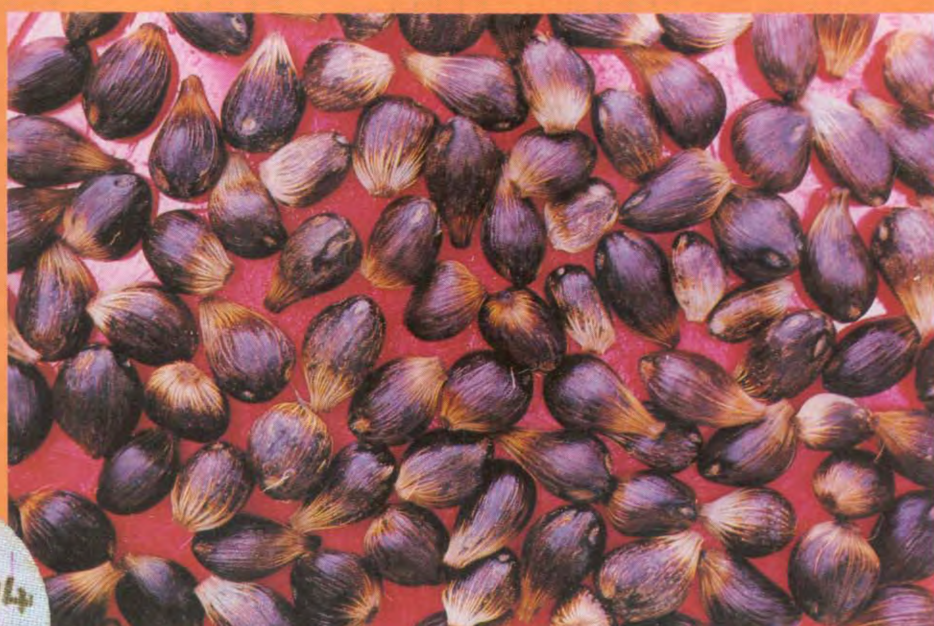
OIL PALM
PRODUCTION TECHNOLOGY



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PREFACE

The demand for vegetable oil during the past two decades has increased at the rate of 5 per cent per annum, while the supply has increased only at the rate of 2 per cent. Production of oilseeds in the country has not been able to keep pace with the increasing demand, necessitating import of vegetable oils. In recent years India has been exploring the possibility of cultivating oil palm, the richest source of vegetable oil crop.

A Central Working Group on oil palm constituted by Government of India in 1986 under the Chairmanship of Dr. K.L. Chadha Commissioner, Horticulture (Currently Deputy Director General (Hort), ICAR) has identified 0.575 million ha of land suitable for oil palm cultivation in the country mainly in Karnataka and Andhra Pradesh and seven other states.

Though the first oil palm plantation in a systematic manner was raised by the State Department of Agriculture, Kerala in a 40 ha area in Thodupuzha in 1960 oil palm was introduced for commercial cultivation in Kerala and Andaman and Nicobar Islands during 1971 and 1975, respectively.

Research on oil palm was a started at Oil palm Research Station, Thodupuzha, under the Department of Agriculture during 1960. The Central Plantation Corps Research Institute (ICAR) started systematic research programme on oil palm during 1975 at its Research Centre, Palode, Kerala.

Establishing a modest gene bank, identifying dura and pisifera parents and producing about 0.4 million tenera hybrids indigenously per annum, standardising seed germination technique and nursery practices, developing suitable agrotechniques including a fertilizer schedule, identifying pests and diseases of oil palm in the country and developing suitable plant protection measure except for spear rot disease, and establishing a commercially viable small-scale extraction mill designed by the Regional Research Laboratory (CSIR) have been some of the major achievements of the Centre.

This technical bulletin records in detail the major achievements of CPCRI in oil palm research and management, entirely achieved indigenously. The Research Centre, Palode has been imparting training in oil palm production technology to scientists, extension officials and farmers and materials contained in the bulletin used to be supplied to the trainees as lecture notes in recent years.

We express our gratitude to Mr. A. Mohandas Moses, IAS, Special Secretary, Ministry of Agriculture, Govt. of India for sanctioning Rs. 97 lakhs as grant for the Oil Palm Training Programme at CPCRI Research Centre, Palode.

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(M. K. NAIR)
Director

HISTORY OF OILPALM CULTIVATION AND POTENTIAL IN INDIA

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Introduction

Nine cultivated annual oilseed crops viz., groundnut, rapeseed, mustard, soyabean, linseed, sesamum, safflower, sunflower, niger and castor contribute to 80 per cent of India's vegatable oil production. Although there has been a continuous increase in the production of edible and non-edible oil, the country has been facing deficit in edible oil requirement. The low productivity of oilseed crops has been attributed to the vagaries of monsoon since nearly 83 percent of the oilseed crops are under rainfed condition. Our per capita annual consumption of edible oil is only 5 kg as against 20 kg or more in the developed countries. Hence in recent years India has been exploring the possibility of cultivating oil palm, the highest vegetable oil yielding crop, as an alternate source.

The supply of vegetable oil during the past 25 years has increased at the rate of 2 percent while demand has grown at the rate of 5 per cent per annum. Palm oil or palmolein contribute to bulk of the vegetable oil import (Table 1).

The Technology Mission on Oilseeds has targetted a production of 26 million tonnes of oil seeds by the end of the century. The area under cultivation of the major oil seeds will be restricted to 25 million hectares which records only a marginal increase over the existing area of 23 million hectares. Thus accent will be to increase production per unit area.

Present status of oil palm in India

Oil palm was introduced to India towards the end of the 19th century as a botanical collection at National Botanic Gardens, Calcutta. Maharashtra Association for Cultivation of Science (MACS) introduced African oil palm (dura) in Pune during 1947-'59. The Association also used to supply seeds of these

Table 1 : Demand and supply of vegetable oils in India (million tonnes)

Year	Demand	Supply	Gap	Imports
1983-84	5.62	4.41	1.21	1.37
1984-85	5.87	4.62	1.25	1.14
1985-86	6.12	4.83	1.29	1.06
1986-87	6.40	5.05	1.35	1.47
1987-88	6.67	5.27	1.40	1.80
1988-89	6.95	5.49	1.47	1.99

(Indian Oil Palm Journal, 1991)

palms to various developmental departments in the state of Maharashtra. Irrigation Department of Maharashtra planted oil palm along the Neeral irrigation canal. Isolated oil palm trees are found in various states of the country probably planted as botanical curiosity. But these are mainly grown under neglected or unsatisfactory management conditions (Chadha and Rethinam, 1991). The first oil palm plantation was raised in a systematic manner in a 40 ha area by the State Department of Agriculture, Kerala at Thodupuzha in 1960. A brief description of subsequent oilpalm plantations established in the country is furnished below:

Andaman and Nicobar Islands

The Andaman Forest Development Corporation raised about 1600 hectares of plantation from the seeds imported from Nigeria, Malaysia, Cote d' Ivoire, Papua New Guinea and Zaire. The problem of low yield obtained in the initial years was overcome by the introduction of pollinating weevil combined with management practices and an yield of about three tonnes/oil/ha/year could be realised. The climatic conditions are ideally suited for obtaining much higher yield through better management.

Oil Palm India Ltd., Kerala

Planting of oil palm was taken up from 1971 to 1982 and an area of 3705 ha was covered with the imported seeds from Malaysia, Nigeria, Papua New Guinea and Cote d' Ivoire. Though the performance was not encouraging in earlier years, management practices including soil and moisture conservation as well as the introduction of pollinating weevil increased the yield of fresh fruit bunches (FFB). Yield level upto 2.7 tonnes of oil/ha/year has been obtained from 1971 plantations. Some of the experimental *tenera* palms have given estimated yield of 4.6 tonnes of oil/ha/year indicating clearly the potential for oil palm cultivation in this area.

Plantations under Department of Biotechnology

The Department of Biotechnology in collaboration with Governments in Andhra Pradesh, Karnataka and Maharashtra has taken up planting of 1000 ha each of oil palm during 1990-91. These plots in Krishna, East Godavari and West Godavari districts of Andhra Pradesh, Shimoga district of Karnataka and Sindhudurg district of Maharashtra are indented to demonstrate the feasibility of growing oil palm under irrigated conditions. The initial performance is very encouraging.

Other plantations

The first small holder planting in Andhra Pradesh was taken up under DRBA by 86 farmers of *Padavegi* and *Lingapalam mandals* of East Godavari district in Andhra Pradesh. Over 160 hectares were planted during 1987-1988 using indigenous seeds from CPCRI, Palode. An oil palm mill with a capacity to process one tonne FFB/hour is being set up at Padavegi using the technical know how from Regional Research Laboratory (CSIR), Trivandrum.

M/S. Navabharat Enterprises has planted over 200 hectares from 1988 onwards in Lakshmipuram (West Godavari) using indigenous seeds. The palm are being maintained under good management and the growth, flowering and early yields are very good. The firm has plan to expand the area up to 3000 ha by involving interested farmers in the locality.

Mr. M.D. Joseph is the first farmer to plant oil palm in a comparatively larger area. He planted 81 ha of oil palm in his tea estate in Quilon district, Kerala State. FFB from this plantation is processed at the Oil Palm India's factory. The Government of Kerala has sanctioned a scheme for establishing a 200 ha pilot project in *Kari* lands of Kottayam district in Kerala. *Kari* lands soils are highly acidic (pH 3.0-4.5) black coloured soils rent rich in organic matter occuring in large isolated patches. Since rice cultivation is not profitable in the area, farmers have volunteered to cultivate oil palm. The performance of a five hectare plantation raised in 1989 is quite satisfactory (Mathai, 1991). One noticeable observation is that there was no ill effects on the palms even under submerged condition for three months.

Oil palm development

Earlier strategy - The possibilities of growing oil palm in India was investigated by Mr. D.H. Uraquhart, former Director of Agriculture, Gold Coast in 1950, Mr. L. Davidson in 1965, Coconut Development Directorate, Cochin in 1976 and Mr. H.Q.R. Reddy and his team in 1972. All these earlier missions were looking for forest land for oil palm development and suggested clearing reserve forests for the purpose.

Future strategy - A team comprising of the author and Dr. KUK Nampoothiri, Scientist-in-Charge, CPCRI Research Centre, Palode, Kerala visited four southern states viz., Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu in 1985 and identified about 2.4 lakh ha under different irrigation project areas. Subsequently another team constituted by Govt. of Karnataka identified 3 lakh ha in Karnataka in 1986 in the five major irrigation project areas viz. Thungabhadra, Upper Krishna, Bhadra, Cauvery, Malaprabha and Ghataprabha.

Bhadra project area in Shimoga district was identified as ideal for oil palm cultivation and the team suggested to take up planting in the first phase since the Bhadra dam supplies water all through the year except in June and December. In this project area now there is a change over in cropping system from paddy to arecanut. The Vijayanagaram canal area of Thungabhadra Irrigation Project and Cauvery Project area were also identified as suitable areas for taking up oil palm in the first phase. The team has suggested that oil palm in the project area of Malaprabha and Ghatprabha has to be taken up with caution since soil is heavy black clay and water in the dam is available only for six months. The team also recommended that in the Upper Krishna Project area, there is need for change in the cropping system from dry land crops to irrgated garden land crops as water is now available after the completion of the project. In the remaining areas, the existing crops have to be replaced in a phased manner. The team also recommended that planting should be taken up from 1987 so as to produce about 1.276 million tonnes of palm oil and 0.127 million tonnes of kernel oil by 2010 AD in Karnataka.

The team headed by Mr. K.M. Tiwari, Ex-President, Forest Research Institute, Dehradun identified 60,000 ha in various Islands of A&N for oil palm cultivation.

Government of India constituted a Central Working Group on Oil Palm under the chairmanship of Dr. K.L. Chadha, Dy. Director General (Hort.), ICAR, New Delhi to examine the question of oil palm cultivation in its entirety. The Working Group constituted a subgroup to visit the various states and study the feasibility of growing oil palm. The central team after visiting several states and discussions with officials of development departments and farmers identified 5.75 lakh ha in nine states as detailed Table 2 (Anonymous, 1988).

In 1987, Dr. D.L. Richardson from Costa Rica visited Andhra Pradesh, Karnataka, Kerala and Maharashtra and opined that modest extent of area should be planted now since none of the areas suggested can be considered as ideal for this crop. He also recommeded location specific research. Subsequently, additional areas to the extent of 10,000 ha in Goa, 61,200 ha in Surat, Valsad, Vadodra, Barouch and Panchmal districts of Gujarat and 0.15 million hectares in Nellore, Guntur, Sreekakulam, Vijayanagaram, Visakhapatanam, Khammam and Prakasam districts of Andhra Pradesh were identified by various teams constituted by state governments.

Table 2 : Areas identified for oil palm cultivation.

State	Area (lakh ha.)
Andhra Pradesh	2.50
Assam	0.10
Karnataka	2.50
Kerala	0.05
Maharashtra	0.10
Orissa	0.10
Tamil Nadu	0.25
Tripura	0.05
West Bengal	0.10
Total	5.75

Problems of oil palm development

i) Oil palm is a new crop to the irrigation project areas and hence there is need for replacing the existing crops in some areas. This requires extension efforts to convince the farmers.
ii) As there is a juvenile period of $3^1/_2$ years to realise the initial yield, support through institutional finances and incentives to the farmers to take up oil palm cultivation are necessary.
iii) The availability of indigenous planting material is limited. At present CPCRI Research Centre, Palode is in a position to produce about 0.4 million *tenera* seeds sufficient to cover only 2000 ha annually. This necessitates import of planting materials from other countries.
iv) There should be processing facilities available at reasonable distances from the plantations since the fruit bunches have to be crushed at least within 24 hours of harvest.

Prospects

i) Institutional finances have to be made available easily through lead banks, NABARD and other financial agencies.
ii) Incentives to the farmers have to be given by way of subsidy to purchase planting materials and improve irrigation facilities.
iii) A separate agency such as Board, Corporation or Federation has to be entrusted with the development of oil palm including processing and mar-

keting.

iv) Assured and timely procurement of FFB from the farmers and prompt payment should be ensured.

v) Production technologies and input requirements should be made available to the farmers at the appropriate time.

vi) Adequate training to the development officers and the farmers is to be given in the production technologies.

vii) Though import of seeds may be necessary at the initial stages, establishment of seed gardens in 3 or 4 states is essential so that the country can be self reliant in the production of quality materials over a period of time.

viii) In the first phase, planting should be taken up in areas ideally suited and further area expansion has to be taken up in a phased manner.

ix) Oil palm cultivation should be taken up in compact blocks of 100-200 ha so that the extraction of oil could be done in a small mill.

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BOTANY

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The oil palm (*Elaeis guineensis* Jacq.) originated in the Guinea Coast of West Africa. Semi-wild and wild palm groves are still existing in the tropical West African countries. In the 15th century, oil palms were introduced to Brazil and other tropical countries by the Portugeese. But it did not flourish in these countries till 19th century. During 1848 the Dutch people imported oil palm seeds from West Africa via Amsterdam and four seedlings were planted in Bogor, Indonesia. The progenies of these palms were planted as ornamental palms in Deli and are later known as *Deli dura*. Commercial planting of oil palm started in Malaysia during 1917.

The Seed

Oil palm seed is a nut consisting of the shell and one, two or three kernels. In most of the cases the seed may have only one kernel as a result of the abortion of the other two ovules in the tri-carpellary ovary. Abnormal seeds may rarely occur giving rise to even five kernels. The size of the seed varies according to the thickness of shell and size of kernel. The seed may weigh from 1 g to 13 g. The shell has long fibres adhering to the seed and short fibres in the form of a tuft at the base. Each seed has three germ-pores corresponding to the three carpels of the ovary. A plug of fibres is formed in each of the germpore. These fibres join at the base to form a plate-like-structure. The kernel is seen inside the shell containing oily endosperm cells which is gray white in colour. The kernel is surrounded by a dark brown testa covered with a net-work of fibres. Embryo is embedded in the endosperm facing one of the germpores. The embryo is straight and about 3 mm long. Its distal end lies opposite to the germpore which is separated by a thin layer of endosperm cells. The testa, the plate-like structure and the layer of endosperm cells together form the operculum.

Seed germination

The process of germination involves the emergence of embryo which forms a button in the beginning. It soon gains a plumular projection while from the end of the embryo the persistant radicle emerges. Both plumule and radicle emerge through a cylindrical ligule close to the seed. The haustorium develops inside the seed rapidly. In three months time, the spongy haustorium absorbs the endosperm fully and fills the cavity of the nut.

Oilpalm seeds do not germinate quickly under natural conditions since it has a long dormancy period. If the seed is planted in sand or soil and allowed to germinate under natural conditions, irregular germination would occur after 3-6 months or longer with total germination of about 50 per cent. It has been found possible to reduce this period and increase the germination percentage by improved techniques.

The seedlings

The plumule does not emerge from the plumular projection until the radicle has reached 1 cm in length. The first adventitious roots are produced in a ring just above the radicle-hypocotyle junction and they give raise to secondary roots before the first foliage leaf is emerged. Two blade-less plumular sheaths are produced before a green leaf is emerged. This leaf is recognised by the presence of a lamina which is produced after one month from germination. After this, leaves are produced at the rate of one leaf per month until the seedlings are six months old. The base of the stem becomes a swollen bulb after about 4 months and the primary roots emerge from it. The first few leaves are lanceolate. In later leaves a split is formed resulting in bifurcate leaves and subsequently the leaflets become entirely separate.

The stem

Initial growth of the palm after the seedling stage is marked by the formation of a wide stem-base without internodal elongation, on which the future stem column can rest firmly. The palm has only one growing point. Branching very rarely occurs possibly due to damage in the growing point. The stem-apex is conical in shape. The mass of young leaves and leaf bases together is known as the cabbage. Stem-thickening is attained through a process called primary thickening which is brought about by the activity of a meristem which continues beneath successive leaf bases. Internodal elongation begins only after attaining the maximum diameter of the stem. When the palms are young, the base of the stem assumes the shape of an inverted cone. Primary roots emerge in large numbers from this cone. As soon as the inter nodes begin to elongate, a columnar stem with adhering leaf-bases is formed. the leaf bases adhere to the stem for at least 12 years or longer. They start falling away from the base, top or the middle of the stem and the palm becomes smooth-stemmed instead or roughstemmed. The leaves are

Fig. 1 & 2. The spiral arrangement of leaves (8+13) produced in an orderly manner which is roughly triangular. This arrangement gives rise to sets of spirals. In an adult palm, two sets of spirals are visible, eight running in one way and thirteen in the other (Fig. 1 & 2). This arrangement is described as (8+13). If the leaf bases are chronologically numbered, it becomes clear that in one way, 8th leaf is seen to be in the same spiral while the other way every 13th leaf appears in the same (more or less vertical) spiral. These spirals are in either direction, left hand or right hand, more or less on a 50:50 ratio. In practice the total number of leaves can be clearly calculated by counting the number of spirals with eight leaves and multiplying the figure by eight and then adding the numebr of leaves in the incomplete spiral. The average increase in height of the stem is from 0.3 to 0.6 m/year. The palm reaches a height of about 30 m. The width of the stem unclothed by leaf-bases varies from 20 to 75 cm. the stem functions as a support, vascular and storage organ. The anatomy of the oilpalm stem is typical of that of monocotyledons. In the cross section, there is a wide central cylinder with a very narrow cortex. In the periphery numerous vascular bundles with fibrous phloem sheaths are embedded in the schlerotic ground tissue. In the central zone the vascular bundles are found embedded in the parenchymatous ground tissue. Longevity of Oilpalm is believed to be upto 200 years.

The leaf

In the crown of the adult palm, about 50 leaves could be observed in various stages of development. Each leaf remains enclosed for about two years and then rapidly develops into a central spear leaf which finally opens. Mature leaf is simply pinnate with linear leaf-

Fig. 3. The leaf Petrole

lets on each side of the leaf stalk. The leaf stalk has two zones, a leaflet bearing portion and the petiole. Two kinds of spines are seen in the petiole region. They are the fibre pines and the midrib spines (Fig. 3). The fibrespines are seen on the lower portion which is a modification of the leafsheath, while the midrib spines are seen in the upper portion of the petiole. These are modified midribs of leaflets. The long leafstalk is a hard fibrous body which may be as long as 8 m. Leaflets are produced by splitting of an entire leaf by the elongation of the leafaxis. Leaflets are arranged laterally in upper and lower ranks, giving a shaggy appearance. Indivitual leaflets are linear having a terminal pair. Each leaf will have about 250-300 leaflets and are about 13 m long and 6 cm broad. The midrib is very rigid and the laminae sometimes tear backwards from tip. The number of leaves produced annually by a mature palm is about 25.

The root system

Oilpalm has a typical adventitious root system. At the seedling stage, adventitious primary roots emerge from the radicle-hypocotyl junction and then from the basal cone or bole. In an adult palm, thousands of primary roots spread from the bole region. Individual primary roots travel upto 19 m from the stem. Two types of primary roots are observed. They are the descending and radiating primaries. The descending primaries are for anchorage. From the radiating primaries, large number of ascending and descending secondaries emerge, more or less in equal numbers. These secondaries give raise to horizontally growing tertiaries. From them a mass of quarternaries develop. The density of all classes of roots in the top 40 cm. of soil usually decreases with distance from the palm. But in adult palms, the total quantity of absorbing roots increases at least to a radius of 4.5m. Absorption of nutrients is through the quarternaries and absorbing tips of primaries, secondaries and tertiaries, bulk of which are seen in the top 15-30 cm of soil.

The anatomy of the roots consists of an outer epidremis and lignified hypodermis surrounding a cortex in which well developed air lacunae are found. Within the cortex is the stele surrounded by a endodermis, vascular strands or xytem and phloem and the pith. The quarternary roots are not lingified and perform the main function of absorption of water and nutrients. The roots of oilpalm are characterised by the presence of pneumathodes. These are seen both in underground and ariel roots. Such roots are supposed to ventillate the root system.

