanical and sun-drying methods

ber get heated. The atmospheric air sucked by the centrifugal blower passes and has contact with the surfaces of these chambers and get heated. This furnace produces hot air up to a temperature of 90°C at an air flow rate of 25 m^3/h by burning sugarcane baggase, stems, stalks of crops etc. at the feed rate of 15-20 kg/h. Provision is also available to control the temperature of hot air by mixing the atmospheric air by adjusting the butterfly valve. The holding bin of the dryer was filled with 2500 nuts and dried at 65°C hot air temperature and 53.46 m^3/h air flow rate. Samples were taken at one hour interval for the determination of moisture content.

The effects of hot air temperature and air flow rate on the drying time of copra in studies conducted with the laboratory model dryer are presented in Fig 3. It is seen that the drying time is reduced when the hot air temperature and air flow rate are increased. The time taken for drying coconut from 56% (w.b) to 6% (w.b) moisture content at 50°C and 19.5 m^3/h of air flow rate is 33 hours. For the same reduction of moisture content, the time taken for drying is 19 hours at 95°C at the same air flow rate. The times required for drying coconut (at 38.37 m^3/h air flow rate) at 50°C and 95°C are 30 and 15 hours respectively. Similarly, when the air flow rate is 82.88 m^3/h the drying times for the same moisture reduction are 23 and 15 hours for hot air temperatures of 50 and 80°C respectively. It was observed that the product dried at 80°C and 95°C hot air temperatures resulted in hardening and discolouration of the copra which are detrimental to the oil extraction. Hence, the drying air temperature of 65°C was found to be optimum in mechanical drying. This is in agreement with the observation of Palmer, (1968).

Under large scale trial, about 2500 nuts were dried in the mechanical drier with the agricultural waste-fuelled furnace. The average hot air temperature was adjusted to 65°C at 53.46 m^3/h air flow rate with coconut shell as fuel. It took 21 hours of drying to reduce the moisture content from 50% (w.b.) to 7% (w.b). The drying characteristic curve is shown in Fig 4. For the same reduction in moisture content by sundrying, the duration was 76 sunshine hours which could be obtained in about 8-10 days. The copra dried in the mechanical dryer will yield up to 65% good quality oil as the drying is under hygienic environment.

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COIR PITH PACKED *CHULHA* IN FUEL ENERGY CONSERVATION

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Abstract: Trials were conducted to use coir dust as a packing material in *chulha* (stove) made up of mild steel sheets having a top opening of 18.5 cm diameter for placement of cooking vessel and 6.5 cm diameter inlet opening at the front for inserting firewood and having central cylindrical welded mesh cage of 8 cm diameter. Results of the experiments on water heating and cooking rice by boiling method revealed that only one fourth of firewood is required as that of conventional single holed mud *chulha*. It is found that the coir pith packed chulha is possessing 47 per cent thermal efficiency and there is no appreciable time difference for boiling of water/cooking of rice compared to the conventional chulha. It is also estimated that there will be an energy saving of 1.35×10^{13} to 1.8×10^{13} kcal with a cost equivalent of Rs 3150 million per annum if all the coir dust available in India are effectively utilized.

Coir dust, an agricultural waste available in plenty in many parts of India, poses disposal problem. With a view to explore the possibility of using its ash as a component of a new cementing material with lime, its hidden characteristic of poor conduction of heat came to light. Hence, trials were conducted using coir dust as a packing material in hearths or *chulhas*. The *chulha* used had a top opening of 18.5 cm inner diameter for placement of cooking vessel and 6.5 cm diameter inlet opening at the front for inserting firewood.

