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Improvement of Oil Palm

K.U.K NAMPOOTHIRI

1. INTRODUCTION

Oil palm (*Elaeis guineensis*) was introduced to National Botanic Gardens, Calcutta as an ornamental plant towards the end of 19th century. Its performance, when grown as a commercial venture in Kerala and Andamans since 1971, gave the confidence in exploiting the crop on a commercial scale and thereby meeting the growing demand for vegetable oil in the country. Oil palm development assumed a new dimension and received substantial government support consequent to the recommendations of the working group constituted by the Government of India (Anon., 1988) which identified an area of 0.575 million hectares in nine states as suitable for oil palm cultivation under irrigated conditions. Subsequent planting of oil palm under the DRDA programme (200 ha) and private holding (40 ha) in West Godavari district of Andhra Pradesh followed by the oil palm demonstration projects under the aegis of Department of Bio-technology in Andhra Pradesh, Karnataka and Maharashtra (1000 ha each) has given additional impetus to the farmers in growing the crop.

Although research work started in 1962 by the Kerala State and subsequently by the Indian Council of Agricultural Research since 1976 at Central Plantation Crops Research Institute, Research Centre, Palode has given technology for higher production through indigenous *tenera* hybrids and about 0.4 million quality planting material is produced per annum the crop improvement programme has to go a long way in this country to develop high yielding *tenera* hybrids which yield at par with those in leading oil palm growing countries.

2. FLORAL BIOLOGY

2.1 Inflorescence

Oil palm is a monoecious, cross-pollinated crop producing male and female flowers separately on the same palm. Each inflorescence primordium is a potential producer of both male and female inflorescences. Inflorescence is a compound spike or spadix carried on a stout peduncle. An inner and outer spathe tightly enclose the inflorescence up to six weeks before anthesis. Inflorescence pushes its way out by splitting open the spathes. Six to ten long bracts are seen below the lowest spikelets two of them extending to the top of the inflorescence.

2.1.1 *Female Inflorescence and Flower*

The female spikelets are thick and fleshy, and develop in the axils of spinous bracts. The flowers are arranged spirally around the rachis of the spikelets. Each flower is in a shallow cavity and is subtended by a bract which is drawn up into a spine. An inflorescence generally contains 100 spikelets with over 4000 flowers. Each female flower is protected by a bract, two floral bracts and two whorls of three perianths each. Ovary is tricarpellary. The two male flowers at the base of the female flowers are abortive. At anthesis, the stigma curves outward. The stigmatic lobes, when receptive, are white to pale yellow in colour. Later on, a red stripe develops along these lobes as the flowers turn purplish indicating the end of receptivity.

2.1.2 *Male Inflorescence and Flower*

The spikelets of the male inflorescence are non-spiny long finger-like structures (Fig. 1). Each spikelet arises from a central stalk bearing 600-1200 male flowers which are yellow in colour having distinct aroma and mature from bottom to top. The flowers are arranged in a triangular bract; it consists of a perianth of six minute segments, a tubular androecium with six or rarely seven anthers and a rudimentary gynoecium. The anthers are bilobed and release pollen grains through the lateral slits. A single inflorescence

Fig. 1 : Oilpalm tree with male flower.

produces up to 50 g pollen which is liberated over a period of two-three days (Pillai and Ponnamma, 1992).

2.2 Pollination

Oil palm was considered as wind pollinated till the work of Syed *et al.* (1982) who showed that it is mainly insect pollinated. The main pollinators are *Elaeidobius kamerunicus, Elaeidobius subvittatus, Mystrops costaricensia* (sap beetle) and *Thrips hawaiiensis.* Only *E. kamerunicus* is available in India, introduction of which increased the setting and fruit development, and led to a substantial increase in yield (Dhileepan and Nampoothiri, 1989).

Although, oil palm is a naturally cross-pollinated species, selfing or controlled pollination can be readily effected. For artificial pollination, male inflorescence is bagged seven days before its opening. Formaldehyde (40 per cent) is sprayed on the spathe and inside the bag which is used for covering the inflorescence. The bags are provided with opaque windows to observe the male flower opening. The inflorescence is protected against entry of ants and other insects. When male flowers open, the inflorescence is cut at its base, removed and dried in an incubator. Pollen is dried along with the bag at 35-40°C for 24 hours. Pollen can be collected by shaking the inflorescence thoroughly. Pollen is sieved and collected in storage tubes. Under natural conditions, it remains viable for seven days. When moisture is reduced to 5 per cent or less and pollen is stored in a deep freeze at -5°C, it can remain viable for more than one year.