Reproduction

In the axil of each leaf, there is a bud which may develop into a male, female or hermaphrodite inflorescence. The oil palm is monoecious (producing male and female inflorescences in the same palm, borne separately). Each infloresence primordium is a potential producer of both male and female organs. Each inflorescence is a compound spike or spadix carried on a stout peduncle. 30-45 cm long spikelets are arranged spirally around a central axis. An inner and outer spathe tightly enclose the inflorescence upto six weeks before anthesis. Afterwards both the spathes are split open and inflorescence pushes its way out. Six to ten long bracts are seen below the lowest spikelets, two of them extend to the top of the inflorescence.

The female inflorecence reaches a length of 30 cm or more before opening. The female spikelets are thick and fleshy and develop in

Fig. 4. Female inflorecence

the axils of spinous bracts (Fig. 4). The flowers are arranged spirally around the rachis of the spikelets. Each flower is housed in a shallow cavity and is subtended by a bract which is drawn up into a spine. At the end of the spikelet also there is a spine. An average inflorescence from a mature palm may have more than 110 spikelets with over 4000 flowers. Each female flower has a protection bract, two floral bracts and two whorls of three perianth each. All these bracts enclose a tricarpellary ovary. The two accompanying male flowers are abortive. At anthesis the trifid stigma curves outward. The stigmatic lobes when receptive are white to pale yellow in colour. Later on a red stripe develops along those lobes as the flower turn purplish indicating the end of receptivity.

The male inflorescence is borne on a longer peduncle than that of the female. The spikelets are long finger-like and not spiny (Fig. 5). Each spikelet is about 10-20 cm long arising from a central stalk bearing between

Fig. 5. Male inflorecence

600-1200 male flowers which are yellow in colour having a distinct aroma and mautre from bottom to top. A mature flower is 3-4 mm long and 1.5 to 2.0 mm wide and is completely enclosed in a triangular tract. It has an outer whorl of three hard and an inner whorl of soft perianth together with six stamens fused to form a tube in the centre. The anthers are bi-lobed and release pollen grains through the lateral slits. The amount of pollen produced by a single inflorescence is upto 50 g. and liberated over a period of 2-3 days.

Male and female inflorescences are produced in cycles. In young palms a great variety of hermaphrodite inflorescences are produced. This consists of male, female and mixed spikelets on the same infloresnce. Young palms occasionally produce a pecular type of infloresnce known as andromorphic. Here the male flowers are replaced by small solitary female flowers arranged in the same manner as that of the male flowers.

Insect pollination in oil palm

The oil palm, hitherto thought to be wind pollinated, has been now proved to be an insect pollinated species. From West Africa, the original home of oil palm, eight species of pollinating weevils were reported by Syed (1979). They belong to the order Coleoptera (Family - Curculionidae, subfamily-Derelominae). Weevils on oil palm in Cameroon include, *Elaeidobius kamerunicus* Fst., E. plagiaus Fah., *E. singularis* Fst., *E. bilineatus* Fst., *E. subvittatus* Fst. and rarely *E. spatulifer* Mshl. The only species found in South America is *E. subvittatus*. Occurrence of *E. kamerunicus* in the oilpalm plantations of Kerala was introduced during 1985 from where it was introduced and got established in Little Andamans during 1986.

The weevils are dark brown in colour. Adult weevils chew the anther filament. Eggs are deposited inside the flowers and larva feed on the spent flowers. Life cycle is completed within 11 to13 days. Males live longer than females. The activity of the insects is in accordance with the receptivity of the male and female inflorescences. It was roughly estimated that 40 palms in a grove might be the minimum to sustain a sufficiently high continuous population of pollinators to pollinate all receptive female inflorescences. The weevils carry maximum pollen during the third day of anthensis (Dhileepan, 1991). Antennae, rostrum, thorax, legs etc. are the main sites of pollen load. *E. kamerunicus* has a fairly good searching ability. It can survive in dry as well as in wet seasons. Their host range is limited to the genus *Elaeis* and even at this level it cannot survive for more than two or three generations, on the most closely related species like *Elaeis oelifera*

E. kamerunicus was introduced in Malaysia during 1981 and was well established over a radius of more than 5 km from the release site within six months. Total yield was 20 per cent higher in Peninsular Malaysia and 53 per cent higher in Sabha, with higher increase in kernel yield (Syed, 1982). Introduction of the weevil in India increased the fruit set from 36.8 per cent to 56.1 per cent resulting in 40 per cent increase in FFB weight and 11 per cent increase in F/B ratio. The maximum attainable pollination potential was as much as 70 per cent with 57 per cent increase in FFB weight. Introduction of *E. kamerunicus* into the oilpalm plantations at Little Andamans increased the FFB weight from 5 to 12 kg.

For introudction, male flowers cut from

palms which have the weevils are transferred to a plantation where one wishes to introduce. In order to make sure that they are not carrying any plant pathogens to other area/countries, we have to breed them under laboratory conditions for seven or eight generations before introduction.

The fruit

Oil palm fruit is a sessile drupe, varying in shape from heary spherical to ovoid or elongate (Fig. 6). They are 3-5 cm long and weigh about 3-30 g. The pericarp of the fruit consists of the outer exocarp or skin, oil-bearing mesocarp and the hard stony endocarp or shell. The endocarp together with the kernel inside forms the seed. Externally the fruit varies considerably at maturity. The exocarp of the external fruits of the bunch tends to be more pigmented than that of the internal fruits. The common type of fruit is deep violet to black at the apex and colourless at the base before ripening. Such fruits are called Nigriscens. Another uncommon type of fruit is green before ripening and this is called the Virescens. Depending on the variation in colour, Nigriscens fruits have been further classified into other sub-groups. Both of the above types of fruits contain varying qualities of carotenoids in the mesocarp.

Depending on the presence/absence of shell and other fruit characters, three fruit forms have been described in oilpalm (Fig. 7). They are :

a) Dura - the percentage of mesocarp to fruit is variable usually within the range of 35-50 per cent. The shell is comparatively thick with a 2-8 mm range and has no ring of fibres around it. The kernel is usually large. Oil-content of dura mesocarp in proportion to bunch weight is quite low at 17-18 per cent. The dura is used as the female parent in breeding programmes.

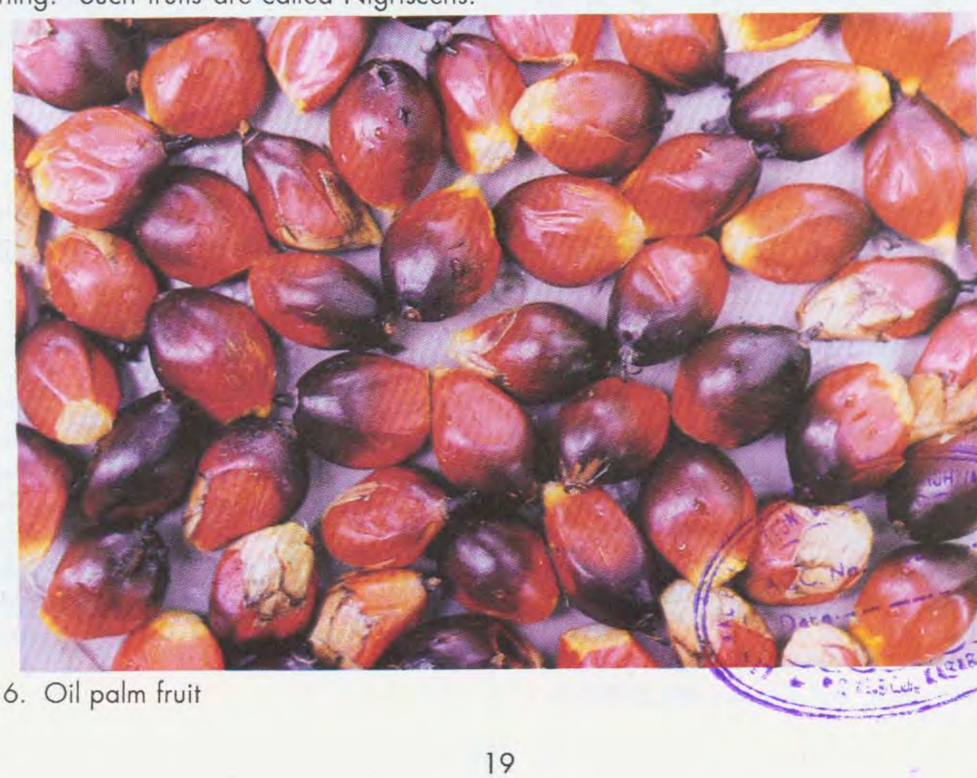

Fig. 6. Oil palm fruit

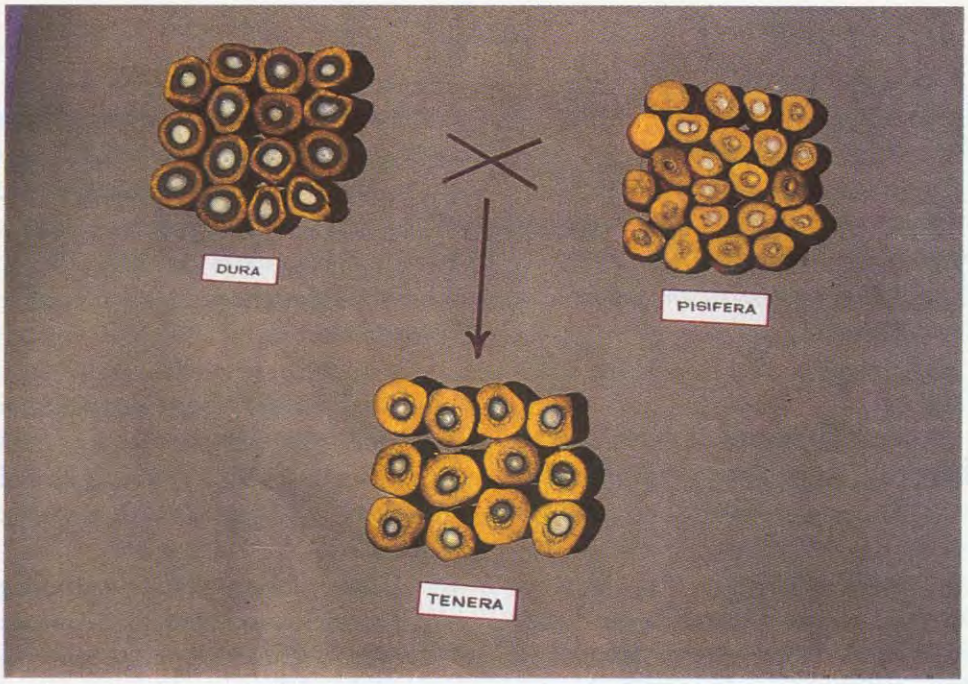

Fig. 7. Three fruit forms of oil palm

b) Pisifera - this fruit type is characterised by the absence of a shell, the vestiges of the shell being represented by a ring of fibres around the kernel, the later being quite small. In the absence of shell, there is a high ratio of mesocarp to total fruit size and the mesocarp oil content is also high. Pisiferas are usually described as female sterile since the majority of bunches abort at an early stage of development. Therefore, *Pisifera* material cannot be used for commecial plantings but is used as the male parent in breeding programmes. By crossing the *dura* and *pisifera* types, the third type *tenera* is produced.

c) Tenera - this type which is currently planted on an estate scale, combines the characteristics of the parent material. Shell thickness ranges from 0.5 mm to 4 mm around which a ring of fibres, is present. The ratio of mesocarp to fruit is comparatively high, usually within the range 60-96 per cent. *Tenera* palms generally produce more fruit bunches than dura palms, although mean bunch size is usually smaller. The ratio of oil to bunch is about 22-24 per cent.

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BREEDING

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Introduction

The ultimate yield of palm oil is dependent on many attributes viz., no. of bunches, bunch weight, no. of fruits per bunch and mesocarp. To achieve the objective of evolving oil palm genotypes with high oil yield, breeders manipulate one or more of these factors by making use of the genetic resources available with them. The main oil palm breeding programmes are from INEC (Zaire), NIFOR (Nigeria), IRHO (Cote d' Ivoire), PORIM (Malaysia) and ASD (Costa Rica). These have been dealt with in detail by Hartley (1988) in the recent edition of his book 'The Oil Palm' and no attempt is made here to go into those details. The broad principles involved in oil palm breeding is discussed with special reference to the work in India.

Commercial planting material

Ever since Beirnaert and Vanderweyen (1941) described the hybrid nature of *tenera*, plant breeders have concentrated on production of thin shelled *teneras* by crossing *dura* (thick shelled) and *pisifera* (shell-less) varieties. Apart from the thinner shells, the fruits have a ring of fibres around the shell. Only *tenera* hybrids are planted on a commercial scale all over the world (Fig. 1)

Fig. 1. Tenera hybrid

Shell thickness is monogenic, *duras* being homozygous for the dominant gene (Sh+Sh+) and *pisiferas* for the recessive (Sh-Sh-) gene. The latter generally has no shell and are mostly devoid of embryo. *Pisiferas* can therefore be produced only by crossing or selfing *teneras*. However, differences in yield are observed when various individual cross combinations are considered. In general, crosses between genotypes of wider origin with contrasting characters give better yields. This can be explained on a mathematical basis. *Deli* with 5 bunches and 20 kg FFB/bunch produces 20x5 = 100 kg FFB; *Lame* with 20 bunches and 5 kg FFB/ bunch also produces 5 x 20 = 100 kg FFB. But when *Deli* is crossed with *Lame* on an average it can produce 156. 25kg FFB instead of 100 kg.

$$\frac{5 + 20}{2} \times \frac{20 + 5}{2} = 12.5 \times 12.5$$

Breeding programme

The present day oil palm breeding programmes are modified versions of reciprocal recurrent selection. This is aimed at identifying *dura* and *pisifera* parents which when combined would give high yielding *teneras*. While *duras* can be assessed based on their own yield, the potential of *pisifera* cannot be directly measured. Its worth has to be gauged based on the performance of their progenies. In hybrid production, sterile *pisiferas* are preferred since fertility is normally related to shell thickness. A negative correlation between fertile *pisiferas* and thinness of shell in their *tenera* sibs has been reported (Sparnaaij *et al.*, 1963).

Based on these information, a breeding programme is outlined in Figure 2.

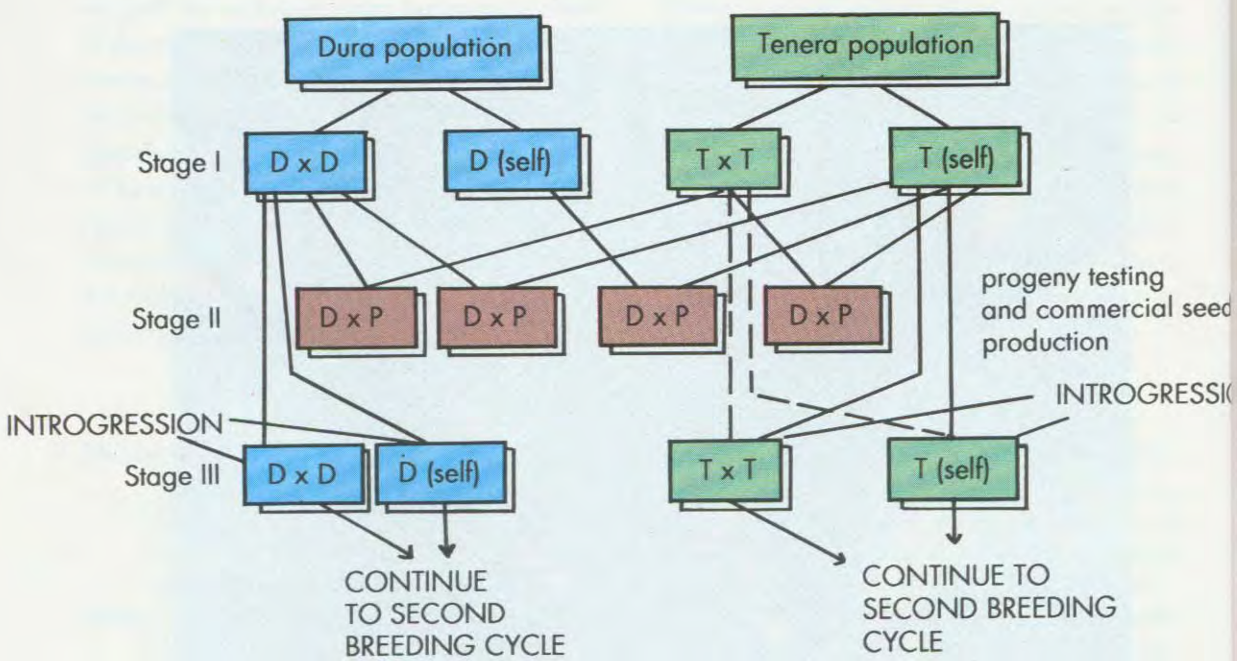

Fig 2. Oil palm breeding programme

In this scheme, *duras* are selected based on a system of family and individual mass selection. *Pisifera* selection is based on the performance in the *tenera* x *tenera* progenies in stage I and in stage II based on the performance of D x P progenies. Deductions made at each stage can be verified from the performance of the progenies obtained by using the selected parents. At each stage it is possible to introgress genes from any desirable new introduction.

Yield improvement obtained by following a systematic breeding programme at IRHO for two cycles is given in Table 1.

The first cycle resulted in 18 per cent yield increase over which 15per cent imporvement was obtained in the second cycle thus obtaining an overall progress of 36 per cent (Gascon *et al.*, 1988)

Performance of tenera in India

Eleven *tenera* hybrid combinations were planted at CPCRI, Palode during 1976 in a randomised block design. The *dura* parents of Malaysian origin available at Thodupuzha and four pollen samples received from NIFOR, Nigeria were used to make these crosses. The performance of these D x P combinations grown purely under rainfed conditions is given in Table 2.

The hybrids 65d x 30.103p and 120D x 30.103P were the best followed by 92D x 30.3154P. Combinations 156D x 30.4336P, 187D x 24.3087P and 269D x 30.4336P were poor performers giving only an average of 63.6, 66.6 and 81.4 kg FFB per palm per year respectively. Such combination wise differences indicate the necessity for identifying specific combinations.

The highest yields were obtained in 1986, for which introduction of the pollinating weevil (*Elaeidobius kamerunicus*) may be one of the main factors (Dhileepan and Nampoothiri, 1989). In that particular year also 65D x 30.103P was the best giving 164.1 kg FFB/palm. This is equivalent to 4.6 metric tonnes of palm oil which can be considered as a very good yield under rainfed conditions.

The boost in yield during 1986 was followed by a drastic reduction in 1987, 88 and 89. A 20 per cent additional dose of fertilizers was given as recommended by Suwandi *et al.*, (1984). By 1990, i.e. after three years, the yield level was restored. The trend in production of bunches was also more or less same as indicated in Table 3.

Table 1. Genetic progress on oil yield (6-9 years average)

Stage	Year	No. of progenies	FFB	oil yield t/ha	Progress
Control (original population)	1960	529	15.0	3.33	100
First cycle	1972	74	16.7	3.93	118
Second cycle	1984	74	19.0	4.52	136

Table 2. Yield of fresh fruit bunches per palm per year and oil yield

Treatments	yield of FFB (kg) 1986	1987	1988	1989	1990	Cumulative average	Oil yield MT/ha/year*
65D x 30.103P	164.1	87.1	86.3	94.4	141.6	124.8	4.6
271D x 30.4336P	146.4	71.5	47.4	68.5	141.3	111.8	4.1
139D x 24.3087P	98.7	61.2	52.9	54.7	116.0	89.1	3.2
156D x 30.4336P	60.8	53.7	27.0	29.1	84.0	63.6	2.4
61D x 30.4336P	138.5	77.4	42.3	55.9	155.2	116.4	4.3
125D x 30.103P	125.7	77.0	85.6	73.8	137.0	113.7	3.8
108D x 30.4336P	123.0	72.9	67.3	64.6	139.8	110.7	3.9
92D x 30.3154P	124.7	91.0	49.8	104.7	161.2	127.2	4.5
269D x 30.4336P	107.2	69.4	28.6	39.8	101.1	81.4	3.0
187D x 24.3087P	63.3	48.8	36.8	40.5	85.4	66.6	2.4
120D x 30.103P	159.2	98.3	87.1	75.4	148.1	128.4	4.5

* Estimated on the basis of highest yield of FFB

Table 3. Number of bunches per palm per year

Treatments	1986	1987	1988	1989	1990	Cumulative average
	per palm per year					
65D x 30.103P	12.6	6.3	4.7	7.0	6.5	6.2
271D x 30.4336 P	12.9	5.7	2.8	6.2	6.5	5.5
139D x 24.3087P	8.7	4.8	3.1	4.9	5.8	4.7
156D x 30.4336P	5.9	3.9	3.3	3.7	4.1	3.7
61D x 30.4336P	9.1	6.2	2.9	5.2	7.2	5.3
125D x 30.103P	11.9	6.1	5.4	6.8	7.3	6.5
108D x 30.4336P	12.0	5.1	3.6	6.0	7.0	5.5
92D x 30.3154P	8.8	6.8	2.8	5.6	6.4	5.4
269D x 30.4336P	8.8	6.1	2.3	4.8	4.9	4.6
187D x 24.3087P	6.7	4.7	2.9	4.1	4.8	4.1
120D x 30.103P	12.2	6.5	4.4	6.7	6.5	6.2

There was a predominance of male inflorescences resulting in low sex ratio which could be due to the rainfed condition in which they were grown. The situation can be improved by supplementary irrigation (Nampoothiri *et al.* 1990). The preliminary reports from Karnataka where oil palm is grown as an irrigated crop support this view (Vasanth Kumar, 1991).

Germplasm

Oil palm (*Elaeis guineensis*) is now generally regarded as having originated in Africa (Chevalier, 1934; Zevan, 1967) and is endemic to West and Central Africa. Another related species, known as American oil palm (*Elaeis oleifera*) is found largely in the Central and South America. This species is gaining growing importance due to it specific advantages which could be exploited through inter specific hybrids. One more species (*Elaeis odora*) has been found in Brazil about which detailed information is not available.

Germplasm assemblage

Assemblage of germplasm is an important part of any breeding programme especially in crops like oil palm which are not indigenous. An organised collection of oil palm materials started in India during the 1960s by the Department of Agriculture Kerala. *Dura* and *Tenera* materials were imported from Malaysia and Nigeria and planted at the oil palm station, Thodupuzha, Kerala. Systematic collection of oil palm accessions was started by the Indian Council of Agricultural Research during 1979 at CPCRI, Research Centre, Palode, Kerala. Many countries are reluctant to spare oil palm planting materials. Therefore, the collection comprised mainly of random samples of *tenera* introduced by various agencies in the country from time to time for commercial purposes. The germplasm bank at Palode comprises of 22 accessions from nine countries (Table 4).