The coir dust was mixed with a little quantity of water so as to have workability by hand. Then two iron pipes/wooden pieces of 6 cm diameter and 18 cm length were installed so that one was fixed in vertical position at the centre of the top opening and the other horizontally in the firewood opening. It was ensured that the two pieces were perpendicular to one another. The processed coir pith was well packed gradually in the remaining space of the *chulha* using a stick. Then two country firewood of suitable size which pass easily into the inlet opening were selected and the fire was lit and inserted into the opening. Repeated experiments showed that the flame is in vertical position and the packed coir pith serves as an absorbent of heat transferred from the central heat source. Further, the coir pith also started burning without any flame, producing heat due to its own calorific value. In this technique, heat transfer from the centre to walls of *chulha* and outside is mitigated to a larger extent due to the surrounding 6.25 cm thick poor conducting packed material. Based upon the same principle, a firewood stove with 16 and 12 gauge mild steel sheet for sides and bottom respectively was fabricated and trials were conducted. A cylindrical shape of 8.0 cm diameter was made with welded mesh (5 cm x 5 cm x 10 gauge x 10 gauge) opened both at the top and bottom and fixed at the centre of the stove to the height of the *chulha*. It has a top covering plate with staggered hole arrangement. The cost of a stove works out to Rs 30 and its estimated life span is 8 to 10 years.

Trials on the stove revealed that 4.5 l of water in an aluminium vessel for raising its temperature by 70°C requires only one fourth of the firewood required in the case of the conventional single

Table 1. Thermal efficiency of *chulhas*

Trial	Coir pith *chulha*			Single holed mud *chulha* (without coir pith)		
	Time, min	Fire wood, g	Thermal efficiency, %	Time, min	Fire, wood, g	Thermal efficiency, %
Heating 4.5 l water (from 28°-98°C)	38	170	47.2	35	720	10.9
Cooking 1/2 kg rice by boiling method	28	205	25	115		
Cooking 1 kg rice by boiling method	42	305	40	930		

Untensil used : Aluminium Fire wood used : Subabul sticks

holed mud *chulha*. Trials on cooking rice in the kitchen also showed a saving of 65-75 per cent of firewood (Table 1).

There is no appreciable time difference for boiling/cooking using coir packed *chulhas* and conventional *chulhas* and the coir pith packed *chulha* is thermally about 4 times more efficient than the conventional *chulha*. In India, the total production of coir pith dust is estimated to be 1.5 million tonnes and with the use of coir pith packed *chulhas* the projected saving of firewood will be 4.5 million tonnes equivalent to a total saving of Rs 315 crores per year.

From the experiments, it is clear that coir pith packed *chulhas* protect natural environment by preventing the cutting of trees for firewood purpose, in addition to helping the disposal of coir pith in the form of ash. The coir pith ash may further be used as a manure. Thus the use of coir pith in *chulhas* not only finds a prominent place in fuel energy conservation but also helps to save an enormous amount of money every year.

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ACTIVATED CARBON FROM AGRICULTURAL WASTES

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Abstract: A process has been developed at the Tamil Nadu Agricultural University to make activated carbon from coconut shell and coir pith. The process involves the pyrolysis of coconut shell/coir pith in a closed chamber at 750° C, done as a first step of carbonization. The recovery of carbonized coconut shell is 24%. After pulverising the carbonized material it is again heated up to 550-700°C with an activating agent ($ZnCl_2$) for activation. The decolourizing power of 75 mg/g has been obtained when zinc chloride is used as the activating agent to the extent of 75% of carbon content. The recovery of activated carbon has been found to be 25% from coir pith and 17% from coconut shell.

The agricultural wastes become an asset when proper utilization is achieved by developing a suitable technology. Efforts should be made to make use of every possible resources available to the mankind. In this line, a process has been developed to make activated carbon from coir pith and coconut shell. With the rapid development of sugar, oil and other chemical industries in India, the demand for activated carbon for decolourization and clarification purposes has largely increased. Activated carbon is a material with a porous structure and acts as a catalyst as well. Granular materials are used for gas absorption and powdered materials are employed for liquid clarification. Though most carbonaceous materials are potential sources of activated carbon, coconut shell and paddy husk are the prominent sources. The superiority of activated carbon obtained from coconut shell can be attributed to its high hardness, freedom from iron and sulphur and the pore size distribution.