The female inflorescences are also bagged at least one week before opening by adopting the same method described for male inflorescence. The opaque window is provided with a hole which is temporarily closed with adhesive tape.

The receptivity of female flowers is watched through the window of the bag and when receptive, pollen is dusted through the hole provided. The pollen is placed in a test tube with a rubber cork carrying two 'L' shaped glass tubes. The adhesive tape of the holes in the window of the bag is opened carefully and one glass tube is inserted into the bag gently and air is blown through the other tube. The pollen spreads and falls on the female flowers. Pollination is done in the morning and has to be done for 2 or 3 days so that all the receptive flowers are pollinated. The bags can be removed three weeks after pollination.

3. CYTOLOGY

The haploid chromosome number of oil palm is 16. Occurrence of 18 and 24 chromosomes in root tip cells has also been reported (Sharma and Sakar, 1956). The chromosomes are small ranging from 1.15 to 2.9 μm in size. It is reported that this species has three pairs of long chromosomes, four pairs of medium sized chromosomes and nine pairs of comparatively short chromosomes.

Mitotic division is generally normal. Aberrant divisions with lagging chromosomes have been reported by Smith and Thomas (1973) in rapid growing callus tissue.

Literature on meiosis is scarce because of the difficulty involved in the study. The first and second meiotic divisions are regular resulting in four daughter cells with 16 chromosomes each. Secondary associations have been reported as in certain other species of palms by Sharma and Sakar (1956). They postulated that this is indicative of allopolyploidy and that the basic chromosome number of eight could be the ancestral complement of these species.

4. FRUIT FORMS

Zeven (1967) considered that the natural habitat of oil palm was in swamps and along river banks. The species occurred originally in palm groves throughout the tropical rain forest belt of West Africa which progressively diminished due to population pressure and consequent land use for food crops. In earlier years, palm oil and kernels were supplied entirely from wild palm groves. The palms in such groves were predominantly *duras* with a very low proportion of *pisiferas* and *teneras.* In Cote d' Ivoire, population of *tenera* varied from 0-41 and *pisifera* from 0-5 per cent (Meunier, 1969). In Nigeria, the percentage of *tenera* varied from 5 to 20 per cent. It was in 1941 that Beirnaert and Vanderweyen described the genetic nature of *tenera.* At present, three varieties are recognised based on fruit forms.

4.1 *Dura*

The fruits are characterised by a very thick shell varying from 2 to 8 mm. This results in a low mesocarp percentage in fruits.

4.2 *Pisifera*

The fruits of *pisifera* have no shell. They may contain embryo (fertile) or may be embryoless (sterile). The latter form is preferred as pollen parents (Pillai and Nampoothiri, 1988).

4.3 *Tenera*

The shell is thin (0.5 to 4 mm). There is a characteristic fibre ring around shell. *Tenera* is the hybrid between *dura* and *pisifera* and is the only commercially cultivated form (Fig. 2&3).

The shell thickness is monogenic. As *pisiferas* are female sterile, they have to originate from *tenera* × *tenera* crosses or *tenera* selfs.

Fig. 2 : Tenera oilpalm in bearing stage.

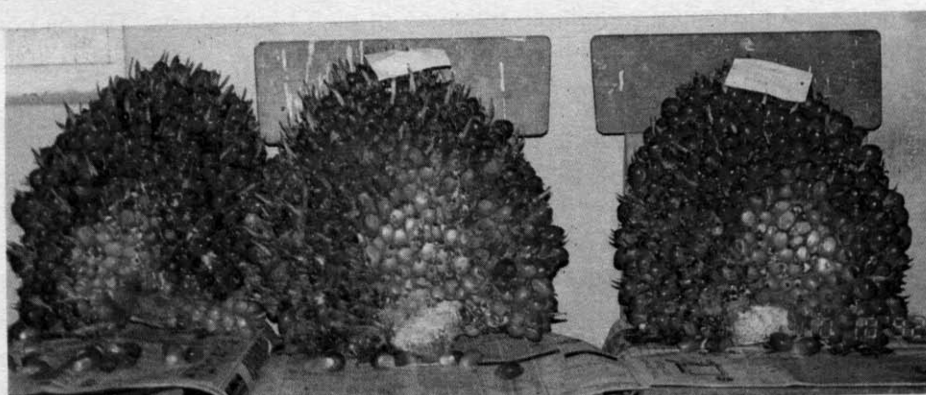

Fig. 3 : Heavy fruit bunches harvested from tenera palm.