The germplasm materials are being evaluated for yield and yield attributes under uniform conditions.

Breeding for dwarfness

Short palms with larger girth and high leaf production, called dumpy palms, were described by Jagoe (1952) in a *deli* population. The well-known palm E 206 has been widely used in crossing programme to evolve dwarf palms. The height increment in further generations was only 16.3 cm in seventh year as against a 35.6 cm growth of non-dumpy palms in eight years. Dumpyness is considered as a homozygous character (Hartley, 1988). The dumpy *dura* x *pisifera* introduced to India from Indonesia however has not shown any height reduction compared to deli *dura* x pisifera during the initial five years growth.

Table 4. Germplasm accessions

S.No.	Source	Year of collection	No. of palms available	Remarks
1.	Nigeria (NIFOR)	1979	119	*Tenera*
2.	Cote'd Ivoire	1981	48	*Tenera*
3.	India (CPCRI)	1982	48	*Tenera*
4.	Republic of Zaire	1982	48	*Tenera*
5.	Indonesia	1986	48	*Delidura x pisifera*
6.	Indonesia	1986	48	*Dumpydura x pisifera*
7.	Malaysia	1987	20	*Tenera*
8.	Cameroon	1988	48	*Tenera*
9.	Costa Rica (ASD)	1990	55	*Tenera*

Interspecific hybridisation

Elaeis oleifera (previously referred to as *Corozo oleifera*) is found mostly in south and central America and is therefore called the American oilpalm. This species is of interest to breeders because of its dwarfness, oil fluidity and resistance to disease noticeably bud rot in Latin America as well as vascular wilt and reduced susceptability to the pest *Coelaenomenodera elaeidis* (LeGueny *et al.*, 1991). Only *dura* fruit forms have been located in this species. Therefore, the crosses are mostly made with *E. guineensis, pisifera*.

The F_1 hybrids are not directly exploited because they are low in fruit/bunch ratio, oil percentage and oil to bunch extraction (17 per cent). Certain hybrids have also been found to be susceptable to freckle (*Cercospora elaeidis*) in Africa. Therefore, a series of back crosses and selections in further generations have become necessary (Corley *et al.*, 1976). So far the interspecific hybrids have not been therefore commercially exploited. Reviewing the work by IRHO, LeGueny *et at.*, (1991) opinioned "Large scale distribution of tried and tested clones with *E. oleifera* genes would be possible in theory, in the first decade of the 21st century". This line of work on inter *specific* hybridisation has not been taken up in India.

The compact and super compact high yielding palms obtained in back cross generations of interspecific hybrids in ASD, Costa Rica give scope for increasing the yield by a clear planting of these dwarf and small crowned palms.

Clonal propagation

Through the improvements in biotechnology, it has been possible to produce large number of clonal plantlets in many crop plants which are true to type progenies. Therefore, the technique of tissue culture was tried on oil palm in many laboratories. This involves selection of suitable tissues from the ortet (clone source) and induction of callus formation and further development using artificial media under controlled laboratory conditions.

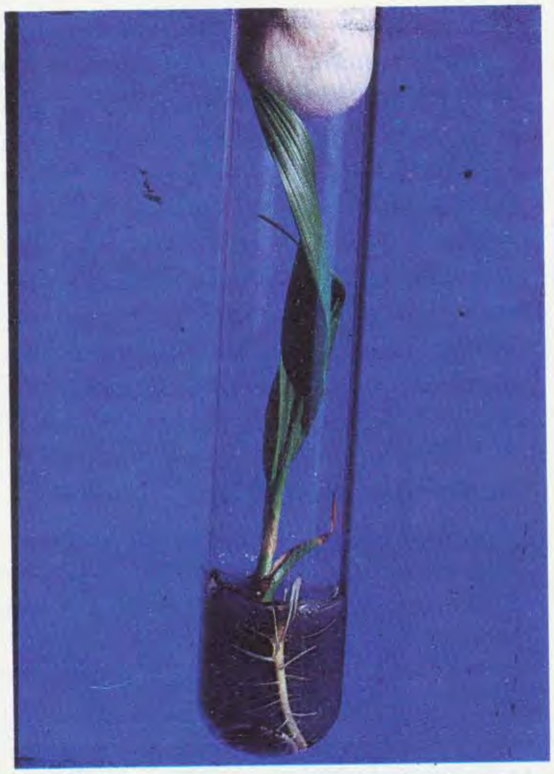

Fig. 3. Tissue cultured oil palm planlet

Since genetic change can occur during such culturing, it is necessary to field test clonal progenies before commercial exploitation. In such a trial in Malaysia planted during 1981-1983 two types of abnormalities viz. mantled poissoni fruit and androgynous inflorescence have appeared (Corley *et al*, 1986). This has caused a set back in the progress on use of clonal material. These abnormalities appear to be due to the use of fast growing cultures. Efforts are underway to overcome this by adjusting culturing methods and various compositions of media.

Clonal plantlets from adult palm tissues have been successfully produced by ORSTEM, France and the performance of these since 1983 are encouraging (Duval *et al.*, 1988). Observations in initial flowering showed that inflorescence production is better synchronised in clones than in seedling progenies. It is also reported that there is considerable improvement in yield and reduction in the within progeny variation in clonal progenies compared to seedling progenies. The tissue culture plantlets are now commercially sold from Tropiclone, Montpellier, France, at a cost of 4.5 US $/plantlet. It is advisable to restrict the extent of clonal progenies in any plantation to 10-15 per cent. (Nampoothiri, 1989)

In India success has been achieved in obtaining plantlets from leaf tissues of oilpalm seedling at CPCRI (Fig. 3) and BARC (Thomas *et al.*, 1985). It has been possible to develop a non-destructive sampling method to collect tissues from adult palms for culturing (Anonymous, 1988). However, it is necessary to produce clonal progenies from such adult palm tissues and field test them before commercial planting.

Commercial seed production

The commercial scale seed production commenced in India only after 1982, when *pisifera* palms were identified in the oil palm plantation, Thodupuzha in Kerala. Prior to that the commercial plantings were taken up using seeds imported mainly from Malaysia, Cote d' Ivoire, Nigeria and Zaire. Now it is possible to produce 0.4 million seeds annaully with present facilities available at CPCRI Research Centre, Palode.

Hybrid seed production is being done by pollinating superior *dura* mother palms with pollen collected from selected *pisifera* palms, which require controlled pollination.

Collection and storage of pollen

Male inflorescence is bagged 7 days before opening of the inflorescence. Before bagging, the spathe of the inflorescence must be sprayed with 40 per cent formaldehyde solution diluted by water in the ratio of 1:9. The solution kills all the foreign pollen grains

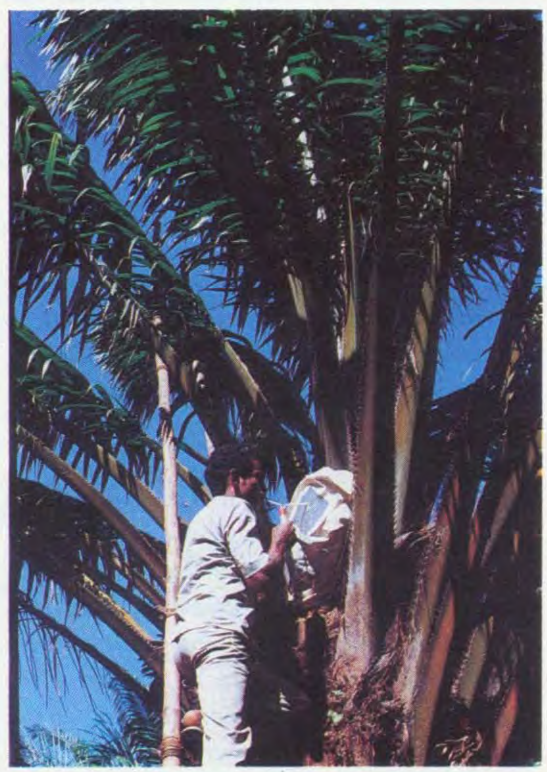

Fig. 4. Controlled pollination

and insects adhering to the spikelets. The bag's interior portion should also be treated in the same manner. The bags used has a celluloid or thick polythene window of convenient size to facilitate observation of the inflorescence. These windows are provided with small holes sealed with adhesive tape so that pollination can be done without opening the bag. A thick band of cotton lint sprayed with formaldehyde and dusted with D.D.T. is kept around the peduncle at the mouth of the bag to prevant entry of ants etc.

After opening of the male flowers, the inflorescence are cut and removed and dried in shade along with the bag. The pollen can be collected in the bag by shaking thoroughly the inflorescence. Pollen is dried along with the bag at 35°-40°C for 24 hr. The pollen can be sieved and collected in storage tubes. It can be stored in a desiccator at room temperature upto 8 weeks. The storage period can be extended for one year by storing the pollen under sterile conditions at less than five per cent moisture in a deep freeze at - 25°C.

The female inflorescence should be prepared and bagged in the same manner as in the case of the male ones, at least one week before the opening of the first female flower.

Pollination

By regular observation of the bagged female inflorescence through the celluloid window, it is possible to find out the day on which the female flowers are receptive. The pollen may be placed in a test tube closed with a rubber cork carrying two 'L' shaped glass tubes stoppered with cotton wool. When the female flowers are at receptive stage the holes in the celluloid window, which is closed with adhesive tape, is opened gently and one of the glass tubes is inserted inside the bag and the air is gently blown through the other glass tube. The adhesive tape is replaced immediately after the glass-tube is withdrawn. The bag is then shaken well to help the pollen to settle on female flowers. Usually pollination is done in the morning. Pollination is to be repeated for three or more days as female flowers are receptive during this period. The bag can be removed four weeks after pollination.

Harvesting and processing of seeds

After harvesting the ripe bunch, the fruits are removed by retting for 5-10 days and repeated washings until very clean seeds are obtained (Fig. 5). Clean seeds would also be obtained by using a de-pericarper. The clean seeds are then dried under shade for about 24 hrs to reduce the moisture content to 18 per cent on dry matter. This is done to avoid premature germination and infection by pathogens. They can be stored for a period of six months whithout loss of viability.

Germination technique

Five hundred seeds each are sealed in thick-guage polythene bags and stored in a germinator which is an insulated room with theromostatically controlled temperature of 38-40°C. Heating for 40 days gives good results although longer period of heating is also not harmful to the seeds. This technique is known as pre-heating. At the end of pre-heating, the seeds are soaked again in water for 2-5 days, with daily change of water, to increase the moisture content to about 22 per cent on dry matter. The seeds are then treated with suitable fungicides and antibiotics after which the seeds are dried for 2 hrs so as to dry


Fig. 5. Clean seeds

the surface moisture. The seeds are then returned to the polythene bags and sealed with enough trapped air inside. The bags are then stored at ambient temperature. Germination commences after 7-10 days and continues for about 30-40 days by which time about 80-90 per cent of the seeds would normally germinate (Fig. 6). This method is called the dry heat method and is the most successful technique. A modified version of this method is the wet heat method. In this, the seeds are not dried to reduce the moisture content to 18 per cent while all the other steps remain the same. Results showed that the dry-heat method is the most efficient method for getting good quality seedlings.

National demand

It is estimated that about 0.575 million hectares in the major irrigation project areas in different states, are suitable for oil palm cultivation in India. To plant even half of this area by 2000 AD, 50 million seeds are required (200 seeds per hectare). At present by using the indigenous material only 0.4 million seeds can be produced annually. Hence it is essential to establish seed gardens of 20 ha area each in various states to produce two million seeds/garden.

This is done by using selected high yielding *dura* palms and *pisifera* palms from *tenera* x *tenera* population available at Oil palm Station, Thodupuzha, Kerala State. These are supplied as sprouts at a cost of Rs. 1.50/ sprout.

Rest of the requirement will have to be met through imports. The sources which have readily agreed to sell seeds are ASD, Costa rica; IRHO, France and Dami Oilpalm Research Station, Papua New Guinea. The cost

Fig. 6. Oil palm sprouts

of sprouts vary from 0.4 to 0.5 US $ depending on the size of the order. Department of Biotechnology, M/s Radhika Vegetable Oils, M/s Godrej Soaps Ltd. and, Sri Ponnambalam Thiruchirappally have imported *tenera* hybrid sprouts from ASD, Costa Rica totalling to over one million (Anon. 1991).

Hartley (1988) lists the following points which the seed purchaser should bear in mind

1. The seeds should be obtained as progenies with information on parental achievements and analysis.
2. A clear definition of the terms 'proved seed' or 'proved parentage' should be obtained if these terms are used by the seller.
3. The following data relating to parents, sites or progeny should be obtained.
   a) Bunch yield at maturity over a given number of years with statement of location, soil, rainfall distribution, water deficit and sunshine.
   b) Fruits/bunch, mesocarp, shelll and kernel to fruit; oil to mesocarp.

Needless to mention that the buyer should make sure that the seeds are produced using parental palms which are free of diseases and pests. It may be pointed out here that since only *tenera* hybrids are commercially planted the seeds will have to be obtained everytime for planting from a known reliable source. Seeds collected from *teneras* grown in plantation should not be used for raising planting material.

Future strategy

The direct usefulness of *teneras* in the germplasm is very limited. It is necessary to collect *dura* parents which have been proved to produce high yielding hybrids. Serious effort has to be made for a systematic collection of oilpalm germplasm materials by prospection in the original habitat of *E. guineensis* and *E. oleifera* in view of the availability of valuable genetic resources in Nigeria, Cameroon, Honduras, Nicaragua, Costa Rica, Panama, Columbia, Surinam etc.

In India we have to use indigenous material to the maximum extent, import proven hybrids and purchase clonal progenies as a short term measure. The long term strategies would involve improvement of the indigenous hybrids mainly through introgression from imported advanced lines, establishing seed gardens to increase hybrid seed production and developing Indian technology for tissue culture.

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MANAGEMENT

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Introduction

Oil palm requires evenly distributed annual rainfall of 2000 mm without a defined dry season since it is continuously growing and yielding all through the year. In areas with dry spell, a deep soil with high water holding capacity and a shallow water table can however, satisfy the water requirement of the palm. Though the crop can withstand 3 to 4 months of dry period, continued moisture stress affects the yield adversely, unless augmented with copious irrigation.

Temperature can be a limiting factor for oil palm production as it influences inflorescence production, initiation of flower primordia, sex differentiation, anthesis, floral abortion and growth rate of palm. Prolonged cooler temperature with less than 19°C reduces the growth rate and leaf production considerably in oil palm. More number of male inflorescences are produced under low minimum temperatures. Best oil palm yields are obtained in places where a maximum average temperature of 29-33°C and minimum average temperature of 22-24°C are available. Higher diurnal temperature variation causes floral abortion in regions with a dry season.

The crop requires 1800-2000 sunlight hours annually for producing good yield. The oil palm growth and yield will be drastically reduced when solar radiation levels fall below 350 Langleys (cal/cm^2/day). Constant sunlight of at least 5 hours per day is required for better oil palm yield.

Though oil palm is considered as a humid tropical crop, it can tolerate a wide range of pedo-ecological conditions. It is found to grow well on a variety of soils. However, moist, deep and well drained medium textured soils rich in humus content are considered ideal. Gravelly and sandy soils, particularly the coastal sands, are not ideal for oil palm cultivation. Heavy clay soils with poor drainage properties may pose problems of aeration during rainy seasons.

Nursery and its management

Direct planting of the germinated seedlings into the mainfield is not advocated mainly due to the anticipated damage of seedlings by rodents and also due to the expected uneven stand in the field. Therefore, a nursery is raised by planting germinated sprouts initially in a pre-nursery bed or in polybags in a primary nursery and transplanting them at five leaf stage to a secondary nursery of larger sized polybags. Raising seedlings in large polybags without a pre-nursery stage is also being practised.

In India thé potting mixture is made by mixing top soil, sand and well decomposed cattle manure in equal proportions. Smaller polybags of 250 guage and 23x13 cm size, preferably black, are used for raising primary nurseries. These bags are filled with the potting mixture leaving one cm at the top of the bag. A healthy germinated sprout is placed at the centre at 2.5 cm depth. While placing the sprout, care must be taken to keep the plumule of the sprout facing upwards and the radicle downwards in the soil. It is better to plant sprouts soon after the differentiation of radicle and plumule. Mulching is beneficial for better growth in the nursery (Gunn *et al.*, 1961). Mulching with palm shell, finely divided bunch refuse, saw dust, groundnut husk or other fibrous material has been found to conserve moisture, prevent compaction of soil and provide certain amount of nutrition to the growing seedlings. Shading is also found beneficial at early stage especially when they are raised under higher temperature conditions in certain parts of India. Adequate supply of water is to be ensured to these seedlings by installing permanent irrigation facility. The seedlings are to be watered daily. Response of seedlings to nitrogen and phosphorus was reported from Nigeria and Malaysia. Application of a fertiliser mixture containing one part of ammonium sulphate, one part of super phosphate, one part of muriate of potash and two parts of magnesium sulphate is recommended @ 15g at one month stage, 45g at three months stage and 60g at six months stage per seedling. This has to be applied 6-8 cm away from seedlings during the first application, 10-12 cm away during second and 15-20 cm away during the third application in primary nursery. Surface soil is slightly scratched at the time of fertilizer application.

Single stage poly bag nursery and secondary nursery

Bevan and Gray (1966) demonstrated that germinated seeds can be directly planted into large black polybags with the advantage of avoiding the pre-nursery stage. Experimental trials conducted in Malaysia have shown that planting of germinated seeds directly into large polybags gives more vigorous larger seedlings than those obtained by raising pre-nurseries. At present the single stage polybag nursery is recommended in India. Since the plants are to remain in these poly bags for more than one year, good quality polybags of 500 guage and 40x45 cm size are to be used. On the lower half of the bag, perforations are made at an interval of 7.5 cm for drainage. A bag can carry 15-18 kg of nursery soil depending on the type of soil mixture used.

Germinated seeds are planted in the same way as described under primary nursery. It is important to provide shade until seedlings attain two leaf stage. This can be done by staking palm leaflets in each bag so as to cover the bag like an umbrella over the developing seedlings. Though the single stage nursery is more labour intensive, it is compensated by the reduction in the overall time for transplanting by about two months. Where two stage nursery system is practised, eight week old pre-nursery seedling (five leaf stage) from smaller bag with its ball of soil is transplanted as such into the larger polybag.

Quencez (1982) suggested water requirement for different stages of growth of seedlings as follows : 0-2 months @ 4mm/day, 2-4 months @ 5 mm/day, 4-6 months @ 7mm/day and 6-8 months @ 10 mm/day. It is better to supply if feasible the daily requirement in two halves to prevent overflow and wastage caused by one time application. Bevan and Gray (1966) suggested application of 9-18 l of water per seedling per week according to the stage of growth and soil type.

Shading the nursery is not a usual practice and is not recommended except under high temperature conditions. In West Africa shaded plants though found taller in the nursery, were slower in growth than unshaded plants (Gunn *et al.*, 1961). Hand weeding is recommended at monthly intervals both in polybags and the intervening ground (Bevan and Gray, 1969). Mulching is practised in certain regions of Central America but not commonly in Asia and Africa.

Field planting

It is necessary to prepare the land for oil palm plantings at least 3 months before transplanting the seedlings to the main field. In the case of forest land chosen for oil palm plantation, the major activities involved are, felling of existing vegetation and piling up and burning of the residue. In soils with low permeability, drainage channels are to be constructed to prevent water stagnation in upper layer of soil. On steep slopes, circular platforms are cut with a diameter of 3-4 m and a slope back to the hill side of 7-8°. However, in very steep slopes of over 20° terracing is required. Clearing paths are constructed in the centre of every other avenue.

Age of seedlings at transplanting

In places with no distinct dry season, it is advisable to plant well grown seedlings of 10-16 months old. In Malaysia, polybag seedlings of 13 months or more gave significantly higher yields in the first three bearing ages than those transplanted at younger ages (Hew Choy Kean and Tam Tai Kin, 1971). From trials conducted in other oil palm growing countries, it was observed that seedlings of 12-14 months of age are the ideal ones for transplanting to mainfield. At this stage, a well developed *tenera* seedling will have a height of 1-1.3 m from base and will have more than 13 functional leaves. These seedlings were found to maintain higher leaf production, bear earlier, produce heavy bunches, give higher fruit/ bunch ratio and a higher oil to mesocarp in the first year of harvest.

Selection of seedlings

All deformed, diseased and elongated seedlings are to be discarded. Differences in the height of healthy seedlings ranging from 90 to 159 cm tend to even up after 14 months of transplanting to mainfield in Malaysia.

Time of transplanting

Transplanting to the mainfield has to be done during the onset of rainy season so that the seedlings can establish under favourable conditions. Most suitable time for transplanting seedlings into mainfield in India is with the on set of monsoon by which time the seedlings are to be at least 12-14 months in the nursery. Accordingly, raising nursery has to be planned well in advance for timely supply of the seedlings.

In very impermeable soils and where there is chance for the seedlings to suffer severely during rainy season, proper drainage has to be ensured. In Kuttanad region of Kerala, oil palm is being successfully grown on raised bunds or terraces which are surrounded by standing water during the rainy season.

Spacing and method of planting

The optimum planting density for oil palm is the density of population that gives maximum production from unit area. When density is less than the optimum level, though individual palm yield increases to a certain extent, the total production per unit area will be lesser. Population above optimum level will also lead to reduced production of individual palms due to competition for water, nutrients and sunlight thus reducing the total yield per unit area. Yields of individual palms are adversely affected due to increased density of planting causing mutual shading of leaves. Although closer spaced palms gave higher yields initially, as the palms grow, mutual shading affects the yield adversely.

Under more favourable conditions a population of 127 - 135 palms per hectare was found to be optimum whereas under less favourable conditions as in India, higher densities of 138 - 150 palms per hectare are recommended.