The process involves two steps, namely, carbonization and activation. A cylindrical container made of MS sheet is housed in a furnace. This container consists of an inlet and outlet and it is kept at an inclination for easy removal of the carbonized material. The coconut shell is crushed into the container. By means of pyrolysis, the charge is converted into carbonized product by heating up to a temperature of 750°C externally using firewood or any agricultrual waste. After carbonization the charge is taken out, cooled in the atmosphere and washed in water to remove ash and other soluble materials, if any. The second step is activation process. The carbonized material is mixed with the activating agent, namely, zinc chloride at different proportions and again heated externally in the closed chamber at 550-700°C for activation.

The influence of the activating agent on decolourizing power of the activated carbon is depicted in Table 1

It is observed that at a concentration of 75% activating agent the decolourizing power of the activated carbon is found to be maximum. The test on decolourizing power was conducted with the activated carbon obtained from various sources and the results are shown in Table 2. The decolourizing power of the activated carbon prepared from coconut shell and coir pith can be very well compared with that of the commercially available activated carbon. The recovery of activated carbon computed for different sources is furnished in Table 3. It can be noticed that the recovery per cent of activated carbon obtained from the agricultural wastes taken for the study is slightly less than

Table 1. The decolourizing power as influenced by varying proportion of activating agent

Proportion of activating agent	Decolourizing power, mg/g
Carbon + 25% $ZnCl_2$	30
Carbon + 50% $ZnCl_2$	40
Carbon + 75% $ZnCl_2$	75
Carbon + 100% $ZnCl_2$	75
Carbon + 200% $ZnCl_2$	70

Table 2. Performance of activated carbon from different sources

Raw material	Decolourizing power, mg/g
Coconut shell	75
Coir pith	55
Paddy husk	45
Commercially available activated carbon	55-225

Table 3. Recovery of activated carbon from different sources

Raw material	Recovery, %
Coconut shell	17
Coir pith	25
Paddy husk	22
Wood	45

that from wood. However, since the availability of wood is restricted coconut shell and pith can serve as alternate raw materials for the manufacture of activated carbon. Moreover, there is ample scope to upgrade the quality of activated carbon prepared from agricultural waste materials.

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PRESERVATION OF COCONUT SAP (*NEERA*)

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Abstract: *Neera,* the sweet toddy collected by tapping the inflorescence of coconut palm is soon fermented to toddy by the action of micro-organisms like bacteria and yeast. If *neera,* as it is, could be preserved for longer periods it would be a much valued soft drink. The present method of adding slaked lime to *neera* is successful in preventing fermentation to a maximum of 24-48 hours only. Hence, different techniques were tried to preserve *neera* for longer periods without degradation of taste and flavour. It was observed that addition of preservatives like sodium metabisulphite was not effective in arresting fermentation. But fermentation was seen completely arrested in *neera* when concentrated to one-fourth of its volume and sterilized. Concentrated neera when reconstituted by adding water was though acceptable as a drink, there was precipitation in the stored liquid. In vacuum evaporated and steamed *neera* there was no precipitation or loss of taste but a colour change from white to yellowish orange was noted. When reconstituted there was no appreciable change in taste and flavour and the colour change was acceptable and hence is suggested to be the best method for preservation of *neera.*

Neera (sweet toddy) is the exudate (sap) obtained from the inflorescence of coconut palm when it is subjected to a process known as tapping. Tapping collectively denotes the various processes of stimulating the toddy yielding part to exude the juice. The fresh sap undergoes first alcoholic fermentation and later acetic fermentation. Alcoholic fermentation is initiated as the sap oozes out from the cut ends of inflorescence. This process is brought about by yeast. Multiplication of yeast can be checked by storing *neera* in refrigerated condition, but bacteria, especially *Staphylococcus* spp. multiply profusely under such conditions. Within a period of 24 hours, the alcoholic content increases by 7 per cent. This is the toddy of commerce. In Kerala, coconut trees are tapped mostly for the purpose of obtaining toddy, a popular intoxicant.