Dense shade affects sex ratio in oil palm. Close planting induces more male inflorescence (Sparnaij, 1960). A very regular planting arrangement with largest possible number of similarly spaced surrounding palms is desirable and triangular spacing fulfils this requirement best (Hartley, 1988). Triangular system of planting with 9x9x9m spacing accommodates 143 palms/ha.

For efficient utilization of solar energy the rows are to be oriented in the North-South direction. Equilateral triangular system of planting with 9 m spacing between palms will allow each plant to occupy the centre of a hexagon thus allowing better use of the area. Different methods of marking planting points are discussed below:

(a) In flat or gently sloping lands the stakes are placed in base line 'B' taken in E-W direction at every 46.8m. (space for 7 rows = 7.8x6). Palm rows are marked at 9 m spacing on those two rows A_1, A_2 in N-S direction by putting stakes. The stakes are placed for remaining palm rows in between these two rows by use of a chain on which marks are made at 9 m spacing. The first mark of this chain is placed on first stake of line A_1 and the seventh mark of the chain on the other end is placed on fourth stake of line A_2. (Fig. 1). Then the stakes are placed on all the marks on chain thus filling the entire area of the block.

(b) Another method is to mark a base line A in N-S direction in one end of a block and put the stakes at 9m spacing on this line (Fig. 2). From this base line another line B_1. in E-W. direction is made with the corner stake on left hand corner remaining the same and stakes are placed at 7.8 m in this line. Similarly, another line B_2 is made after 54m (6x9) from line A. Now a chain is used on which marks are made at every 4.5m with two different colours so that the distance between similar coloured marks is 9m. Thus the marks on even numbered positions have one colour and odd numbered positions have another colour.

The first (odd) mark is placed on the 2nd stake of B_1 and last mark on second stake of B_2. Now mark palm positions by placing the stakes on the other colours (even). Remove the chain and place it on 3rd stake of B_1 and B_2 and mark the positions by putting stakes on other coloured mark (odd) and continue till the block is completed.

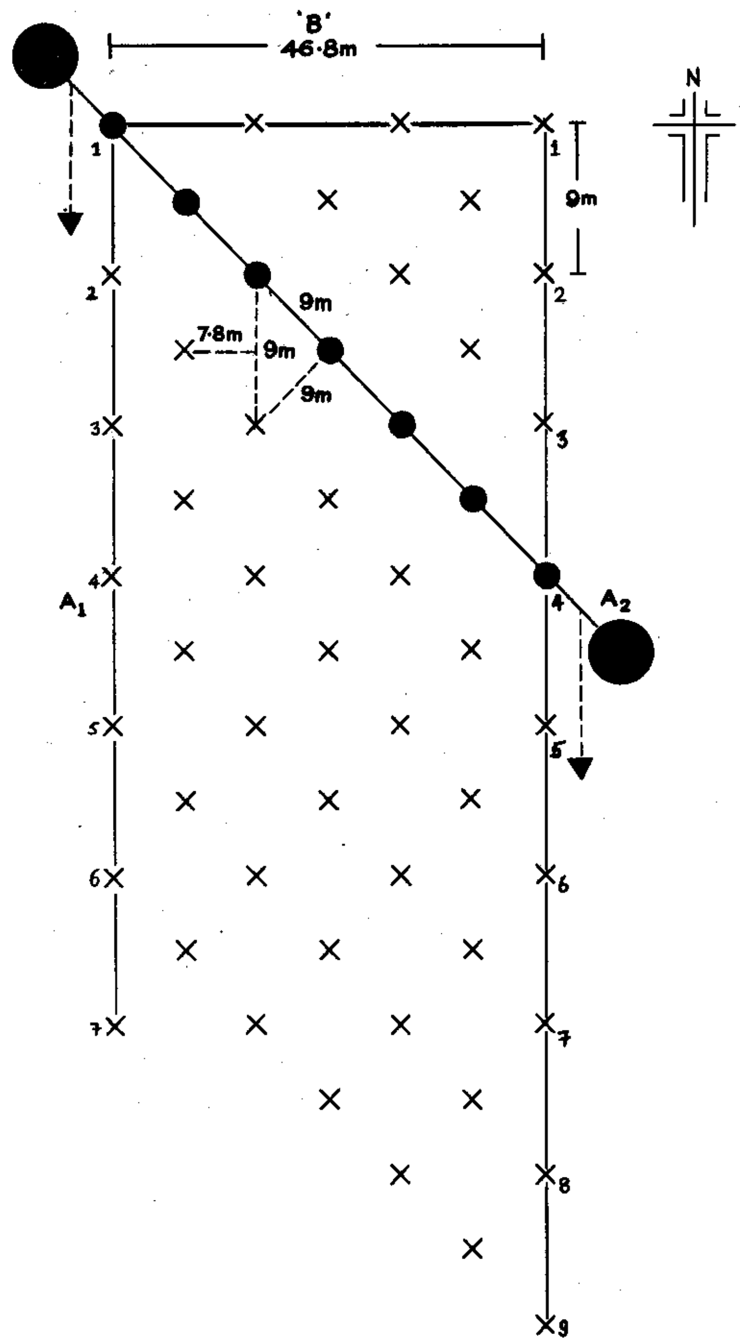

Fig. 1 : Equilateral triangular system of planting - Method 'A'

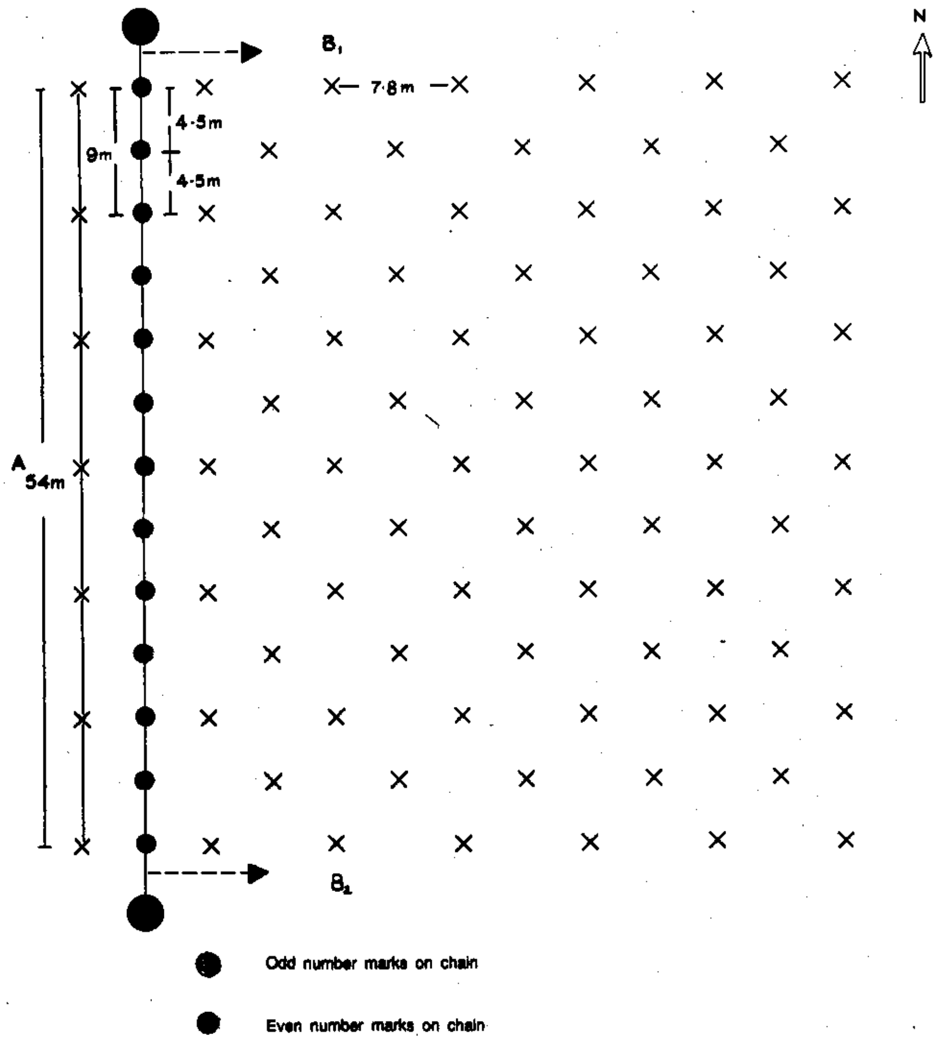

Fig. 2 : Equilateral triangular system of planting - Method 'B'

Transporting seedlings and preparing pits

While transporting seedlings to the planting site one hand is placed at the bottom of the bag while holding the plant collar with the other one. Leather gloves can be used to avoid injury with spines of the leaves.

Pits of 60 cm^3 are taken prior to planting, and filled with surrounding top soil and allowed to settle. In the refilled and root zone soil, a depression sufficient to cover the ball of earth is made at the time of planting.

After removing the bag by cutting edges, the plant is carefully placed in the depression with the ball of earth. The surface of the ball of earth must be at the soil level as planting below or above the soil level is not congenial for the later development of the seedlings. The space in between the ball of earth and the hole is filled and compacted.

Protecting the seedling by placing wire net around the base of the seedling at the time of planting is practised in areas where wild boar or rodents are prevalent. Rock phosphate is applied @ 200g. per planting pit. Nitrogen is not usually applied in the planting pit as the application of fertilizer may damage the root system and affect survival of the plants if there is a dry period soon after planting. Nitrogen and Potassium are usually applied 4-6 weeks after planting. In Mg deficient soils magnesium is applied @ 100g anhydrous $MgSO_4$ or 200g epsum salt per seedling.

Replacement and gap filling

Field inspection is carried out one to two months after planting to gap fill dead plants. Replanting is carried out during the onset of next monsoon. These palms are to be given special care so that they can catch up with the rest of the plantation. Yeow *et al.*, (1981a) observed that early production of more female inflorescences in the initial 30 months, is an indication of high yielders and all those that fail to produce female bunches will remain as poor yielders. However, replacements are found to be affected to some extent by the vigorous growth of the neighbouring palms which will shade the replanted palms.

Establishment and management of cover crops

The more commonly used cover crops that can establish very well in oil palm plantation in India are *Pueraria phaseoloides, Calopogonium mucunoides, Centrosema pubescens* and *Mimosa invisa*. *Pueraria* is found to establish very well and spread fast in the oil palm plantations of Kerala and Andhra Pradesh. *Pueraria* seeds require treatment with concentrated sulphuric acid (scarification) or soaking for 12-24 minutes and subsequent heat treatment for one hour at 39-40°C. Inoculation of the seeds with specific Rhizobium species has to be carried out for better nodulation and rock phosphate has to be applied at the time of planting. *Calopogonium mucunoides* seeds are soaked in conc. H_2SO_4 for 15-20 minutes and the acid is repeatedly washed out with hot water. Maintenance of these covers consists of cutting back the adventitious growth to 30 cm by cutlassing sometimes as many as six times a year. Rings around the palms need frequent clearing to keep the palm basin clear so that the palms are not covered by the creepers especially the young palms. As the palms grow and shade the area, ground cutlassing can be reduced to one or two ring cutlassing depending on the growth of the cover crops. Cutlassing of *Pueraria* is carried out twice in young plantations and once in adult plantations in Cote d' Ivoire (Surre and Ziller, 1963).

Mixture of three cover crops viz. *Calopogonium*, *Centrosema* and *Pueraria* are also successfully raised in oil palm plantations in Asian countries.

Ablation

The bunches produced initially will be very small and have low oil content. Removal of such inflorescences is called ablation or castration. Removal of all inflorescences during the initital three years is found to improve vegetative growth of young palms so that regular harvesting can commence after three and half years of planting. Ablation is done at monthly interval by pulling out the young inflorescence using gloves or with the help of devices such as narrow bladed chisels. Ablation improves drought resistance capacity of young palms by improving shoot and root growth especially in low production areas where dry condition exists.

Pruning of leaves

In oil palm two leaves are produced per month. Therefore, it becomes necessary to prune excess leaves so as to gain access to bunches for harvest. Severe pruning will adversely affect both growth and yield of palm, cause abortion of female flowers and also reduce the size of the leaves. It was suggested by Yeow *et al.*, (1981 b) that palms aged 4-7 years should retain 6-7 leaves per spiral (48-56), those aged 8-14 years 5-6 per spiral (40-49) and those above 15 years should have 4-5 leaves per spiral (32-40). Leaf pruning is carried out in India using chisels (Fig. 3) so that leaf base that is retained on the palm is as short as possible for otherwise it may catch loose fruits, allow growth of epiphytes and the leaf axils form a potential site for pathogens. The leaf petioles are removed by giving a clear cut at a sufficient distance from the base of the petiole using a sharp chisel for young palms and with the long sickle in taller palms.

Pruning is preferably carried out at the end of the rainy season. It is also better to carry it out during the low crop season when labourers are also available. Pruning is

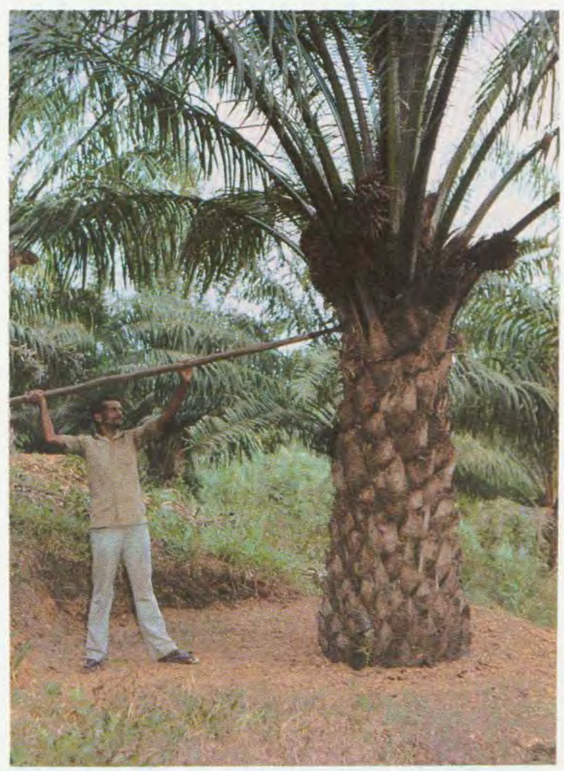

Fig. 3 : Leaf pruning

confined to only lower senile leaves during initial harvests but when canopy closes in later years, leaves are cut so as to retain two whorls of fronds below the ripe bunch. (Turner and Gillbanks, 1974).

Weed control

The basin area of oil palm is kept free of weed growth through ring weeding. It is more important for young palms, roots of which are to be kept free from competition from weed. Depending on the extent of weed growth and rainfall, hand weeding is carried out even up to four times in a year during early years of the plantation which is progressively reduced to two rounds a year.

Herbicide application has become common in recent years. Care must be taken in the choice of herbicide and its application to prevent the damage of young palms. It is recommeded to preferably apply contact herbicides rather than translocated herbicides. Translocated herbicides like paraquat which is inactivated when contacted with soil are also used. Herbicides such as 2,4-D, 2,4,5-T, halogenated aliphatic acids dalapon and TCA are found to produce abnormalities in oil palm seedlings and are to be avoided (Hartley, 1988). Herbicide mixtures of 2kg ai of paraquat with 3-4 kg atrazine monuron and diuron per ha of sprayed ground applied twice a year has been found to give control of weeds in young palms in Nigeria (Sheldrick, 1968).

Maintenance of paths

In young plantation, the maintenance of paths is important for inspection and in later years for harvesting. This is carried out by timely weed control as done in the case of ring weeding.

Water requirement

Continuous soil moisture availability encourages vigorous growth and increases yield of oil palm. Adequate supply of water, good soil depth and water holding capacity contribute to water availability. In oil palm as water deficit increases, stomata will remain closed and the development and opening of spear will be inhibited. Water deficit adversely affects flower initiation, sex differentiation and therefore, results in low sex ratio due to production of more male inflorescences. Relationship between water deficit and bunch yield were reported by IRHO.

Irrigation experiments conducted in Grand Drevin and La Me (Ivory Coast), Benin (Dahomey) and Malaysia have all indicated the positive effects of irrigation on leaf production , sex ratio, reduction in inflorescence abortion and overall bunch yield and oil yield. (Desmarest, 1967; de Taffin and Daniel, 1976; Corley and Hong Theng Phong, 1981). From irrigation trials conducted in West African countries where several months of dry period exists, it has been reported that with irrigation, yield levels as high as that of far east could be obtained. In India, oil palm planting programmes are envisaged in relatively dry regions of Karnataka, Andhra Pradesh and Tamil Nadu with assured water supply. The growth of palms so far is very encouraging and the palms have started yiedling after three years.

It is established that oil palm needs 120-150 mm of water to meet its monthly evapotranspiration needs. In areas where sufficient perennial water source is available, basin irrigation is possible. But where the terrain is undulating and water is scarce during summer months, drip irrigation is recommended which has the advantage of water economy and limiting the loss. It is recommended to keep four drippers per palm in the weeded palm circle to supply at least 90 litres of water per palm per day during summer months which will vary according to the ETP values in a locality.

Fertilizer requirement

Based on fertilizer experiments conducted under rainfed conditions in India, the following fertilizer schedule is recommended for oil palm until specific results are derived from multilocational fertilizer trials.

Fertilizer recommendation for oil palm

Age	Nutrients (gram/palm/year)		
	N	P_2O_5	K_2O
First Year	400	200	400
Second Year	800	400	800
Third Year and onwards	1200	600	1200

Method of fertilizer application

The fertilizers are preferably applied in two equal split doses during May-June and September-October by uniformly spreading them within a 2 metre circle around the base of the palm and forking to incorporate them into the soil. Supply of sufficient quantity of green leaves or compost is advantageous

Fig. 4 : Fertilizer application

especially where the soil is poor in organic matter content. Mg deficiency can be corrected through the application of 500g $MgSO_4$ palm/year magnesium sulphate.

Urea is found to be the most economic nitrogen source if losses by volatilisation and leaching are minimized. Rock phosphate and muriate of potash are the best sources for phosphorus and potassium respectively. During the initial years, fertilizers may be applied within the area covered by the crown canopy. In the case of older palms, fertilizers are applied depending on the concentration of roots and are usually applied in the weeded circle. Appropriate soil conservation methods such as growing cover crops and platform cutting (on slopy lands) enhance the efficiency of fertilizers by preventing losses through run off.

Nutrients - Functions and deficiency symptoms

The effect of major nutrients on growth and yield of oil palm has been studied in most of the oil palm growing countries in Asia and Africa (Nair and Sreedharan, 1982.)

Nitrogen In oil palm, characteristic yellowing symptoms are developed under N-deficiency conditons. Nitrogen is found to be essential for rapid growth and fruiting of the palm. It increases the leaf production rate, leaf area, net assimilation rate, number of bunches and bunch weight. Excessive application of nitrogen increases the production of male inflorescences and decreases female inflorescences thereby reducing the sex ratio.

Phosphorus In oil palm seedlings, P-deficiency causes the older leaves to become dull and assume a pale olive green colour while in adult palms high incidence of premature desiccation of older leaves occurs. Phosphorus application increases the bunch production rate, bunch weight, number of female inflorescences and thereby the sex ratio. However, lack of response to P due to P-fixation in soils is very common in the tropics. Eventhough the main effect of phosphorus on the productivity of the palm has not been significant in most studies, it gives a positive interaction with nitrogen and potassium.

Potassium When potassium is deficient, growth as well as yield is retarded and it is translocated from mature leaves to growing points. Under severe deficiency, the mature leaves become chlorotic and necrotic. Confluent orange spotting (Bull, 1954; Hartley, 1988) is the main K-deficiency condition in oil palm in which chlorotic spots, changing from pale green through yellow to orange, develop and enlarge both between and across the leaflet, veins and fuse to form compound lesions of a bright orange colour. Necrosis within spots is common, but irregular. Mid crown yellowing (Chapas and Bull, 1956; Hartley, 1988) is another prominent K-deficiency condition of the palm in which leaves around the 10th position on the phyllotaxy become pale in colour followed by terminal and marginal necrosis. A narrow band along the midrib usually remains green. There is a tendency for later- formed leaves to become short and the palm has an unthrifty appearance with much premature withering.

Potassium removal is large compared to the normal exhangeable K content in most top soils. It is mostly required for the production of more number of bunches, maximum number of female inflorescences, increased bunch weight and also for increasing the total dry matter production and yield.

Magnesium In adult oil palm and in seedlings in the field, severe Mg-deficiency symptoms are most striking and have been named as 'orange frond' (Hartley, 1988). While the lowermost leaves are dead, those above them show a gradation of colouring from bright orange on the lower leaves to faint yellow on leaves of young and intermediate age. The youngest leaves do not show any discolouration. The most typical Mg-deficiency symptom is the shading effect in which the shaded portion of the leaflet will be dark green while the exposed portion of the same leaflet is chlorotic. Heavy rates of K applications induce Mg-deficiency, particularly on poor acid soils.

Among the major nutrients, calcium and sulphur, and probably chlorine, may not pose much problems to oil palm cultivation in the country.

Micronutrients Micronutrient elements, iron, manganese, copper and zinc are not generally found limiting in the nutrition of oil palm on acid soil conditions. Boron deficiency is occasionally found on young palms in the field being; a reduction of leaf area in certain leaves producing incipient 'little leaf', advanced "little leaf' with extreme reduction of leaf area and bunching and reduction in the number of leaflets and 'fish-bone' leaf. The 'fish -bone' leaves are abnormally stiff with leaflets reduced to projections. Leaf malformations including 'hook leaf' and corrugated leaflets are some other associated symptoms. Soil application of 50–200g borax decahydrate, depending on age, and severity of symptoms, is practised for correcting the malady. (Rajarathnam, 1972; Hartley, 1988).

Multiple cropping

Though intercropping is not a normal practice in oil palm plantations, there is ample scope for intercropping in the initial years of the plantations. Growing food crops in oil palm plantation is common in Africa. In American Plantations, grazing of cattle or sheep is also practised in oil palm plantation. During the early years of the plantation, maize, cassava and yams (*Dioscorea sp.*) which require more light and during later years shade tolerant crops like *Colocasia* and *Xanthosoma* are successfully grown along with oil palm. Both the main crop and intercrop have to be separately manured to reduce competition for nutrients. It is better to confine intercropping to strips 4-5 m width between rows and down the avenues instead of intercropping the whole area.