The unfermented sap, *neera,* as it is commonly referred to, is a delicious non-alcoholic nutritious soft drink. If it can be properly processed and as such it has scope for commercial utilization in India and abroad. Considering the potentialities of preserved *neera,* studies were undertaken at the Department of Plant Pathology, College of Agriculture, Vellayani, Trivandrum on the preservation of *neera*.

Addition of 2 per cent citric acid led to relatively sparse growth of microbes, but induced acetic acid fermentation on storage. Incorporation of CO_2 was found to be effective in controlling fermentation due to yeast but the bacillus type organisms multiplied and degraded the *neera* resulting in putrification. Storage of *neera* with excess glucose could prevent, to a great extent, the multiplication of bacteria but the yeast survived.

Five coconut palms of the Agricultural College Farm were tapped for the collection of *neera.* Care was taken to minimise contamination during the tapping process. The clay applied at the cut ends of the inflorescence was treated with Bordeaux paste to provide a concentration of 250 ppm copper. For collection of *neera* 200 gauge clean polythene bags were used instead of earthern pots. The sap thus collected was processed following the various methods discussed hereunder.

Neera collected at an interval of about 12 hours was used for observation. *Neera* collected in this manner is sweet to taste with a pH range of 4-5. Occasionally, *neera* which is acidic to taste and with a pH less than 4 is obtained due to damage of spathe as a result of improper tapping and such damaged spathes are promptly removed. The following methods of preservation were tried. (1) Sterilizing *neera* at 90°C and 100°C for 20 minutes; (2) Adding sodium metabisulphite (3) Concentrating *neera* and (4) Vacuum evaporation and sterilization of *neera*. For sterilizing *neera* at 90°C and 100°C for 20 minutes a thermostatically controlled water bath was used. *Neera* was concentrated at 100°C to one-fourth of its volume. The concentrated *neera* was sterilized again at 100°C for 20 minutes after pouring in 750 ml bottle which was plugged with cotton wool. Vacuum evaporation was carried out to one-fourth of its volume and it was then sterilized at 90°C for 20 minutes and bottled. Microbial count of *neera* was assessed periodically by dilution plate method on yeast extract, malt extract agar, beef extract agar, host extract agar and peptone dextrose agar media.

Microbial count of *neera* sterilized at 90°C and 100°C showed that most of the microbes are killed by sterilizing *neera* at 90°C and 100°C for 20 minutes. Since *neera* is a highly nutritive medium, it is likely that spores are not formed and that may be the reason why all the micro-organisms are inactivated by this type of sterilization. *Neera* sterilized in this manner when stored for a week becomes a clear liquid with precipitates settled at the bottom of the container. The taste of *neera* sterilized is not very much appreciated.

Addition of sodium metabisulphite @ 10, 25, 50, 75 and 100 ppm was not found to arrest fermentation. Fermentation was completely arrested in concentrated and sterilized *neera*. The colour of the concentrated *neera* is yellowish to brown. This may be due to caramelization of sugars when *neera* is concentrated at 100°C. Concentrated *neera* also when kept for more than a week separated into two layers. Concentrated *neera* can be reconstituted by adding water. The reconstituted *neera* had an acceptable taste and flavour.

In vacuum evaporated and steamed *neera* there were no micro-organisms for a period of 6 months. There was no precipitation or loss of taste in this technique but there was colour change from white to yellowish orange. This can be suggested as the best method for preservation of *neera*, the sweet exudate so that it will be acceptable as a soft drink.

It can be seen that the minimum pH of 3.7 was observed for *neera* collected by the traditional or usual method. The pH was seen increased in the processed *neera*. Maximum protein was observed in *neera* collected by the usual method and minimum in *neera* steamed and autoclaved at 90 and 100°C.

Neera which is vacuum concentrated and steamed contains the maximum amount of total sugars and minimum amount of reducing sugars. It recorded the highest pH of 4.7. Hence, vacuum evaporation and then steaming is observed to be the best method of preserving *neera* among the methods of preservation tried in the study.