Intercropping with tropical tubers is possible in India. Annuals like tobacco and chillies are being successfully grown in young plantations of Andhra Pradesh and Karnataka. Mixed cropping experiments with shade loving bushy perennials were also conducted in oil palm plantations. From trials conducted at CPCRI Palode, cacao was found to come up very well in oil palm plantations without any adverse effect on yield of oil palm. Robusta coffee is also found to be a successful mixed crop in Africa and Far East. Vanderweyen (1952) recommended planting of cacao when the palms are 7-8 years old and attain a height of 1.8 m in two rows between normally spaced palms at 9 m triangular spacing. Marynen (1960) from trials in Zaire suggested that

Fig. 5 : Intercropping with tobacco

coffee can be planted along with oil palm and may be removed after seven years. More field trials are necessary to find out the advantages of various cropping systems during different stages of oil palm growth.

Harvesting

Proper and timely harvesting of fruit bunches is an important operation which determines the quality of oil to a great extent. The yield is expressed as fresh fruit bunches (FFB) in kg per hectare per year or as oil per hectare per year. The bunches usually ripen in six months after anthesis. Unripe fruits contain high water and carbohydrate and very little oil. *As the fruit ripens oil content increased to 80-85% in mesocarp. Over ripe fruit contains more free fatty acids (FFA) due to decomposition* and thus increases the acidity. Usually the ripe fruits attached to the bunches contain 0.2 to 0.9 % FFA and when it comes out of extraction plant the FFA content is above 3%.

Ripeness of the fruit is determined by the degree of detachment of the fruit from bunches, change in colour and change in texture of the fruit. Ripening of fruits start from top downwards, nigrescens fruits turning reddish orange and the virescens (green) to reddish brown. Fruits also get detached from tip downward in 11-20 days time. Ripeness is faster in young palms than in older palms for the bunches of equal weight.

The criteria used in determining the degree of ripeness based on the fruit detachment are as follows:

a) fallen fruits : 10 detached or easily removable fruits for young palms and 5 for adult palms.

b) number of fruits detached after the bunch is cut : 5 or more fruits/kg of bunch weight.

c) quantity of detachment per bunch : fruit detachment on 25% of visible surface of bunch.

These criteria could be applied with flexibility.

Frequency of harvesting

Harvesting rounds should be made as frequent as possible to avoid over-ripening of bunches. A bunch which is almost ripe but not ready for harvest for a particular harvesting round should not be over-ripe by next round. In lean period of production, harvesting can be made less frequent and it should be more frequent in peak periods. Harvesting rounds of 7-14 days are generally practised. Other factors determining the harvesting frequency are, extraction capacity of the mill, transportation facilities, labour availability and skill of the workers. In India, harvesting is usually carried out with a chisel of 6-9 cm wide attached to a wooden pole or light hollow aluminium pipe. Bunches are cut without damaging the petiole of neighbouring leaves and trying not to eliminate the leaf that supports it. Use of narrow chisel is usually carried out till the palm reaches two meters above the ground. For taller palms upto 4 meters , a wider chisel of 14 cm is used. The curved knife is attached to a long bamboo or aluminium pole with screws or steel wires to harvest from taller palms. In uneven stands, an adjustable, telescopic type of pole is in use.

Economics

A detailed account of the economics of oil palm cultivation in India has been furnished by Varghese and Nampoothiri (1988). The data furnished therein is modified using current labour charges and oil price and the details on various investments and returns from one hectare adult plantation is furnished in the Table 1, 2. This excludes the cost of land as we expect government owned land, leased land, or already owned property will be used for oil palm cultivation. From the fourth year, the yield of bunches increases upto tenth year and a stabilized bearing is attained thereafter. The investment during first year under irrigation will be almost three times of that under rainfed conditions mainly on account of the initial expenditure required to install the drip irrigation systems. With irrigation the annual returns will exceed the annual expenses from the first harvest itself i.e. during the fourth year after planting. By the end of sixth year the total returns will be more than total investments including all the expenditure for installing pumpset and the drip irrigation system. A minimum of 22t FFB per hectare can be expected from the tenth year onwards.

1. Labour cost is calculated @ Rs. 40/- per day.
2. Yield of 15t under rainfed and 22t under irrigated condition are the actual average yield obtained at Palode from 10th year onwards. This can go up to 30t/ha with high yielding genotypes and added management practices as is estimated from the initial growth of palms in Andhra Pradesh and Karnataka.
3. Capital investments such as cost of land, cost of pumpset and irrigation system, etc. has not been included.
4. Intercropping is also possible in oil

palm plantations with annual crops during the initial 5 years and again after 10 years. Profitability from intercropping has not been taken into account.

Table 1. Income from one hectare of oil palm plantation - pure crop - after yield stabilization (10th year onwards)

Produce	Rainfed - average yield obtained at Palode		Irrigated - average yield obtained at Palode		Irrigated - anticipated yield with high yielding Genotype and added inputs.	
	Quantity and Rate	Amount Rs.	Quantity and Rate	Amount Rs.	Quantity and Rate	Amount Rs.
FFB Yield/ha Oil 20%	15t 3t @ Rs. 20,000/-t	60,000	22t 4.4t @ Rs. 20,000/-t	88,000	25t 5t @ Rs. 20,000/-t	1,00,000/-
Kernel oil	300kg @ Rs. 35/- kg	10,500	440 kg @ Rs. 35/- kg	15,400	500 kg @ Rs. 35/- kg	17,500/-
Fronds (firewood)	24 frondsx 140 @ Rs. 3/24.	420	24 fronds x 140 @ Rs. 3/24 fronds	420	24 fronds x 140 @ Rs. 3/24 fronds	420/-
Total income		70,920/-		1,03,820/-		1,17,920/-

Table 2. Cost of production and extraction charges (Rs.) per hectare

	Rainfed	Irrigated
Labour cost 150xRs. 40/-	6,000	8,000 *
Fertilizer cost	2,000	2,000
Plant protection cost	200	200
Total cost of production	8,200	10.200
Oil extraction charges	7,000	8,000
Total expenditure	15,200	18,200

* 200x40

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PESTS

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Introduction

In equatorial Africa, which is the native home of oil palm (*Elaeis guineensis* Jacq.), except for the incidence of Hispid beetle *Coelaenomenodera minuta*, no other major insect pests are noticed. However, in all the other countries, where oil palm is an introduced crop, pest problems have been frequent and severe. In India also, oil palm is infested by a wide range of fauna which include insects, birds and mammals (Dhileepan 1989, 1990).

INSECT PEST COMPLEX

In India, since the import of germplasm is in the form of seeds/sprouts, possibilities for introduction of the pest species from other countries are limited. But many of the pest species of related palm species such as coconut and areca palm, have got adapted to oil palm. Survey of oil palm plantations and nurseries in India indicated that about 59 species of insects attack oil palm (Dhileepan, 1988, 1991a, 1991b, 1992). Eight out of 20 species of insects infesting oil palm nursery are known pests of areca palms. Among the 49 species of insects infesting adult oil palms, 14 species are known pests of coconut and 19 species are known pests of areca palms. Insect pests of oil palm in India are more or less same as those reported from Malaysia and other South-East Asian countries.

Pest of oil palm nursery

1. The spindle bug

The spindle bug *Carvalhoia arecae* Miller & China (Miriidae: Heteroptera), primarily a serious pest of areca palms, has in recent years attained the pest status in oil palm also. However, intensity of infestation by C. *arecae* in oil palm is comparatively lesser than in areca palms. The nymphs and adult bugs suck the sap from the spindle and the unfolding leaves, resulting in linear necrotic lesions (Fig. 1). Infestation by *C. arecae* in the oil palm nursery was noticed only in Kerala, where the intensity of infestation ranged from 11.8 to 31.8 per cent. At Palode spindle bug infestation was noticed throughout the year, and the

Fig. 1. Spindle bug infested leaf

incidence was highest during the month of June. In the nursery, the spindle bug infestation was higher when the seedlings were maintained under areca garden than under oil palm plantation.

The tussock caterpiller

The tussock caterpiller *Dasychira mendosa* Hb. (Lymantriidae : Lepidoptera) a polyphagous insect, is a known pest of areca palm, cacao and other crops. They also infest oil palm, especially in the nursery at Palode and Shimoga. The larvae feed on the young and mature leaves, causing considerable defoliation. The percentage of seedlings defoliated ranged from 3 to 11 at Palode and around 20 at Shimoga. In Kerala, though infestation by *D. mendosa* was noticed throughout the year, the highest incidence was recorded during the months of June-July, coinciding with the onset of rains.

Other insects infesting nursery

Pseudococcids (*Dysimicoccus brevipes* and *Palmicultor* sp.) and Margarodids (*Icerya aegyptiaca*) infest the spear leaves of oil palm seedlings. Aphids *Mysteroneura* setariae and *Schizaphis rotundiventris* colonizing on the under-surface of older leaves, and Pseudococcid *Pseudococcus citriculus* encrusting spear leaves are the potential pests. Occasionally *Spodoptera litura* also causes defoliation in Kerala and Andhra Pradesh. Cockchafer beetles (*Apogonia* sp. and *Adoretus* sp.) and grasshoppers make short feeding holes in the older leaves of the seedlings. Other insects infesting oil palm nursery include *Gangara thyrsis, Paratettix* sp., *Proutista moesta*, termites, and *Ricania speculum*.

Pest of adult palms

In the adult palms, the rhinoceros beetle *Oryctes rhinoceros* (L.) and the red palm weevil *Rhynchophorus ferrugineus* (Oliver) are the major pests, while Limacodids and Psychids causing frequent defoliation and Coccoids infesting fruit bunches are minor pests. Termites and Pseudococcids are the potential pests (Table 1).

The rhinoceros beetle

The rhinoceros beetle *Oryctes rhinoceros* (L.) is primarily a serious pest of coconut palm, and in recent years has attained the pest status in oil palm also (Dhileepan, 1988). Infestation by *O. rhinoceros* was noticed in the oil palm plantations in Kerala, Karnataka, Andhra Pradesh, Maharashtra and Gujarat states, as well as in the Little Andaman Island (Table 2). The adult beetle which bores through into the spear leaves, resulting in snapping of the fronds at the feeding sites (Fig.2). However, unlike in coconut, damage to inflorescence was not noticed in oil palm. In the oil palm plantations, failed female inflorescences, dead palm trunks, persistent leaf axils and empty bunch heaps, act as breeding sites for the pest. However, intensity of infestation by *O. rhinoceros* in oil palm is relatively less than that in coconut.

The red palm weevil

Infestation by the red palm weevil *Rhynchophorus ferrugineus* (Oliver) was noticed in majority of the oil palm plantations in Kerala, usually resulting in death of the palms. However, intensity of infestation by *R. ferrugineus* in oil palm was less frequent when compared with that in coconut palm. Damage is due to the feeding activity of the grubs, usually 12-87 per palm, which bore through

Table 1. Important insect pests of oil palm in India

Insect pest	Family	Nature of damage	Category
COLEOPTERA			
Oryctes rhinoceros (L.)	Scaraebaeidae	Adults bore into fronds and spindle	+++
Rhynchophorus ferrugineus (Oliver)	Curculionidae	Grubs feed on soft tissues of stem and meristem and kill the palm	+++
HETEROPTERA			
Carvalhoia arecae M. & C.	Miriidae	Adults and nymphs infest spears in the nursery and cause spindle necrosis	+++
HOMOPTERA			
Pinnapsis aspidistrae (Signoret)	Diaspididae	Encrust ripe and unripe fruit bunches	++
Hemiberlesia lataniae (Signoret)	Diaspididae	- do -	++
Chrysomphalus aonidum Linn.	Diaspididae	Encrust fruit bunches and leaves	++
Dysmicoccus brevipes (Cockerell)	Pseudococcidae	Infest male and female inflorescences and ripe fruit bunches	++
Palmicultor sp.	Pseudococcidae	Infect spear and unfolding leaves	++
LEPIDOPTERA			
Dasychira mendosa Hb.	Lymantriidae	Larvae cause defoliation in nursery	+++
Manatha albipes Moore	Psychidae	Larae cause defoliation in adult palms	+
Metisa Sp.	Psychidae	Defoliation due to frequent out-breaks	+++
Eumeta sp.	Psychidae	- do -	++
Thosea andamanica Holloway	Limacodidae	Defoliation due to frequent out-breaks	+++
Darna Jasea (Swinhoe)	Limacodidae	Larvae cause occasional defoliation	+
ISOPTERA			
Odondotermes sp.	Termitidae	Feed on the roots, inflorescences, spear and fruit bunches.	++

+++ Major pests ; ++ Minor pests ; + Potential pests.

Table 2. Intensity of infestation by *Oryctes rhinoceros* in the oil palm plantations in India.

State	area (ha)	% infestation
Kerala	3860 ha	1.5 - 13.5
Andhra Pradesh	1050 ha	0.3 - 15.0
Karnataka	1020 ha	3.6 - 63.6
Gujarat	2 ha	15.0 - 20.0
Little Andamans	1593 ha	<0.01

and feed on the softer tissues of stem and meristem. Palms infested by *R. ferrugineus* show gradual wilting and drying of outer whorl of fronds. In some cases, rotting of spear was also noticed. Except for the stray incidence at Manvi (Karnataka) and Eluru (Andhra Pradesh), infestation by *R. ferrugineus* has not been reported from other oil palm growing areas of this country.

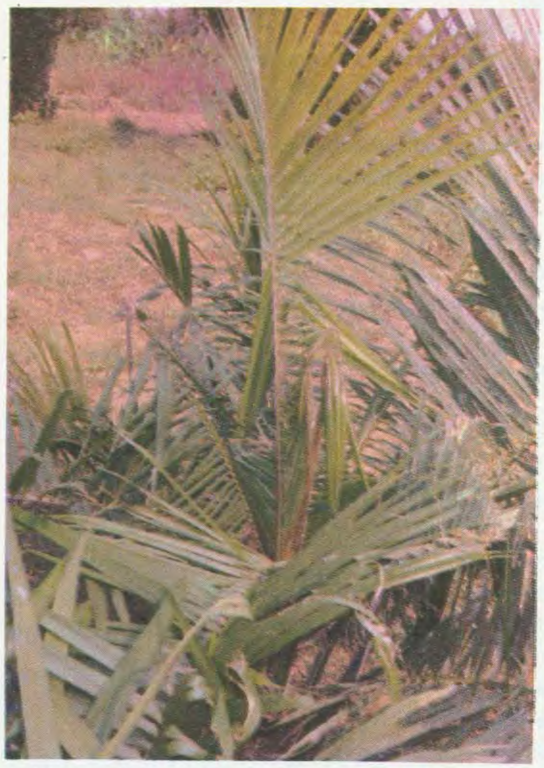

Fig. 2. Rhinoceros beetle infestation

Scales and mealybugs

Around 20 species of Coccoids (Pseudococcids, Diaspids, Coccids and Margarodids) were reported in India (Dhileepan, 1991b, 1992). Among them Diaspids *Hemiberlesia lataniae* (Signoret), *Chrysomphalus aonidum* Linn. and *Pinnapsis aspidistrae* (Signoret), and Pseudococcid *Dysmicoccus brevipes* (Cockerell) infesting oil palm fruit bunches are of economic importance (Table 1). At Chithara and Kulathupuzha plantations in Kerala, 3.1 to 10.7 per cent of the unripe bunches and 39.5 to 100 per cent of the ripe bunches were infested by Coccoids. However, the actual economic loss due to this pest, particularly the quality of oil is yet to be assessed. The pseudococcid *Palmicutor* sp. infested the spear cluster and unfolding leaves of the newly planted oil palm in Shimoga in Karnataka State, resulting in yellowing of unfolding leaves and stunted growth of the palm.

Nettle caterpillers and case worms

So far, nine species of caseworms (Psychids) and three species of nettle caterpillers (Limacodids) infesting oil palm were recorded (Dhileepan, 1991b, 1992). Among them Psychid *Manatha albipes* Moore causing occasional defoliation in Yeroor plantation is of economic importance (Table 1). In Little Andaman Island, Psychids Metisa sp. and *Eumeta* sp., and *Limacodid Thosea andamanica* Holloway, attained major pest status, causing severe defoliation (Fig 3) due to frequent out-breaks. Infestation by Psychids and Limacodids was restricted mostly to outer whorl of fronds and occasionally in the middle whorl of fronds.

Termites

In Andhra Pradesh, termite *Odontotermes* sp. infested the spear leaves, male inflorescence and fruit bunches in the main field. Termite attack was noticed in 22.7percent of the field planted palms in Andhra Pradesh, and was restricted to oil palm plantations with red soil and without adequate irrigation. In Karnataka, two species of termite, *Pericapritermes* sp. and *Hypotermes* sp. feed on the root of the seedlings maintained in polybags, resulting in stunted growth of the seedlings.

Other sap feeding insects

In the young oil palm plantations at Palode, infestation by *Carvalhoia arecae* was noticed only when under-planted in areca

Fig. 3. Psychid infested oil palm

garden; while no incidence was noticed when planted in cleared forests or under-planted in coconut garden. Occasional infestation by *C. arecae* was also noticed in the young field-planted palms at Charmadi, Karnataka State. In Little Andamans, the aphid *Astegopteryx rhaphides* (Van der Goot) encrusted the oil palm and coconut leaves during summer months. Among the other sap feeding insects, *Proutista moesta* (Westwood), which is noticed in all the oil palm growing areas, attains importance, as they are known to be vector of MLOs (Mycoplasma like organism) causing root (wilt) disease of coconut and yellow leaf disease of areca palms in Kerala.

Pest incidence in relation to intercrops

In Andhra Pradesh and Karnataka States, the pest incidence varied depending upon local crops as well as upon the intercrops. In Karnataka, Pseudococcid (*Palmicultor* sp.) infestation was more prevalent, when oil palm was grown near sapota (*Achras sapota*) trees. Similarly, oil palm nurseries located near sugarcane fields had a very high incidence of aphid infestation. In Andhra Pradesh, defoliation by *Spodoptera litura* was noticed when oil palm was grown near tobacco fields or when tobacco was grown as an intercrop with oil palm. In both Karnataka and Andhra Pradesh, infestation by *O. rhinoceros* in oil palm was more severe, when under-planted in coconut gardens, than as a pure crop. However, raising other intercrops like sorghum, maize, mulberry, lilly, onion, chilly, banana, groundnut etc., as practised in Andhra Pradesh, did not cause any pest problem to oil palm (Dhileepan, 1992).

Strategies for pest management

Oil palm is an entomophilous crop, and hence the pollinating weevil *Elaeidobius kamerunicus* Faust was introduced and established in all the oil palm plantations in India (Dhileepan and Nampoothiri, 1989. Indiscriminate application of pesticides will adversely affect the weevils, thereby the normal fruitset as well. Hence use of pesticides is to be restricted, unless it is essential.

Biological control

In nature, the rhinoceros beetle is suppressed by entomopathogens like *Baculovirus oryctes* (virus) and *Metarhizium anisopliae* (fungi). Re-release of Baculovirus of *Oryctes* in the oil palm plantation at Palode minimized the pest incidence. The spindle bug *Carvalhoia arecae* is also naturally suppressed by an entomopathogen *Aspergillus candidus* Link, during the rainy season, which is the peak period of pest incidence (Dhileepan et al., 1990). Various Diaspide infesting oil palm at Palode and Yeroor are naturally suppressed by Coccinellid predator *Chilocorus nigrita*. Introduction of *C. nigrita* to the other oil palm plantations like Chithara and Kulathupuzha appear promising. In Little Andaman, the Diaspid *Aspidiotus destructor* infesting oil palm leaves are naturally suppressed by Coccinellid *Chilocorus coelosimilis*.

Cultural control

i) Field sanitation and elimination of breeding sites like dead palm trunks, empty bunch heaps, etc., within the plantations are essential for the management of both red palm weevil and rhinoceros beetles.

ii) When the infestation by rhinoceros beetle is very high, especially in young plantations, hand picking of the adult beetles using hooks is very effective.

iii) For red palm weevils, use of attractants incorporating fermented sugarcane juice, acetic acid, oil palm petioles, yeast, etc., to collect and kill the adult weevils is recommended.

iv) Regular weeding of the oil palm plantation will minimize the damage by cockchafers, grasshoppers and burrowing rodents.

Chemical control

i) For rhinoceros beetles, placing 3-4 napthalene balls in the youngest spear axils at weekly intervals is recommended.

ii) For spindle bug, when the intensity of infestation is very high, placing 1-2 phorate sachets (0.2 g ai) in the axils of the new leaves is advised.

iii) For palms with advanced stage of infestation by red palm weevil, stem injection of 5-8 ml of monocrotophos is advised.

Vertebrate pests of oil palm

The following vertebrate pests have been found damaging oil palm fruits and crop in the field.

Birds

Crows - *Corvus splendens protegatus; Corvus macrorhynchus culminatus* .
Mynah - *Acridotheres tristis tristis*
Babbler - *Turdoides affinis affinis*
Parrots - *Psitticula krameri manillensis*

Rodents

Black rat - *Rattus rattus wroughtoni*
House rat - *Rattus rattus rufescens*
Lesser bandicoot - *Bandicota bengalensis*
Larger bandicoot - *Bandicota indica*
Indian gerbil - *Tatera indica cuvieri*
Western Ghat squirrel - *Funambulus tristriatus*

Porcupines - *Hystrix india*

Larger mammals

Wild boar - *Sus scrofa*

Birds feed on the mesocarp and cause fruit loss upto 2.8 t/ha/year (Dhileepan, 1989). Rodents tunnel into the bole of the young seedlings and kill them. Wild boar dig up newly planted seedlings and chew them up.

Schedule V of wild life protection act 1972 as amended up to date, classifies crows, fruit bats, mice and rats as vermins and all other wild vertebrates in Indian territory are protected under wild life protection law. In order to maximise oil palm production, it is essential to minimise, divert, scare or stop these pests from the plantation. Oil palm seedlings and young palms upto the age of three years are more prone to rodents and wild boar damage after which the palm becomes sturdy and resistant to their attack. Since any one of these methods is completely fool-proof, a management practice based on an integrated approach is outlined below:

Fruit bunch covering against avian pests

Covering the bunches with different materials such as wire nets, reed baskets, plaited coconut leaf baskets and senile oil palm leaf are effective in preventing the fruit damage. But senile oil palm leaf covering is more practical and economical as the material is readily available and involves only the labour charge and cost of rope bits (Fig. 4) (Table 3).