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Plenary Session

RECOMMENDATIONS

In commemoration of the Golden Jubilee of the establishment of the first ever coconut hybrid plantation in the world at Nileswar in Kerala, a National Symposium on Coconut Breeding and Management was held at the Kerala Agricultural University Campus, Vellanikkara, Trichur, India from November 23 to 26, 1988. The current status of breeding coconut for improvement of yield, quality attributes and resistance against pests, diseases and stress conditions and the progress achieved in the field of biotechnology were reviewed. Formulation of appropriate management strategies for economic yields and efficient methods for processing and utilization of products and byproducts was also given serious thought in the scientific sessions.

GERMPLASM COLLECTION, CONSERVATION AND EVALUATION

There is great need for extensive survey of the coconut germplasm available in the various coconut growing countries of the world and germplasm repositories will have to be developed at international and national levels. It is necessary that the germplasm materials are characterized thoroughly so that the accessions could be effectively utilized in breeding programmes. *In vitro* techniques using embryos and solid endosperm cylinders should be used in the collection and exchange of germplasm materials. Techniques such as cryopreservation should also be adopted in the conservation of coconut germplasm reserves. Maintenance of the germplasm in more than one location should be preferred to on account of safety reasons. In the above context it was recommended that:

Conservation of endangered germplasm material

1. Specific emphasis may be given for collecting endangered germplasm material as in the case of local cultivars in Indonesia which are fast disappearing due to large scale planting of coconut hybrids.

Exchange of materials

2. There should be exchange of genetic materials available in various coconut research centres. Since this involves intergovernmental collaboration, steps are to be initiated at the international level.

Conservation of coconut genetic materials

3. Due care should be taken to conserve the available materials in sizable numbers preferably in more than one location.

Germplasm utilization - identification of prepotent palms

4. It would be possible to identify prepotent palms on the basis of the performance of their progenies. Correlations between adult palm characters and seedling traits have also been established. The number of prepotent palms on record is very scanty at present. It is therefore, necessary to identify additional prepotent palms so that the varietal improvement programme involving prepotent palms could make a significant impact on coconut improvement.

International collaboration for germplasm collection and utilization

During the first technical session on "Breeding for Higher Nut and Copra Production and Better Quality Attributes" the need for international co-operation in collection and utilization of coconut germplasm was stressed. In pursuance of the deliberations, informal exploratory discussions were held by a Working Group of delegates which identified gaps on which the symposium recommended the following:

5. For collection and conservation of coconut germplasm, embryo transfer technology developed may be made available to all the countries.

6. Most of the coconut group countries need trained and technically competent people to handle collection, conservation and utilization of coconut germplasm. This calls for organising training programmes on regional basis. These training programmes should be oriented towards standardizing collection, characterization and preliminary evaluation procedures and should also include zygotic embryo culture technique.

7. The efforts for characterizing and cataloguing the germplasm are very meagre. There is need to update the descriptor list prepared by the IBPGR in 1978 and also standardizing procedures for collection of data.

8. In order to conserve the coconut genetic resources on long term basis there is need for establishing a regional genebank in the Indian Ocean region. India has started a World Germplasm Centre in the Andaman Islands managed by the ICAR. Similar regional banks in the Pacific and the Atlantic may also be thought of as a global strategy for conservation.

9. For effective use of the collected material, a global data base needs to be established for coconut germplasm.

10. For pursuing the above suggestions and for drawing up an effective programme, the symposium recommended that a Steering Committee may be constituted by the IBPGR for coconut genetic resources. This committee should act as an advisory body for national genebanks, an advisory body on quarantine aspects, and for preparing an inventory of available germplasm in different countries.

11. The symposium endorsed the Work Group's recommendation on the organization of an International Congress on Coconut within the next 2 to 3 years on the theme "Conservation and Utilization of Coconut Germplasm".

HETEROSIS BREEDING AND HYBRID SEED PRODUCTION

Exploitation of hybrid vigour

12. Inbreeding depression in coconut has been reported from the Pilicode Centre of the Kerala Agricultural University, India. It is necessary to intensify studies on the exploitation of selected inbred lines of promise.

Studies on 'Komadan' variety of coconut

There are conflicting reports on the status of 'Komadan' of Kerala as to whether it is a stabilized cultivar or a natural cross hybrid. Superior nut yield of this variety has already been established. It is necessary that:

13. Intensive studies on the genetic make up of this variety are initiated to determine the genetic status of the 'Komadan' type.

Hybrid seed production programme

At present there is lack of a national level policy on hybrid seed production. A large number of exotic cultivars and selected indigenous types have been under trial since the fifties at the Nileswar and Pilicode stations of the Kerala Agricultural University and Kasaragod station of the CPCRI. Among the several coconut cultivars, a few have proved to be consistently superior to the popular West Coast Tall variety. Widespread cultivation of the promising cultivars will help to augment the productivity of new plantings and will also improve the out-turn of copra from the existing holdings through underplanting by the exploitation of xenia effect. It was therefore, recommended that:

14. The Coconut Development Board may take steps to establish initially at least one seed production farm in Kerala. In this, separate blocks of promising cultivars such as Cochin China, New Guinea, Laccadive Ordinary, Kappadam etc. could be planted in blocks along with a few selected dwarf cultivars. Such farms can serve as a reliable source for seed material of superior cultivars and of hybrids identified suitable for the country.

BREEDING FOR PEST, DISEASE AND ENVIRONMENTAL STRESS RESISTANCE

Breeding for disease and pest resistance

15. There is a need to establish correlation between meteorological factors and the pattern of incidence of the fungal diseases on the basis of epidemiological factors so that the variation in the resistance spectrum of the varieties as influenced by the environmental parameters could be forecast.

16. There is great need for intensifying work on breeding superior varieties possessing resistance to major diseases and pests which occur in different countries. The existing germplasm materials will have to be carefully screened with reference to their innate susceptibility to the major diseases and pests. In such studies the identity of the varieties should be very carefully determined and documented.

17. While breeding varieties for resistance to diseases, the pathogen involved in the malady should be identified correctly.

18. The bud rot caused by *Phytophthora* spp. is a very serious problem in all the coconut growing areas of the world. It is therefore, necessary that emphasis be given on breeding for resistance to *Phytophthora* spp.

19. In the screening trials against *Phytophthora heveae,* the Rennell Tall and Polynesian Tall are reported to possess relative tolerance. These talls should be included in the breeding programmes to develop lines resistant to *Phytophthora.*

20. Hybrids with Malaysian Tall and Polynesian Tall as parents are found to be resistant to *Phytophthora heveae.* These hybrids may also be screened for their reaction to *P. palmivora.*

Breeding for drought resistance

It is of great importance to

develop/identify varieties of coconut possessing remarkable resistance to drought conditions in most of the coconut growing countries. Considering the need for the work on these lines to be intensified on a priority basis, the symposium recommended:

21. While characterizing the cultivars for drought resistance, it is necessary that the varieties are catalogued on the basis of biochemical and physiological parameters as well as on the basis of the rooting pattern. Further, in such studies on drought tolerance, the rate of transpiration in relation to photosynthetic efficiency be studied in the background of the variation in leaf nutrient levels and nut production and develop criteria for defining drought tolerance on the basis of the critical levels of the biochemical and physiological parameters.

22. Most of the hybrid varieties so far developed do not possess tolerance to drought conditions. It is necessary that the hybrid derivatives of coconut palms are thoroughly screened for their resistance/tolerance to drought conditions. In the hybrid COD X WCT it has been observed that the precocity of bearing is due to the female parent. Therefore, to develop hybrids possessing precocity of bearing and drought tolerance the combination involving COD and LO appears to be more promising. Studies on this line need to be intensified further.

BIOTECHNOLOGY IN COCONUT DEVELOPMENT

Tissue culture technology is used as a tool for commercial propagation of many plant species including oil palm. However, propagation of coconut palms by *in vitro* methods remains still as a challenge. There is an urgent need to standardize a protocol for micropropagation of coconuts. Some of the progress made so far was presented and discussed.