Table 3. Cost of protection of oil palm fruit bunches from birds using different treatments

Treatments	Cost of material (ready for use)	No. of times used	Material cost per bunch (90-91 rates)	Labour charge for fixing per bunch	Total cost per bunch	Efficiency (% of FFB protected	Defects if any.
1. Wire net: 60 x 90 cm 1/2" x 22 gauge binding wire	7.91	3	2.96	1.10	4.06	80-90	Birds may peck through
2. Reed basket locally made fixed with rope	15.40	3	5.40	1.10	6.50	100	2-3 additional leaves have to be cut for fixing
3. Plaited coconut leaf basket locally made fixed with rope	3.30	1.2	3.15	1.10	4.25	80-85	birds may peck through
4. Senile oil palm leaf tied with rope	0.40	1	0.40	1.10	1.50	95-100	leaves become too brittle if kept before 3 months

Labour charge : Rs. 40/- per day

Fig. 4. Covering of fruit bunches against avian pests

Wild boar scaring device

A local wild boar scaring device (Fig. 5) has been improved to scare away wild boar from entering into nurseries and young oil palm plantations. The device consisted of (i) 18 gauge g.i. wire (ii) guide hooks (iii) crushing slabs (iv) poles of approximately 1 meter high (v) junction box having the scaring crux (vi) 4" long oval plays and (vii) 5 g cracker made of gunpowder.

The project area is fenced with the 18 gauge g.i. wire at 8" height on two lines parallel from ground supported on the poles and kept in position with the help of guide hooks. The poles are positioned at 3 to 10 m spacing depending upon the terrain of the land. Junction boxes are made with the help of 4 poles, two crushing slabs, the two oval plays and cracker. This may be spaced at 5 to 15 meters apart depending on the landscape, boundaries, roads etc. The two fencing lines arriving at the junction boxes from oppisite sides are joined on to the oval plays and pulled closer and held in position with the help of a crushing slab hung from a third play kept on the first two plays. Underneath this crushing slab a cracker is kept. When the animal hits the fence, it will cause the first plays to pull apart and the crushing slab with the cracker hung will fall on to the crushing slab kept directly underneath, making the cracker burst. The method has been found very effective in scaring awary the animals.

Rodent control:

Among rats, the burrowing type is more serious which tunnel into the bole of the seedling which may cause even the death of seedlings. Different baits such as acute poison

Fig. 5. Wild boar scaring device

baits (zinc phosphide, aluminium phosphide etc.), anticoagulants (warfarin, fumarin, bromadiolone, brodifacum), and traps such as iron live traps, snap traps, deathfall trap, bow trap etc. may be used as an integrated approach to minimise the rodent damage to the crop.

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DISEASES AND DISORDERS

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Oil palm, a new crop to the country is reported to be affected by a number of diseases and disorders (Kochu Babu, 1988; 1989; Kochu Babu et al. 1990). Among these, only spear rot causes considerable economic losses. Other devastating diseases like vascular wilt, fatal yellowing, sudden wither and Ganoderma basal stem rot reported from other oil palm growing countries have not been reported so far from India. A brief description of the diseases and disorders identified so far in India and the management strategies for seed, nursery and oil palm plantations are given in this treatise.

Fig. 1. Brown germ disease

Seed

Spoilage of oil palm seeds by microbes occurs during storage and germination. Brown germ disease and *Schizophyllum* seed infection were observed in a few seed lots at Palode.

Brown germ disease

Brown germ affecting seeds during storage and different stages of germination is on record from several countries (Turner, 1971). At Palode losses upto five per cent have been recorded on preheated seeds. In such cases rotting of embryo and kernel was observed only on cracking of seeds. Just emerged sprouts show light brown spots on radicle causing discolouration and rotting. In most of the cases rotting extends to the mycropyle and subsequently the embryo ceases to develop. Sporulation of fungi are seen on the rotten area (Fig 1). The fungi isolated from affected seeds are *Aspergillus niger, A. terreus, Penicillium* sp., *Trichoderma viride, Botryodiplodia theobromae* and *Rhizopus nigricans*, which are ubiquitous in their distribution as saprophytes.

Mycophagous nematodes are abundant in some seed lots which hasten the spread of infection by fungi. Brown germ occurrence can be checked by removal of the mesocarp remnants, maintenance of seed moisture levels at 17 per cent during storage and preheating. Wet seed treatment in Emisan (Methoxy Ethyl Mercury chloride) 0.1 per cent solution for 20 min. before preheating of seeds is recommended to control the rot. In the event of post emergence rot the same fungicide treatment need to be repeated.

Schizophyllum seed infection

Few seed lots with more mesocarp remnants and high moisture levels during storage showed infection by *Schizophyllum coomune.* Occurrence of this disease has also been reported from Colombia, Malaysia and Papua New Guinea (Turner, 1971; Williams and Liu, 1976).

White patchs of fungal mycelium are noticed over the shell which later colonise the kernel also. Fructifications are formed at high moisture levels. Prophylactic seed treatment by dipping in emisan 0.1 per cent solution for 20 min. can prevent the infection.

Quarantine seed treatments

Methyl bromide fumigation of seeds at normal moisture content of 18 per cent affect seed germination and seedling vigour and hence cannot be used for seed treatment indiscriminately (Kochu Babu et at. 1991). However, the possibility of methyl bromide fumigation of oil palm seeds with low moisture content of 10 per cent at 75-80°F with 2 lb methyl bromide/1000 cft for 18 hrs without impairing viability, germination and seedling vigour has been indicated. The International phytosanitary seed treatments for disinfection of seeds consits of washing for 2 min in 0.2 per cent thiram plus 0.1 per cent teepol prior to preheating, during soaking after preheating, prior to despatch and on arrival at destination (Turner, 1981). Besides this the introduced seeds are to be kept under observation to spot out diseases.

Nursery

Early leaf diseases

Infection of young seedlings by species of *Glomerella, Botryodiplodia* and *Melanconium* are referred to as early leaf diseases (Turner, 1981). Incidence levels to the extent of five per cent has been observed in the nurseries raised in Karnataka. The symptoms caused by *Botryodiplodia* and *Glomerella* are described below:

Botryodiplodia theobromae

Small light brown spots develop on the distal portions of the leaves, which later change to dark brown. These lesions enlarge and are surrounded by yellowish halo. The entire leaf tips gets affected. Black dots (pycnidia of the fungi) are visible on the lesions. Healthy leaves coming in contact with the diseased one get infected.

Glomerella cingulata: The symptoms are different from that of *Botryodiplodia* in that lateral expansion is restricted by veins. Yellow to brown watersoaked lesions develop between veins and elongate. These lesions turn black and are surrounded by yellowish halo. The tissues at the centre dry and become brittle. Small dark dots (acervuli of the fungus) are seen in the lesions.

Clipping of the severely affected leaf protions and spraying with dithiocarbamates 0.2 per cent effectively control the disease.

Leaf rot

Stray incidence of leaf rot has been recorded in the primary nursery seedlings during the rainy period. The infection begins at the base of the spear as irregular pale olive green patches surrounded by brown zone, which later turn dark brown before drying. The pale dessicated tissues in the centre of the lesions shred easily and become tattered in appearance. *Corticium solani* is the causal agent of this disease. Excess shade is conducive to the disease. Removal and destruction disease affected leves and application of carbendazim 0.1 per cent are recommended for controling the disease.

Nursery spear rot

This has been reported from the secondary nursery seedlings raised at Palode (Kochu Babu, 1990). The symptoms are quite different from the nursery spear rot caused by *Phytophthora arecae* reported from Republic of Zaire and *Fusarium* spp. reported from Malaysia.

Water soaked lesions develop in middle leaflets of spear leaves. They later become light brown and extend to the tip of the spear. When the spear unfurls, the rotten area becomes dessicated. The young leaves show distinct marginal chlorosis comparable to the spear rot in adult palms. Subsequently emerging leaves show drastic reduction in leaf size. Such seedlings need to be culled out and destroyed.

Leaf spots

In general, leaf spot incidence is not comon in all nurseries where prophylactic sprays are followed regularly. *Curvularia* and *Pestalotiopsis* are the causative organisms involved.

In the case of leaf spots caused by *Pestalotiopsis palmarum* and *P. monochaetoides* large irregularly shaped orange red lesions occur in older leaves of secondary nursery seedlings. Later these lesions become necrotic with dark grey margin and light brown centre.

Leaf spots caused by *Curvularia lunata* and *Curvularia geniculatus* were recorded on primary and secondary nursery. Small circular translucent yellow spots appear on unfurling spear and young leaves. These later enlarge and become brown with a sunken centre and yellowish orange halo. The lesions range from 3 to 7 mm in diameter. In severe cases, the lesions coalesce causing a complete die back of leaf tissues. Characteristic persistence of primary lesions within the necrotic area is noticed.

Developmental abnormalities

Leaf enations and crinkle

In the primary nursery seedlings the leaves show flaps and crinkling mainly due to temporary water deficit during the emergence of leaf. Deficiency of Boron has also been indicated in some instances. With copious watering, the symptom disappears in the emerging leaves.

Collante

Collante is a symptom associated with inadequate soil moisture condition. Though it occurs in all stages of nursery, severe symptoms are observed in the primary stage. Planting of seedlings in the field during dry weather also induces collante symptoms. In the affected seedlings the leaves fail to unfuril properly with a constriction developing in the central portion of the leaf. The veins become prominent and the leaves, rigid. In extreme cases the leaf remains as a woody spike without separation of leaflets. The symptoms are not seen in fresh leaves, when adequate watering is done.

 

Fig. 2 & 3. Spear rot

Diseases of adult palms

Spear rot

Spear rot associated with foliar yellowing has been recorded from the oil palm plantations in Kerala (Kochu Babu, 1989). So far this disease has not been observed in the plantations of Andamans, Andhra Pradesh, Karnataka and Maharashtra.

Yellowing of the youngest whorl of unfolded leaves is the initial visible symptom (Fig. 2 & 3). Yellowing starts from the tips of leaves and spreads mostly along the margins of leaflets. The chlorotic area later turns brown and dries up. In few cases, one or two affected leaves break at the leaf base and hang down from the crown.

At the onset of yellowing symptoms water soaked lesions are seen at the central portion of youngest spear which subsequently spreads either way and simultaneously rotting also sets in. Rotting is confined to portions about 500 cm from the meristem . The rotten tissues emit foul smell.

Yellowing or rotting does not spread to the older leaves in the whorl. The bunches produced prior to disease incidence in their leaf axils mature normally. Rotting and reduction in leaf size occur in the subsequently emerging leaves. With disease advancement rudimentary leaves even without leaflets are produced. As the disease advances, the trunk gradually tapers and inflorescences abort before emergence resulting in total loss in productivity. The symptoms are distinctly different from diseases like crown disease, fatal yellowing, patch yellows, wither tip and spear rot-bud rot-little leaf disease complex reported form other oil palm growing countries.

Occurrence of the disease is generally found in low lying marshy places, valleys and hill slopes. The *tenera* x *tenera* population planted at a spacing of 5 m apart on a steep slopy land had the highest incidence of 40 per cent in plantation under Oil Palm India Ltd. About 5 per cent of the replanted seedlings in this plot also had disease recurrence during 1 to 3 years after planting.

The etiology of spear rot in India is yet to be established. The microorganisms isolated from spear rot affected palms are: *Bacillus subtilis* (Ehrenberg) Cohn, *Botryodiplodia theobromae* Pat., *Colletotrichum gloeosporioides* (Penz.), *Curvularia lunata* (Wakker) *Boedijn*, *Enterobacter* sp., *Fusarium moniliforme* Sheldon, *Fusarium moniliforme* var. *intermedium* Neish & Legget, *F. moniliforme* var. *subglutinans* Wollenw. & Reinking, *F. oxysporum* Schlecht, *F. pallidoroseum* (Cooke) Sacc., *F. solani* (Mart.) Sacc., *Pestalotiopsis palmarum* (Cooke) Steyaert, *Pseudomonas* sp., *Phomopsis elaeidis* Punith. and *Setosphaeria rostrata* Leonard. Among them the most consistent fungal isolates are *F. moniliforme* and *Colletotrichum gloeosporioides*. None of these fungi and bacteria were pathogenic either individually or in combinations. Macro and micronutrient status in diseased and healthy palms show no significant variation.

Electron microscopic studies with the samples from six spear rot affected palms in the early stage of disease revealed the presence of Mycoplasma Like Organisms (MLOs) in the sieve tubes of rachillae of unopened inflorescence and submeristematic tissues (Dr. Solomon, Personal communication). Apart from the presence of the organisms, structural changes like phloem necrosis, compression of sieve cells and presence of large number of organelles in cells adjoining the vascular tissues are very much evident. However the involvement of MLOs in the etiology of the disease is yet to be confirmed through transmission trials.

In view of the uncertain etiology, roguing of affected palms and burning *in situ* is recommended at present to prevent the spread of this malady.

Bud rot

Bud rot reported to occur in all oil palm growing countries has been noticed in the plantations of Kerala, Karnataka and Andhra Pradesh (Kochu Babu, 1990). Higher disease incidence is noticed in young plantations. Rotting initiates at the basal portion of the spear closer to the meristem and extends to the whole spear. The spear could be easily pulled off. Cleaning the affected tissues and drenching the crown with carbendazim 0.1 per cent cures the disease. The leaves emerging immediately after the application of fungicides are shorter and successively emerging ones are normal.

Crown disease

This juvenile disease occuring frequently on palms during the first 3 years after planting has been reported form many oil palm growing countries. In India the disease has been observed in the nursery stage and field planted palms in different states.

During the early phase of the disease brown lesions with water soaked margin are observed on the middle portions of the internal leaflets. No rotting is apparent in the spear externally. When the affected spear unfurls, it develops a characteristic bending in the middle of the rachis. The leaflets on either side of the curved portion of the rachis are either completely rotten or a few stumps remain. The recovery of the disease affected palms is spontaneous and hence control measures are not taken up usually. Non-pathogenic microorganism such as *Fusarium moniliforme, F. semitectum* and *Colletotrichum gloeosporioides* were isolated from the disease affected tissues.

Upper stem rot

Recently this disease was identified in the oil palm plantations of Andamans Forest and Plantation Development Corporation, Little Andamans. Rotting on the upper portions of stem was observed in the 1975-76 plantations on 42 palms distributed in 12 foci in the 160 ha area raised with seed materials introduced from NIFOR, Nigeria.

The symptoms are gum exudation, bleeding and rotting of the stem. Gum exudation and stem bleeding occur at any point above 50 cm from the bole reigon. Decay of inner tissue is observed on chipp- ing of the bark as the disease advances. In due course rotting extends internally in an irregular pattern (Fig. 4). The dark brown lesion also extends laterally causing dry rot of the stem. Externally the presence of fibrous strands is noticed. As the rotting advances internally the palm snaps at the site of rotting.

Fig. 4. Upper stem rot

The presence of healthy tissues above and below the lesion indicates that the infection is likely to be localised. Upper stem rot caused by *Phellinus noxius* has been reported from Malaysia (Sharples and Jorgensen, 1930) and Indonesia (Turner, 1971) and several other countries (Turner, 1981). However, fructifications of this fungus are not observed on the diseased palms in Little Andamans.

Identification of the disease in the ealry stage and removal of rotten tissues, swabbing with Calixin 0.1 per cent followed by application of hot coal tar is recommended to save the infected palms. This should be followed by plugging the holes with a paste containing sand, cement and BHC to provide mechanical support to the palm and to prevant further attack by rodents, insects etc.

Bunch failure

Bunch failure is most frequent in 3-10 year old palms, often to the extent of 20 per cent. The range of under development of fruits in a bunch may vary from 0 to 100 per cent. The tips of under developed fruits turn black and later become necrotic. Reddy *et al.* (1987) reported the occurrence of *Marasmius* bunch rot in oil palm plantations of Forest and Plantation Development Corporation, Little Andamans. They also recorded bunch rot in the plantations at Yeroor in Kerala and the association of *Ceratostomella* sp.

Marasmius palmivorus is saprophytic in nature usually colonising leaf axils and leaf bases. The bunches in the middle stages of development (8-12 weeks) are mostly invaded by the pathogen. Bunches produced during March-May are affected to the maximum extent. Neither the sex ratio nor the pollen load in the atmosphere has any effect on bunch failure.

Retension of rotten imature bunches serves as a source of infection on fresh bunches. Periodical cleaning of the crown reduces the load of inoculum and fresh incidecne . Bunch failure may also result from lack of adequate pollination, in which case assisted pollination is to be resorted to. Though bavistin 0.2% spray alone had no effect on bunch failure, complete control could be obtained through crown cleaning, assisted pollination and bavistin 0.2% spray when applied together. The bunch failure incidence is found to be low in Forest and Plantation Development Corporation of Little Andamans (Chander Rao et at., 1990) and at Palode (Dhileepan and Nampoothiri, 1989) after the introduction of the pollinating weevil, *Elaeidobius kamerunicus*.

Leaf rot

Mathai *et al.* (1989) reported the occurrence of leaf rot in Chithara and Kumarakom of Kerala. Brown spots with yellow halos appear on the leaflets of inner whorl leaf lamina. Palms of all ages are found affected; but the severity is on palms up to ten years of age. Though *Colletotrichum gloeosporioides* has been reported as the causal agent, earlier inoculation trials could not establish the pathogenicity.

Leaf spots

Leaf spots caused by *Pestalotiopsis* spp. are noticed on the lower whorls of leaves. Magnesium deficiency favours disease incidence. The first symptom is the appearance of brown spots on leaflets, later spreading to the whole leaflets. The centre of the lesions are light grey to brown with numerous black dots, the acervuli of the fungus. *Pestalotiopsis palmarum*, *P. glandicolax* and *P. monochetoides* were isolated from the infected leaves at Palode (Kochu Babu et al., 1990).

Petiole spots

Occurence of these spots on petiole has been noticed on 52 per cent of the palms in Palode plantations (Kochu Babu et at., 1990). Irregular spots ranging from 2-12 mm are noticed on the outer surface of the petiole. This appears to have no harmful effect on the palms. *Cryptosporiopsis* sp. was isolated from the lesions.

Other diseases

Shanta et al. (1970) reported that oil palm is a natural host of coconut root (wilt) pathogen, when it was believed to be caused by a virus. Flaccidity, the diagnostic symptom of coconut root (wilt) disease has been taken as the criterion for symptoms on oil palm.

Reddy *et al.* reported infection by *Fusarium oxysporum* f. sp. *elaeidis* on 950 out of 1,25,000 oil palm seeds imported form Nigeria.

Wither tip disease incidence in Oil Palm Research Station, Thodupuzha, Kerala state was recorded by Rajan *et at.* (1980). They implicated *Fusarium oxysporum* as the causal agent. Subsequent study however indicates that the disease found in Thodupuzha is actually spear rot.

Fruit tip rot and basal fruit rot have been recorded from the Oil Palm India Plantation, Chithara by Mathai *et at.* (1991). *Diplodia tubericola* and *Colletotrichum gloeosporioides* have been identified as the pathogens of fruit tip rot and basal fruit rot respectively.

Disorders

Besides these diseases, few disorders are also recorded in the Indian plantations. the nutritional disorders are covered under the chapter on 'Crop Management' and are not discussed here.

Leaf base wilt

Recently leaf base wilt has been observed in 14 year old plantatins of Palode and Yeroor estates. The lower whorl fronds subtend downward from the point of insertion on the stem and hang around the stem giving a skirt of wilted fronds. These fronds do not dry up immediately. In general the bunches in the axils of the subtended leaves show rotting in the immature stage itself. The factors suspected as the cause of this disorder are frond length, bearing nature and nutritional status of major elements (Turner 1981).

Wind damage

Crown fracture or head bending

Two to three young leaves and group of spear cluster break at the petiole base and hang on to the crown. Occurrence of this would induce the affected palms to enter a prolonged male phase. The fractured portions on removal and treatment with protective fungicide allow the new leaves to emerge without hindrance. In the case of untreated ones crown twisting occurs.

Pinnae fragmentation and lodging of palms

The common symptom on palms exposed to severe wind is the shredding of pinnae resulting in hanging of leaflets leaving the midrib projecting. Heavy winds cause reduction in assimilative area to about 25 per cent and induces the formation of male inflorescences and reduce yield (Turner, 1981).

In young plantation severe wind blow causes lodging. The leaflets get damaged due to constant rubbing with other leaves. Staking of seedlings is essential in such wind prone areas.

Important Diseases in other countries having quarantine significance

Freckle

This is the most widespread leaf disease on nursery seedings and field palms in West Africa. The disease occurs throughout the year on all varieties and at all stages of growth from young seedlings to adult palms. Though not fatal, the disease can cause a reduction upto 10 per cent photosynthetic leaf area leading to reduction in vegetative growth and delay in onset of fruiting. Initial symptoms occur on the youngest fully opened leaves of prenursery or nursery seedlings as discrete, hyaline, pin point spots which later enlarge, becoming slightly sunken and dark brown in colour and may be surrounded by a distinct orange yellow halo. In the final stages, the lesions coalesce and cause desiccation and death of whole leaflets.

The disease is caused by *Cercospora elaeidis*, which is not present in the south east Asain countries. the conidia of this fungus is reported to be spread through pollen as contaminant. Hence the import of pollen from Africa needs a quarantine check. *Elaeis oleifera* and the hybrids with *E. guineensis* are highly susceptible to this pathogen.

Vascular wilt

This disease was first observed in Zaire and later in all West African countries. Although it is regarded as a disease of adult palm it is reported from grown up seedlings in nursery also. Young palms of 3-15 years age are reported to be mostly affected.

First visible symptom in nursery is growth retardation and flat topped appearance showing a desiccated outerwhorl of leaves. Pinnate leaves are not produced if infection is early. Severe necrosis of vascular tissues induces water stress leading to yellowing of older leaves. In field palms the young leaves become bright yellow and the leaves produced subsequently are shorter giving flat topped appearance. The outer leaves become desiccated. In the chronic type, the palm tapers and may linger on for several years. In acute type, the older leaves fracture near the base and hang downwards around the upper part of the stem and die within a few weeks or months. Internally the peripheral vascular bundles are discoloured.