Regeneration of plantlets by culturing coconut inflorescence through calloid embryoids is encouraging. The technique appears promising. However, commercial utilization of this technique may take considerable time. The zygotic embryo culture techniques have been standardized and embryo culture techniques will be useful for germplasm exchange and conservation by cryopreservation.

Regeneration of plantlets through embryo callus using IAA conjugates is very promising. There is hope of getting somaclones and variants. Development of haploid embryo-like structures from microspores has been reported. It may be possible to obtain homozygous lines by anther culture techniques. In the light of these, the symposium recommended:

23. The techniques for clonal propagation of coconut by somatic embryogenesis by leaf tissue culture should be perfected for propagating elite palms.

24. Since *in vitro* culture of coconut tissue appears extremely difficult unlike other plant systems, a close collaboration between plant-tissue culturists, plant physiologists and biochemists is needed to solve the problem since the physiology of the donor palms and the biochemical status of ex-plant tissues play an important role in regeneration.

25. Embryo culture techniques can be exploited for germplasm exchange and cryopreservation of germplasm material.

WATER MANAGEMENT

One of the basic reasons for the low productivity of palms in Kerala is that the crop is grown under rainfed conditions. The crop is prone to moisture stress for periods ranging from four to six months every year. The symposium recommended that:

26. Water management studies should be taken up in all the major agro-ecological situations so as to find out optimum irrigation schedules and economic irrigation methods. Studies should also be taken up on fertilizer-irrigation interactions.

NUTRITION

27. There is a dire need for conducting long term fertilizer experiments with new hybrids since studies on their fertilizer requirement are only a few in the country.

28. In addition to major nutrients, the response of the hybrids and important cultivars to Ca, Mg, S, Na, Cl and Zn should also be studied. Attempts should be made to group the hybrids according to their fertilizer response and recommendations formulated for different agro-ecological situations.

29. The copra and oil content of coconut show considerable variations in different parts of the country. Studies on the pattern of variations in the output of copra and recovery of oil as well as the variations in the qualitative attributes of oil are necessary to understand the pattern of such variations in relation to agronomic and meteorological parameters.

ROOT (WILT) MANAGEMENT AND REHABILITATION

30. The need for integrated management methods to sustain the level of productivity of root (wilt) affected coconut palms has become fully established. The components of this integrated programme consist of appropriate balanced NPK fertilization, growing *in situ* of suitable green manure crops and their incorporation and conducting prophylactic sprayings to prevent the incidence of the leaf rot and other fungal diseases. At present in most of the holdings in the root (wilt) affected areas, a very large number of palms are in the advanced stage of infection and those affected before flowering need to be removed on a priority basis. Regarding the adoption of the integrated management methods, there is an imperative need for large scale adoption of the technology by following a crash programme.

31. The ecological environment in the homesteads differs from that in the research stations. Hence the farming systems and crop models developed in the stations should be tested under farmers' field conditions and suitable modifications made.

32. The economics of different farming systems should be worked out based on the results gathered from these adaptive trials conducted in farmers' fields. The yield prediction models developed in the research stations should also be tested under actual farming situations

PRODUCTION STATISTICS

The statistical procedures that are adopted for analysis and interpretation of data generated from long and short term experiments are at considerable variance at present. The need for a modern approach in statistical analysis of data has been felt quite often. In order to draw valid and meaningful conclusions of adaptive value it is necessary that there is uniformity of procedures adopted in the statistical analysis of the data. It was therefore, recommended:

33. The existing designs for statistical analysis may be reviewed to formulate more appropriate methodologies suitable for the coconut palm. For this an inter-institutional meeting involving the statisticians/agronomists/plant breeders might be convened.

PROCESSING TECHNOLOGY, PRODUCT DEVELOPMENT AND MARKETING

The importance of the end-products in terms of better material, thermal energy conversion and mechanical energy conversion was highlighted. The nutrients and food aspects were discussed and the recovery of fat, protein etc. in a more efficient and effective way was analysed. Under management, the unit operations involved in coconut harvesting, dehusking, drying, shelf life etc. were discussed.