The disease is caused by *Fusarium oxysporum* F. sp. *elaeidis*. Though systemic infection of seeds is not yet prove proven the spread through seeds and pollen as contamination is reported (Flood, 1990). This aspect needs to be looked into during the import of planting materials.

Sudden wither

This has a widespread distribution on oil palm and coconut throughout South America and is considered to be a potential limiting threat to *E. guineensis* especially in Colombia. Initially the tips of the terminal leaflets of the older leaves become brown, later spread to leaflets of younger leaves and within a month all the leaves become bronzed. Rotting and premaute fall of fruits and dealth ensues in a month after the onset of leaf symptoms.

Fatal yellowing (Marchitez progesiva/lethal spear rot)

Fatal yellowing primarily recorded in Colombia but also found in Panama, Ecuador and perhaps in Nicaragua and Costa Rica is more often associated with mature palms (Turner, 1981). Chlorosis of youngest whorl of leaves, spear rot, fungal lesions on the petiole of chlorotic leaves and snapping of the leaves at the lesion site are the symptoms. The affected palm dies in a period of 4-5 months.

The disease is of unknown etiology. However *E. oleifera* and its hybrids with *E. guineensis* are reported to be tolerant to the disease.

Leaf mottle

This fatal disease is reported to occur in nurseries and field palms in Ecuador and Peru. The earliest symptoms are found on the spear leaves. Paler linear spots appearing as continuous long mottled streaks appear on the spear leaves. Mottling symptoms are seen on the rachis also. Spear rot is frequently seen when chlorosis has set in.

The etiological agent is not identified so far. *E. oleifera* and its interspecific hybrids show a range of tolerance to the disease.

Cadang-cadang

Cadang-cadang, a viroid disease on coconut in Philippines has been observed on oil palms also. As oil palms are more susceptible to this viroid, it affects the development of the oil palm industry in Philippines (Turner, 1981). As viroids are sap transmissible and can be seed borne, introduction of the planting materials should be avoided/restricted.

Red ring disease

Red ring - primerily a coconut disease - is reported on oil palm also in the Latin American countries. *Rhadinaphelenchus cocophilus*, a nematode is the causative agent, transmitted by the red palm weevil, *Rhynchophorus palmarum*. Since the disease is not reported from areas other than West Indies and Latin America, care should be taken while introducing planting material.

Conclusions

It should be borne in mind that copper fungicides are phytotoxic to oil palm. A constant vigil has to be kept on the planting materials so that curative treatments can be taken up early. It is necessary to give emphasis on pathological investigations of the recorded diseases in view of area expansion programme in the country. As a precaution, the oil palms planted in *Ganoderma* basal stem rot affected gardens in nearby areas need to be periodically checked as it has been proved to cross infect these palms in Malaysia.

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NUTRITIONAL ASPECTS OF PALM OIL

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Oil extracted from the fleshy orange-red mesocrap is known as crude palm oil (CPO) which on refining becomes palm oil. Kernel oil extracted from seeds resembles coconut oil. The palm oil as such is realiably consistant in quality, can be easily refined and is readily acceptable as an edible oil. Its versatality makes it a suitable raw material for many uses both for edible and non-edible purpose.

Edible uses

For making margarine as it has the correct consistancy and does not turn rancid easily.

Due to its nonfoaming property it is used as an excellent deep frying medium.

As a shortening agent in manufacture of bakery items.

To make vegetable oil based ice cream.

As a substitute for cocobutter in chocolate making industry.

Non - edible uses

Palm oil is an important source of C16-C18 fatty acid for detergency and is used in manufacturing soap. Basic oleochemicals such as fatty acids, fatty methyl esters, fatty alcohols and fatty nitrogenous derivatives can be produced from palm oil. These products are used to manufacture various formulated oleochemical products especially surfactants and detergents.

Chemical composition of palm oil

Palm oil contains two fractions, the stearin and palmolein fraction. The stearin fraction contains more saturated fatty acids and is solid at normal temperature while palmolein has more unsaturated fatty acids and is liquid at normal temperature. Palm oil consists of largely triglycerides which are esters of glycerol with fatty acids. The fatty acids are straight chained with usually even number carbon atoms and saturated or unsaturated in C - C linkage. Palm oil contains about 40 per cent each of palmitic acid and mono unsaturated oleic acid with about 10 per cent disunsaturated linoleic acid, 5 per cent stearic acid and small proportion of other acids like lauric, myristic, palmitoleic and arachidic acid. (Chan, 1983) (Table 1).

Table 1. Composition of fatty acids in Palm Oil (Chan, 1983)

Fatty acids	Carbon No. and No. of double bonds	Percentage
Lauric acid	C - 12	0-0.4
Myristic acid	C - 14	0.6-1.7
Palmitic acid	C - 16	4.1-1-47.0
Palmitoleic acid	C - 16.1 (9, monoene)	0-0.6
Stearic acid	C - 18	3.7-5.6
Oleic acid	C - 18:1 (9, monoene)	28.2-43.5
Linolenic acid	C- 18:13 (9,12,15 Triene)	0-0.5
Arachidic acid	C-20	0-0.8
Iodine Value		52%

Melting point of palm oil ranges between 50 and 55°C. (Tan ches Hong, 1974). The melting point of triglycerides increased with increase in length of the fatty acid chain and decreases with increase in unsaturation (Tjang and Olie, 1972). Palm oil has a relative density of 0.8927 and refractive index 1.4553 (Maclellan, 1983). Apart from the triglycerides the palm oil contains a number of minor constituents. Though some of these compounds are negligible in quantity they are very important from nutritional point of view. These minor compounds are carotenoids, tocopherols, triterpenes, phytosterol, phospholipids, glycolipids, aliphatic alcohols, copper and iron. (Gottenhos and Vies, 1983).

Chemical composition of palm kernel oil

Palm kernel oil is one of the main byproducts in palm oil industry. Palm kernel oil and coconut oil are alike in chemical composition and are generally known as lauric acid oils. Palm kernel oil is entirely different from mesocarp oil. It contains high proportion of saturated fatty acids (Chan, 1983) (Table 2).

Table 2. Composition of fatty acids in palm kernel oil (Chan, 1983)

Fatty acids	Carbon No.	Range %
Caprylic acid	C-8	3-5
Caproid acid	C-10	3-7
Lauric acid	C-12	40-52
Myristic acid	C-14	14-17
Palmitic acid	C-16	7-9
Stearic acid	C-18	1-3
Oleic acid	C-18:1	13-19
Linoleic acid	C-18:2	0.5-2.0
Arachidic Acid	C-20	Trace

Nutritional aspect of palm oil

Fats and oils are generally used for making food to make it tastier and palatable. It also provides energy and acts as a medium of transport of fat soluble Vitamins. Palm oil, provides nine kilocalories of energy per gram compared to four kilocalories for proteins and carbohydrates. No significant difference is noted in digestibility as compared to many other fats.

Palm oil contains about 50 per cent saturated, 49 per cent monounsaturated and 10 per cent polyunsaturated fatty acids. The oleic acid and linoleic present in the palm oil are essential for human as well as animal nutrition. About 43 per cent of oleic acid present in the palm oil is effective in lowering the blood chlesterol, 10 per cent linoleic acid present will provide the essential fatty acid requirement and hence palm oil could be used as a sole source of fat in human nutrition. Over and above palmitic acid which is the principal saturated fatty acid present, palm oil is considered to possess a less cholesterol raising effect than short chain lauric and myristic acid which are present only in traces.

Minor components of palm oil

Nutritive value of palm oil mainly depends on the presence of minor components. The main minor components in unprocessed palm oil are carotenes, the vitamin E (tocopherols and tocotrienols), the sterols, the phospholipids and the glycolipids and triterpinoids and squalene. (Table 3)

However, in the refined palm oil, all the components except the carotenoids are present. The carotenoids are generally removed or destroyed while refining. As an antioxidant, the tocopherols and tocotrienols, the unsaturated analogues of vitamin E plays an important role in nutrition (Abdul Halim Hassan, 1987).

Table 3. Minor components of crude palm oil.

Main minor components	Unrefined palm oil (ppm)	Refined palm oil (ppm)
Carotenoids	500-800	–
Vitamin E	800-1000	360-610
Sterols	360-620	100-160
Lipids		
Phospholipids	5-130	traces
Glycolipids	1000-3000	traces
Aqualene	429-929	184-364

Carotenoids

Among the edible oils, palm oil has by far the highest concentration of crotenoids of which alpha and beta carotenes constitute about 90 per cent. These carotenoids are precursors of vitamin A, the vitamin that prevents night blindness, aids the maintainance of the epithelial tissue and promotes growth. The carotenes are compounds containing long chain isoprenoid units containing conjugated double bonds with a beta-ionone ring. Beta-carotene is a symmetrical molecule in which both halves have the retinene configuration so that the cleavage of beta carotene results in the formation of two molecules of retinal which is reduced to retinol. So the beta-carotene is the most efficient provitamin A since the beta-ionone ring is present at both the ends of the molecule. Other carotenes have vitamin A activity but they have only half potency.

The average range of carotenes in palm oil is in the range of 500-700 ppm. It is a rich source of provitamin A and can be supplimented for vitamin A deficiency diet. (Ooi, Ong and Ooi, 1985). It has been observed that a daily dose of 4.0 ml palm oil given to children at the age of 1 to 5 years, decreased Xerophthalimia significantly from 7 to 3 per cent. Recent reports show the dietary beta-carotene reduces human cancer rates (Ooi, Ong and Ooi, 1985).

Table 4. Vitamin A potency of carotenoids

Carotenoids	Potency (Iu/hg)
Alpha-carotene	0.90
Beta-carotene	1.66
Gamma-carotene	0.72
Lycopene	Nil

Vitamin E

This is a fat soluble vitamin comprising mainly the tocopherols and tocotrienols. Vitamin E acting as an antioxidant, arrests the oxidative detereoration of cellular membrane. It is not limited to a single compound but is associated with eight derivatives, four of which are saturated phytyl side chain and others are unsaturated prenyl side chain.

Sterols

Sistosterols, camposterol and cholesterol are the sterols found in palm oil which serve as a minor dietary source of steroidal hormones.

Lipids

Phospholipids and glycolipids are the two lipid components present in the palm oil where glycolipid is more predominant. These compounds serve as the lipid components of cell membrane. Phospholipids are not antioxidant synergistic in the presence of tocopherol and tocotrienols because of this property phospholipids are sometimes added to oil to promote its oxidative stability.

Squalene

Squalene has been found to be able to arrest the formation of cholesterol by inhibiting the cholestrol forming enzyme activity.

Palm Oil in India

Palm oil for edible purpose is being increasingly used in India recently. The first oil palm cultivation in India was started in 1962 at Thodupuzha, Kerala State. This was followed by large scale cultivation by Oil Palm India. But the oil produced at these centres were not used for edible purposes. the one available in Indian market is the refined "Palmolein" imported from Malaysia. A small scale palm oil extraction unit which is suitable for Indian condition has been designed and installed at CPCRI Research Centre at Palode. This pilot plant is completely fabricated with indigenous know how and has a capacity of one ton Fresh Fruit Bunch (FFB) per hour.

Preliminary analysis of the crude palm oil extracted by the pilot plant indicated that the free fatty acid content (FFA) is less than one per cent, the carotene is 700 ppm, and moisture and other impurities are less than 0.2 per cent. It is also a good source of vitamin E, the tocopherol content is being 800 ppm. (Arumughan et al. 1989). A sensory evaluation experiment was conducted on CPO from which it was found to be is acceptable for direct consumption. The only demerits indicated were thick consistency, red colour and high smoke point. Hence the CPO was further purified in a private factory and was subjected to sensory evaluation. The purified product had a vide acceptance compared to CPO since it has a fairly good colour, flavour and consistancy. The product can be sold in the open market on its inclusion in the list of consumable oils under the food act. However, in India much more research work on the quality as well as on the nutritional aspect of CPO has to be undertaken.

Palm oil and health

It reduces the value of total cholesterol, triglycerides, VLDL - Cholesterol, LDL Cholesterol level and increases the 'protective' HDL level

It decreases the blood cholestrol level, probably due to the presence of two unsaturated hypocholestermic fatty acid namely oleic acid and linoleic acid which are present at a level of 44 and 10 per cent respectively in refined palm oil. Another explanation is that both crude and refined palm oil contain significant amount of tocotrienols which are reported to inhibit the cholesterol synthesising enzyme (Chong, 1989, Abdul Halim Hassan, 1988).

Saturated fatty acids, in particular palmitic acid, are said to promote platelet and predispose to thrombosin formation. But, contrary to this explanation, palm oil which is rich in palmitic acid is antithrombotic and reduces platelets aggregation like polyunsaturated oils (Chong, 1989).

Palm oil possesses a distinct tumor inhibiting effect compared to polyunsaturated oils.

The recommendation of the usage of oils which are rich in polyunsaturated fatty acids for lowering the blood cholestrol has now been questioned and cautioned against excessive consumption of diet rich in linoleic acid and pointed out that the following difficulty may be associated with such a diet. It may be promoting cancer development, suppressing the immune development, depressing the 'protective' HDL and increasing the risk of formation of gall stone. So current dietary recommendation now stipulate that polyunsaturated fatty acid content should not exceed 10 per cent of the total calories.

In conclusion palm oil which contains saturated and unsaturated fatty acids in equal amounts and also a good source of vitamin A and E can be used as dietary fat. It is equivalent or better than all other fats which are now available in the market.

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CULTIVATION OF MUSHROOMS ON OIL PALM FACTORY WASTES

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Introduction

Mushrooms are prefered as an alternative sources of food and valued for its flavour and nutritional value. Mushrooms cultivation is mainly confined to indoors, is labour intensive and provides employment opportunities.

In palm oil factory, two types of sterile byproducts are available ; one after the sterilization of fresh fruit bunches (FFB) at 3 kg/ cm^2 pressure for one hour and stripping. This is known as bunch refuse. The second type of byproduct is called mesocarp waste and is obtained after the extraction of palm oil. During the processing of 1000 kg of FFB, about 350 kg bunch refuse and 150 kg of mesocarp waste are obtainable. At present these wastes are used either as fuel to the boiler or as mulch in plantations.

MESOCARP WASTE

This has been found to be very ideal for the cultivation of oyster mushrooms (*Pleurotus* flabellatus) (Fig. 1). also called as wood fungus and as 'Dhingri' in Hindi and 'Chippi koon' in Malayalam.

About 40 species of oyster mushrooms suited to various temperate and tropical zones are available. Oil palm is a tropical crop having higher field adaptability and their cultivation is less expensive.

The species which give higher bio conversion efficiency are *Pleurotus florida, sajor-caju.P.citrino pileatu and P. flabellatus* (Fig. 1). Growth and yield are better in ambient temperature of 20-30°C.

The cultivation technique is very simple involving less capital investment. Thatched sheds with sufficient ventilation and high relative humidity are ideal. Wooden frames are made at a height of about 2.5 meters from ground level so as to enable hanging of substrate beds for spawn run. A mud/brick parapet is to be provided on the side of the shed. The space between the parapet and the roof can be covered with a layer of plaited coconut leaf and the inside with a gunny screen to absorb moisture and provide humidity and coolness. River sand is spread over the floor to retain moisture and increase humidity in the shed.

Preparation of substrate

Unlike the conventional paddy straw substrate, mesocarp waste does not require sterilization. The waste obtained fresh from factory is dipped in two changes of cold water for about 10 minutes primarily to remove oil remnants. Then excess moisture is drained by squeezing.

Spawn preparation

Spawn is the vegetative seed material of mushrooms. Pure culture of the mushrooms are obtainable from agencies or can be isolated from sporocarps on potato dextrose agar medium. These need to be maintained on

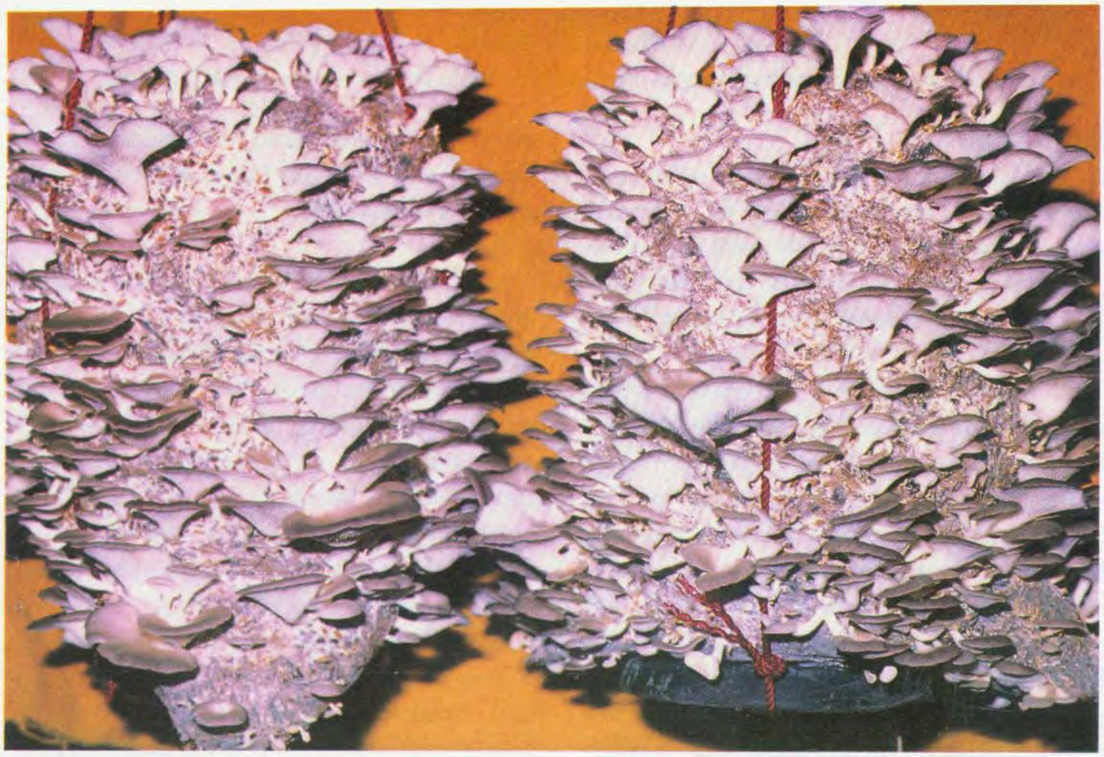

Fig. 1 : Oyster mushroom (*Pleurotus flabellatus*) on oil palm mesocarp waste.

media in test tube slants in refrigerator. Grains like paddy, wheat, sorghum etc are used as substrates for making spawn. Cleaned grains are half cooked in sufficient water and allowed to air dry on gunny bags for about an hour. Calcium carbonate @ 2 per cent of dry weight of grades is mixed with the grain and filled in empty glucose bottles to two third capacity. The filled in bottles are plugged with cotton preferably non absorbant and steam sterilized (autoclaved) at 1.4 kg/cm^2 pressure for 2 hours.

After cooling, the bottles are inoculated with pure cultures of mushrooms under aseptic conditions and incubated for mycelial ramification preferably at 24±3°C for 15 days.

Spawning

The spawn is removed from the bottles using a clean needle/rod. Multilayered spawning technique in polybags is adopted for cultivation. Polythene bags (150-200 guage) of 45x30 cm punched with holes can accommodate 2 kg of the substrate. A 100 m layer of the substrate is filled in the polybag and spawn is applied preferably along the periphery along with rice bran (2%) as starter. The polybag is filled with the substrate spawn and rice bran, is multilayered, compacted, tied and kept as hangers or racks. Application of greeze on racks prevents access to ants. Keeping a bamboo pipe of 2-3 cm diameter in the centre of substrate is advantageous for watering. About 100 gm of paddy grains spawn (5 per cent) is used per bag.

In 15 days, the mycelia ramifies (spawn run) on the substrate. At this stage the polybags are ripped open and kept on hangers and watered thrice daily using rose can.

Cropping

Mushrooms buttons (pinheads) appear in 5-7 days which can be harvested in about three to four days. Mushrooms are to be harvested before the upcurving of the margins of pileus. Flushes continue to appear for a period of two months, but about 71 percent of the cropping is obtainable within a month after spwan run.

Harvesting and storage

The mushrooms are picked up carefully without damaging the buttons. The debris from lower portions of sporocarp are removed and the mushrooms are packed in polythene bags with small holes. Marketing afesh is good or it can be stored in refrigerator for 2-3 days. An yield of 800-1200 gm of fresh mushrooms can be obtained from a bed of 2 kg.

BUNCH REFUSE

Bunch refuse, another lignocellulosic waste is suitable for the cultivation of paddy straw mushrooms (*Volvariella volvacea* and *V. diplasia*) (Fig. 2). These mushrooms come up well in places where temperature ranges from 25 to 35°C.

Preparation of spawn

Fresh paddy straw is chopped into small pieces of about 3 cm length and packed tight in long necked bottles. The filled in bottles are soaked in water overnight and excess water drained off.

Coarsely powdered red gram powder is sprinkled in the bottle after making a hole in the centre of straw. The bottles are plugged with cotton and sterilized at 1.4 kg/cm^2 for one hour. After cooling, pure culture of *Volvariella volvacea* or V. *diplasia* is inoculated under aseptic condition and incubated for mycelial run.

Within 15 days mycelia ramifies and formation of chlamydospores of the fungus on the peripheral side of straw indicating sprawn maturity

Paddy straw spawn can be substituted by wheat grains spawn as described under oyster mushrooms.

Preparation of substrate and spawning

Washed bunches are arranged to form a layer (75x45 cm) on a raised platform in a thatched mushroom shed. Since ants are a manace on bunches, the raised platform are to be kept ant free by retaining water around the pillars of the platform.

Bits of paddy straw spawn are inoculated on bunch refuse around the layer. Coarsely powdered red gram powder is applied over the spawn as a starter.

Subsequently 2 to 3 similar layers are made and spawned after placing the top layer and applying spawn over the layers are compacted and covered with polythene sheet.

Spawn is applied at the rate of one

bottle per bed of 75x45x30 cm size.

The beds are checked for moisture levels once in 4 days. After 10 days when the mycelial ramification is complete, the sheets are removed and the beds are to be watered thrice daily with rose can.

Bottoms of the mushrooms appear in about 2-3 days and can be harvested in another 2-3 days time when they are egg stage. If harvesting is delayed the mushroom opens resulting in higher crude fibre content (Fig 2).

The shelf life of paddy straw mushroom is less (24 hours in refrigerator) when compared to oyster mushroom and hence need to be sold out immediately.

An yield of about 2 kg can be obtained from a bed of size 75x45x30 cm. Since it requires larger area for utilization of bulk quantity of bunch refuse, cultivation under shade in palm basin is advisable. Under field conditions about 50 per cent of the crop obtainable from indoor cultivation can be harvested. This enables the bulk utilization and production of mushrooms.

The cost of cultivation of one kg of mushrooms is less than Rs. 10/-. At the present selling price of Rs. 40/-, a net return of over Rs. 30/- is obtainable.

Fig. 2 : *Volvariella volvacea* on oil palm bunch waste

PROCESSING TECHNOLOGY

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Introduction

Processing is an integral part of oil palm plantation development. Modern Palm Oil Mills (POM) therefore are designed to match with plantation size for their captive use. In palm oil processing, there exists two contrasting situations : (a) Modern large scale POM designed to process 20 to 80 tonnes fresh fruit bunches (FFB)/hr and (b) traditional processing. While a high degree of process efficiency and good product quality have been achieved by large scale mills, the traditional processing suffers from lack of efficiency and quality problems. There is therefore, a need for an intermediate technology between these two extremes to cater for the specific requirements of small sector, with emphasis on

1. the use of locally available infrastructure for design and fabrication of equipments,
2. the design of appropriate size POM to match the plantation size in the small sector (100-1000 ha),
3. Process optimization to achieve process efficiency and product quality comparable with international standards and
4. modification of technology to produce end products to suit local needs.

There have been attempts in the past to design small scale POM. The Pioneer Mill introduced in the late 1940s (Cornelius, 1963, 1983; Van Looy, 1981) was the first venture in this direction. This mill was designed to process loose fruits using centrifugal extraction technique. Poor efficiency and oil quality coupled with high labour requirements adversely affected its success. Subsequently Stork-Amsterdam introduced the Junior Oil Mill with a capacity to process 1-3 tonnes FFB/hr (Blaak, 1979). Later using de-wecker, Luxembourg designed the mini-mill with a capacity of 1.5-3.0 tonnes FFB/hr (Hartley, 1988). These two designs had incorporated techniques to produce good quality palm oil with higher efficiency unlike the Pioneer Mill and they were primarily designed for the African plantations. The oil palm plantations of Africa suffer from low productivity. Higher capital outlay in hard currency for these mills therefore, deterred the small co-operatives from going for these technologies. Concurrently there had also been indigenous attempts in Africa to evolve low cost technology commonly known as village oil mill using locally available talents and resources (Nwanze, 1965; Blaak, 1979). These were basically attempts to improve the traditional methods. Higher labour requirements, low throughput, poor oil recovery and oil quality problems have been the disadvantages of village oil mills.

Looking into the evolution of palm oil mill from earlier traditional methods of Africa, through Pioneer Mill to the present day most modern large mills of South East Asia, it is apparent that palm oil extraction requires certain minimum level of technology for process efficiency and product quality. With this understanding, a judicious mix of the modern technology and manpower is employed in the design of the small mill with emphasis on the indigenous resources and domestic needs.

Technology for edible raw palm oil

Palm oil is derived from the fleshy mesocarp of the fresh oil palm fruit of right maturity essentially through a wet rendering process. Presence of an extremely active lipase in the mesocarp renders the oil inedible unless proper care is taken from harvesting through transport to subsequent processing of the fruits. Laboratory studies have shown that this enzyme is bound to the membrane of fat globules and any damage to the membrane triggers the activity and the free fatty acid (FFA) released thus, could be as high as 60 per cent depending on the severity of damage. High FFA not only makes the oil inedible but also makes rate of rancidity faster, fixes the colour and increases refining loss. Palm oil mills, therefore, should be located in the palm plantation in order to process the fruits immediately after harvest. Modern mills have been designed to match the size of plantation to cater to the fruit yield of the captive area. Unlike in Malaysia and elsewhere, in India smaller plantations with mills of matching capacities are suitable. RRL (T) therefore, has developed the technology to process fruits from 200 hectare oil palm plantation with a capacity of one tonne FFB/hr. The steps in the process are briefly as follows :

Harvest

Harvesting of fruits at the right maturity is important with respect to yield and quality of palm oil, since immature fruits yield less oil and over mature fruits have high FFA (Arumughan *et at*, 1989). Excessive bruising of the fruit bunches should be avoided during harvest and transport for the reasons already stated. Processing of the FFB within 24 hours after harvest is essential to obtain edible quality raw palm oil. Various devices and methods are available now to avoid damage to the fruit during harvest and transport (Fig. 1).

Sterilization

This serves the dual objectives of inactivation of the enzyme lipase and loosening of the fruits from the bunch. It also softens the cell wall and coagulate proteins that facilitate oil extraction in the subsequent stages. A horizontal type steriliser is adopted to minimise bruising of fruits. The FFB are loaded in a perforated cage and is placed in the steriliser. The steriliser is a long cylindrical vessel provided with steam inlet and outlet, pressure guage etc. Sterilization of FFB for 60 minutes at 45 psi has been found to be optimum to achieve the objectives mentioned above.

Stripping

The processing of sterilization loosens the fruits but does not separate them from the bunch. the loose fruits are stripped off with the aid of a mechanical bunch stripper. This device is a rotary drum with baffles and perforations. When the sterilized bunches are thrown into the rotating drum (20 rpm) the fruits are separated from the bunches and loose fruits fall through the perforaters and the empty bunches pass through the other end of drum.

Digestion

Purpose of digestion is to convert the loose fruit into pulp and in the process the cell walls are broken facilitating release of oil with the help of thermal and mechanical energy. The digestor is a vertical jacketed cylindrical

Fig. 1 : Harvested bunches ready for processing

vessel fitted with a centrally mounted agitator having specially designed blades rotating at slow speed (25 rpm). The loose fruits are charged into the digestor from the top with the aid of an elevator. Live steam is injected into the jacket and into the vessel to maintain the temperature at 95°C. The digested mash with semi-solid consistency is discharged through a discharge chute at the bottom.

Pressing

The digested mash consisting of oil, water, seed, fibre and other suspended matter is charged into a perforated cage and subjected to pressing. The hydraulic press is fitted with a plunger matching with the cage diameter. The pressing is done while the mash is hot (80-90°C) at 750 psi. The hot oil water mixture with suspended solids is expelled through the perforations leaving the solid press cake in the cage.

Clarification

The oil water mixture is filtered to remove the fibrous debris and is collected in the clarification tank. Clarifier is a vertical cylindrical vessel fitted with steam coil. The oil water-mixture is diluted with hot water (1:2) and heated to 95°C. The oil being lighter, rises to the top and is decanted continuously into a collection tank. The watery sludge at the bottom is discharged as waste.

Purification

The crude palm oil from the clarifier is passed through a high speed centrifuge at 80°C to remove the traces of solid inpurities and water. The pure raw palm oil thus obtained is stored in tanks.

Vacuum drying

Excess moisture in the oil leads to FFA release and quality deterioration on storage. Vacuum drying is adopted in the process to remove the excess moisture.

Oil storage

The raw palm oil is stored in tanks provided with steam coils.

Nut recovery

Palm kernel oil is derived from the palm nut recovered from the press cake. After extraction of palm oil, the press fibre has a moisture content of 45-50 per cent. Mechanical recovery of the seeds involves breaking and drying the press cade, followed by separation of the nuts. The meat recovery has also been designed to match the one tonne FFB/hr palm oil mill. The unit consists of a steam jacketed paddle, conveying and cake breaking section. During the passage, the press cake is broken with the help of the rotating paddles and the press cake is also dried as it is heated in the steam jacket. The dried press cake is separated into fibre and nut is a vertical separating column using suction. The lighter fibre is drawn into a cyclone and the heavier nuts are allowed to fall into a horizontal rotating nut polishing drum. The fibre thus separated is used as boiler fuel. Final removal of residual fibre from the nuts is achieved in the polishing drum along with grading of the nuts based on size.

The small palm oil mill envisages only upto the nut recovery stage and the nut as such as a saleable product. To recover the palm kernel and shell mixture thus obtained is separated into kernel and shell in a clay bath maintained at a particular specific gravity. The shell being heavier, sink and the kernel being lighter floats and is skimmed off. The separated kernel is dried to a final moisture of 6-8 per cent. The kernel is powdered and steam conditioned followed by expression of oil in expeller. The kernel oil is similar to coconut oil in fatty acid composition. The palm kernel oil recovery is about 2 per cent on FFB as it fetches a premium price.

The indigenous small mill

To suit the requirements of socio-economic conditions prevailing in India and considering the prospects of small sector plantations, Council of Scientific and Industrial Research in collaboration with Indian Council of Agricultural Research has designed and established a commercially viable small scale extraction mill at Central Plantation Crops Research Institute (Research Centre) Palode.

Its essential factors are

* Capacity to process one tonne FFB/hr.
* Waste fired boiler to generate high pressure steam. Adoption of horizontal steriliser and rotary drum stripper.
* Integration of digester and hydraulic press.
* Continuous clarification.
* Very low oil loss through sludge and hence elimination of sludge oil recovery.
* Purification of raw palm oil by high speed centrifugation.
* High quality raw palm oil with less than 2% free fatty acids.

* Process efficiency of 90%
* Compact layout and self-contained plant building with service facilities.
* Low investment and low cost of production. Totally indigenous design and fabrication.
* Easy maintenance.
* Suitable for 200 ha plantation.

Capacity

Mill capacity of one tonne FFB/hr was arrived at, considering capital cost for the process equipments and utilities. This can serve a plantation of 200 ha. The basis of calculation has been average annual yield of 15 tonnes FFB/ha; 15 per cent of it being harvested during the peak 3-4 months. The mill therefore, has to operate three shifts as the case may be during the remaining months.

Design Considerations

Steam generation

A loco type boiler that makes use of the mill and plantation waste has a capacity to generate 600 kg steam/hr, with a miximum pressure rating of 10 kg/cm^2. Better thermal efficiency has been made for both natural and induced draft. Fuel feeding is done manually.

Sterilizer

Two horizontal type sterilizers with a capacity of one tonne FFB each are employed. Each sterilizer can accommodate two perforated cages on trolley wheels. Sterilization is carried out at steam pressure of 3 kg/cm^2 as practised in large mills. Total sterilization time including weighing, loading, and unloading ranges from 90 to 120 minutes. At present, loading and unloading are done manually. (Fig. 2)

Fig. 2 : Sterilizer

Stripper

A standard model mechanical rotary drum stripper is employed that can handle about two tonnes of bunches/hr. (Fig. 3)

Digester and hydroulic press

The loose fruits from the stripping area are fed manually to the bucket elevator which in turn feeds the digester. The digester is a vertical jacketed vessel provided with beater arms, feeding and discharge chutes and live steam injection facilities. While in operation a temperature of 95°C to 100°C is maintained for the mash. with a holding capacity of 400 kg, the digester can handle about one tonne of fruits/hr and feeding and discharge can be made continuous. Hydraulic press of 100kg capacity is used for the expression of the hot mash. The perforated cage can hold about 60 kg mash and each pressing cycle is of 5 to 6 minutes duration. Both digester and press are integrated with a platform to facilitate handling of the hot mash. The crude oil from the press is collected by channels and is discharged into a transit tank. (Fig. 4).

Clarification

Clarification is carried out by overflow technique. The clarifier is a cylindrical vessel of 400 l capacity provided with steam coils. Clarification is done continuously. With proper digestion and oil-water ratio in the clarification, the oil content of the sludge is less than 20% and hence oil recovery from the sludge is avoided here.

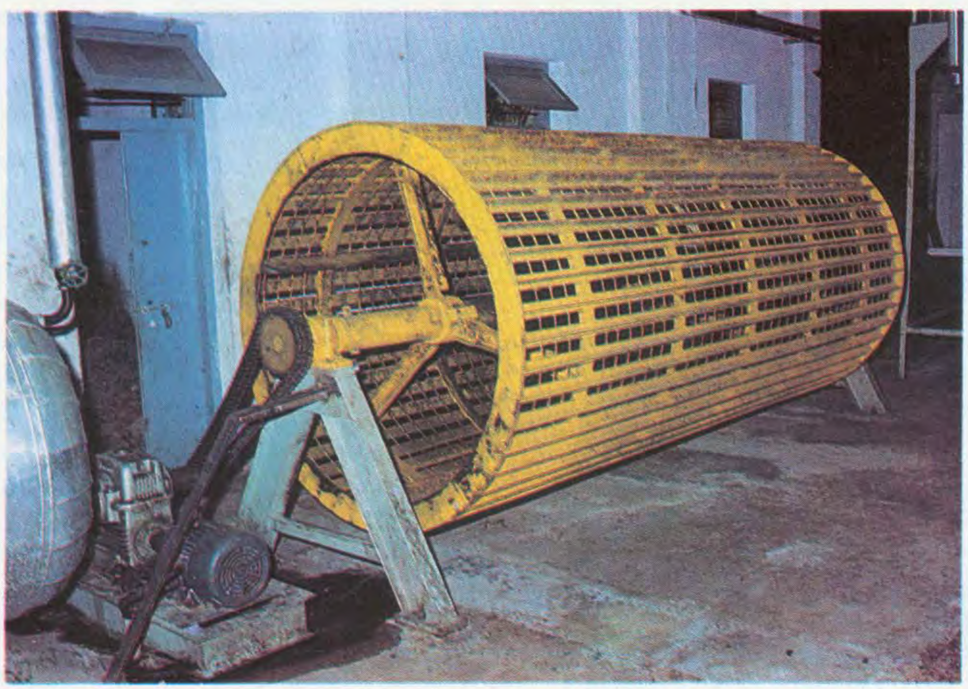

Fig. 3 : Stripper

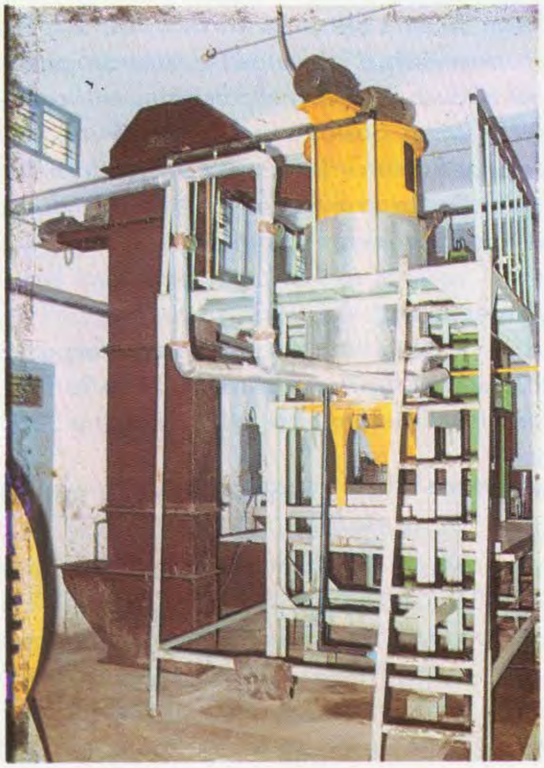

Fig. 4 : Digester

Purification

The clarified oil is further purified by using a bowl type high speed centrifuge of 500 l/hr capacity. This operation facilitates the removal of sludge impurities and excess moisture. The purified raw palm oil from the centrifuge is discharged into a storage tank fitted with steam coils.

Process efficiency and product quality

Data from a few trials are presented in Table 1. Oil loss at sterilization, pressing, clarification stages were calculated from the analytical data. Loss of oil through the unstripped fruits is not accounted here. It was observed that some bunches could not be stripped completely inspite of maintaining a steam pressure of 3 kg/cm^2. Densely set fruits in these bunches resulted in inadequate steam penetration and this aspect requires further standardization. Oil content of the press fibre is also fairly high which again demands optimization of pressing conditions.

The overall efficiency of about 90% suggests that the performance of the small mill is comparable with that of large mills. The free fatty acid content of less than 20 per cent in the raw palm oil demonstrates that high quality oil could be extracted in the small mill. Detailed analytical data of raw palm oil support the

Table 1. Analytical data on oil recovery and loss

Sl. No.	Oil loss				Fibre (Dry)		Oil recovery		Oil quality	
	Sterilizer % oil	Condenate % oil	Sludge % oil	% oil FFB	% oil	% oil on FFB	% Recovery	% oil on FFB	% FFA	% Moisture
1.	0.40	0.05	1.90	0.70	15.00	0.90	89.00	18.30	2.00	0.21
2.	0.40	0.05	1.61	0.66	14.50	0.88	92.00	20.00	1.44	0.18
3.	0.35	0.04	1.80	0.66	16.20	1.00	88.80	19.00	1.50	0.20
4.	0.36	0.04	1.30	0.68	13.40	0.80	92.00	21.40	1.20	0.22
5.	0.31	0.03	1.70	0.73	14.30	0.93	92.20	21.80	1.82	0.20
Average	0.36	0.04	1.66	0.68	14.70	0.90	91.00	19.80	1.80	0.20

soundness of the oil in terms of chemical and physical quality parameters. (Table 1).

Inspite of the good performance of the small mill, higher labour requirements is a major disadvantage. Though complete automation is not feasible, some of the present manual handling processes need to be mechanized; for instance, loading and unloading in the sterilizer, feeding to the stripper etc. With this mechanization about 15 persons (unskilled, skilled and a qualified engineer) per shift are required for the operations of the small mill. The energy requirement part from steam is about 15 K Wh/tonne of FFB. Subsequently a full-fledged commercial palm oil mill with a capacity of processing one tonne FFB/hr has been commissioned by the Regional Research Laboratory, Trivandrum in West Godavari district. for the Andhra Pradesh Oilseed Growers Federation.

Investment

Capital investment for establishing one tonne FFB/hr mill is presented in Table 2. This mill is sufficient to cater to the need of a 200

Table - 2 : Investment for establishing a mill of one tonne FFB/hr capacity.

	Equipments		Cost (Rs. in million)
1.	Horizontal sterilizers with cages	2 Nos	0.60
2.	Rotary drum stripper with screw conveyor	1 No.	0.45
3.	Digester, complete with bucket elevator	1 No.	0.50
4.	Hydraulic press (100 tonnes)	1 No.	0.30
5.	Clarifier	1 NO.	0.06
6.	Centrifuge	1 No.	0.18
7.	Vacuum drier	1 No.	0.18
8.	Vibrating screen	1 No.	0.05
9.	Industrial balance	2 Nos.	0.05
10.	Storage tanks (40 K L)	2 Nos.	0.25
11.	Nut recovery unit (cake breaker, Polishing drum and cyclone collector)	1 No.	0.65
12.	Material handling systems		0.40
13.	Process pumps, pipes etc.		0.08
14.	Steel structures (for supports, staging etc.)		0.20
15.	Spares and accessories		0.20
16.	Miscellaneous items		0.15
17.	Contingencies and other over heads		0.50
			4.80
Utilities			
1.	Locotype agrowaste fired boiler		0.58
2.	Steam line		0.17
3.	Electrical		0.38
4.	Water supply		0.15
5.	Plant building (800m^2)		1.40
6.	Miscellaneous		0.52
			3.20
	Total		8.00

hectare oil palm plantation. The investment includes plant building with a roofed area of $800m_2$, equipments and material handling systems and the site fabrications. Utilities such as steam, power and water supplies are also included. The total investment for this mill at the present price level (1991-92) is Rs. 8 million. Investment per unit throughout for the small mill is still lower compared to that of large mills, primarily because of total indigenous design and fabrication. The small mill also has easy maintenance, amenability to local situations etc.

Economics of palm oil mill

This palm oil mill produces raw palm oil as the main product and palm seed as the by-product. The sale price of raw palm oil can be taken as Rs. 20,000/- tonne and that of palm seed can be taken as Rs. 2,000/- tonne. The one tonne mill catering 200 hectares would produce 600 tonnes of raw palm oil and 300 tonnes of palm seed. The mill capacity can be increased as there is sufficient flexibility in the design and capacity utilization. The cost of production is Rs. 15,500 per tonne of palm oil of which Rs. 10,000 constitute the cost of raw material. After the pay back period (10 years) the cost of production comes down to Rs 12,500 per tonne. The mill may be commissioned when the plantation is 4 years or 5 years old so that the full capacity utilization would be achieved within 3 to 4 years. Though this may cause some wastage of fruits in the 3rd or 4th year, it is advisable since capital investment on the mill in the 3rd year itself may result in more economic loss compared to wastage of fruits in the early years. It is estimated that the loans taken for establishing the mill could be paid back in 8 years. Therefore, the one tonne FFB/hr palm oil mill is commercially viable.

Generally, oil palm plantation and palm oil mill function as an integrated system; the plantation being a captive unit for the mill. This is to ensure assured supply of fruits to the mill which is vital for the economic viability. In the present situation the palm oil extraction mill is treated as an independent unit managed either by a co-operative or by a group of farmers owning plantations. The procurement price of FFB is taken as Rs. 2000/- tonne. This is equivalent to 14 per cent value of FFB, assuming that 20 per cent is the recoverable oil from FFB. More information are required with regard to productivity, oil content, seasonal fluctuations etc. to fix the procurement price under Indian condition. Price upto 15 per cent on oil value could be adopted considering all aspects which may take some more time to arrive at the optimum level without affecting the producer and processor.

The countries where oil palm is grown differ widely in their infrastructural facilities and capital investment capabilities. Therefore, there is greater need for a flexible approach to the design and size of a palm oil mill to suit the local requirements. The capital cost on per tonne basis could be brought down, provided local infrastructure is fully utilized. Similarly the performance of the smaller mills in terms of efficiency and product quality could be brought to the level of larger mills by proper design of the mill as demonstrated here. The small mills are suited for small holdings, scattered plantations and during the initial years of large scale plantations. Neverthless, large mills with capacities ranging from 5 to 10 tonnes/hr can co-exist if situation warrants.

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