The following recommendations emerged:

34. In coconut cream preparation stabilization of emulsion homogenisation technology, pasteurisation and packing aspects play a vital role in the value and quality of the product namely, coconut cream. The gaps identified are the technology upgradation of production of coconut cream powder and preservation of taste of coconut water besides quality for social acceptance and a common machinery system for the preparation of value-added items such as beverages, coconut water and coconut cream.

35. The possibility of developing cold process for coconut oil as against wet process needs examination. In Sri Lanka coconut water is blended with toddy at 25 per cent in the preparation of vinegar. This technique appears to be promising for adoption in India.

36. The tree climbing unit, the dehusking equipment and drying unit involve more of human energy which has to be tackled with the help of suitable guidance including optimum management technique. Mechanised dehusking and improved drying technology involving solar energy and farm waste will be more useful in future.

37. Research is to be strengthened on shelf-life of wet kernels by appropriate chemical treatment.

38. Construction of water tank through ferrocement models and development of flooring tiles besides roofing materials using coir fibre will play an important role in rural development particularly in the construction of low-cost houses. Efforts should be taken to promote this technology and its popularisation.

39. Product diversification should receive major attention in terms of coconut product and byproduct processing and development for stabilized economy of the state in particular and the country in general.

40. Development of simple kits for moisture determination of copra and curing of coconut leaves for securing long life need to be popularised in the rural areas through commercial channels.

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Appendices

APPENDIX 1

National Symposium on Coconut Breeding and Management

DETAILS OF TECHNICAL SESSIONS

Sl. No.	*Technical session*	*Date & time*	*Chairman*	*Rapporteurs*
1	2	3	4	5
1	Breeding for higher nut, copra production and better quality attributes	23 Nov. 1988 11.30 - 18.00	Dr.M.V. Rao Special Director General ICAR New Delhi Co-Chairman: Sri.K. Satyabalan Scientist (Retd.) Sudhalayam Ernakulam	Dr.K.U.K. Nampoothiri Scientist & Head CPCRI Research Centre, Palode Trivandrum Dr.R. Gopimony Professor, College of Agriculture, KAU Vellayani, Trivandrum
2	Breeding for pest, disease and environmental stress resistance	24 Nov. 1988 9.00 - 12.00	Dr.M.K. Nair Director CPCRI Kasaragod	Dr.K.M.N. Namboodiri Professor, College of Horticulture, KAU, Vellanikkara Dr.E.V.V.B. Rao Project Co-ordinator (Cashew) NRCC Puttur, Karnataka

1	2	3	4	5
3	Biotechnology	24 Nov. 1988 12.00 - 13.00	Dr.C.A. Ninan Professor & Head Dept. of Botany Kerala University Trivandrum	Dr.C. Padmanabhan TNAU, Coimbatore Dr.N.K. Vijayakumar Associate Professor College of Forestry KAU, Vellanikkara
4.	Crop management	24 Nov. 1988 14.00 - 17.00 & 25 Nov. 1988 10.30 - 13.00	Sri.P.K. Thampan Chief Coconut Development Officer, Coconut Development Board, Cochin	Dr.K.M. Varadan Scientist, CWRDM Calicut Dr.R.R. Nair Associate Director RARS, KAU, Kumarakom
5	Processing technology, product development and marketing	25 Nov. 1988 14.00 - 17.00	Prof.K.R. Swaminathan Dean, Faculty of Agrl. Engineering TNAU, Coimbatore	Dr.V.Radhakrishnan Professor College of Horticulture KAU, Vellanikkara Dr.C. Arumughan RRL, Trivandrum
6	Plenary Session	26 Nov. 1988 9.00 - 13.00	Dr.E.G. Silas Vice-Chancellor KAU Vellanikkara	Dr.M. Aravindakshan Director of Research KAU, Vellanikkara Dr.C.C. Abraham Associate Director KAU, Vellanikkara

APPENDIX 2

National Symposium on Coconut Breeding and Management

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