Dura		*Pisifera*
Sh^+ Sh^+	X	Sh^- Sh^-
F1	Sh^+ Sh^- *Tenera*	
F2: Sh^+ Sh^+	Sh^+ Sh^- Sh^+ Sh^-	Sh^- Sh^-
Dura 25%	*Tenera* 50%	*Pisifera* 25%

5. BREEDING METHODS

The primary objective is to evolve genetically superior oil palm genotypes with higher oil yield. This can be achieved by manipulating any one or more of the factors contributing to yield, viz., number of bunches, bunch weight, number of fruits per bunch, mesocarp and oil content.

5.1 Selection

It is essential to use high yielding mother palms for hybrid production. For this, records on various yield and yield attributes are maintained on individual palms. The characters considered for selection are number of female inflorescences, sex ratio, number of bunches, weight of fresh fruit bunches, percentage of fruit per bunch, fruit weight, percentage of mesocarp/fruit and percentage of oil in the mesocarp. Of these, number of bunches, weight of single fruit and percentages of mesocarp and kernel per fruit are given the maximum weightage because of high heritabilities. The oil content, on the other hand, seems to be less heritable (Meuniar *et al.,* 1979a).

Studies so far indicate that nursery selection is unlikely to result in substantial genetic improvements. The practical solution would, therefore, be to reduce the non-genetic variation to the extent possible and reject weak seedlings when appreciable variation still exists. Generally, there is a culling of 15 per cent each at germination and nursery stages.

5.2 Hybridisation

Earlier breeding programmes were based on mass selection and family selection taking yield and yield attributes into consideration. There was a major change in the approach since the monogenic inheritance of shell thickness was elucidated.

Since only *tenera* hybrids are planted commercially, the present day breeding programmes are designed to produce the best *dura* × *pisifera* combinations. A simple procedure will be to test a large number of crosses to find out the best performer and produce seeds of these combinations by re-employing the 'proved parent' for many years till the parental palms are alive (Hartley, 1988). However, this places serious limitations on the quantity of seeds which can be produced.

The present day programmes are modified versions of reciprocal recurrent selection. This aims at identification of suitable *dura* mother palms and *pisifera* pollen parents which, when combined, would give high yielding *teneras.* Since *pisifera's* potential cannot be directly evaluated, they are tested in T × T crosses and palms are selected from the segregating populations. An outline of the breeding programme is given in Fig. 2.

Tenera × *tenera, tenera* (selfs), *dura* × *tenera, dura* (selfs) and *dura* × *dura* are produced from cycle 1. The best progenies in *tenera* × *tenera* and *dura* × *tenera* are identified. Let us take that $T_2 \times T_3$, $T_2 \times T_8$, in the t × t trial and D1 × T_5, $D_4 \times T_5$, $D_1 \times T_8$ and $D_4 \times T_8$ in the D × T trials gave outstanding progenies. The *dura* × *pisifera* parents for the D × P crosses will be the following:

	Dura	*Pisifera*
1.	D_1 and D_4	T_5 and T_8 selfed
2.	T_2 selfed	T_3 and T_8 selfed
3.	T_3 and T_8 selfed	T_2 selfed
4.	D_1 selfed	T_5 and T_8 selfed
5.	D_4 selfed	

It can be seen that in certain cases the parents are derived from *tenera* breeding only (items 2,3) whereas in some others (1,4,5), parents have been selected from results of both the *tenera* and *dura* breeding. If inbreeding depression is noticed, desired *tenera* can be produced by appropriate crossing and selfings. *Dura* source will be D_1(self), D_4(self) or $D_1 \times D_4$(self). *Pisifera* source will be $T_5 \times T_8$, T_5(self) or T_8(self).

The cycle of breeding can be continued bringing in more and more improvement with progressive cycles of breeding. Better results are obtained if populations of wider origin, African and *Deli duras*, for example, are used. So also introgression of genes from introductions made from time to time should be advantageous.

Variations in performance of different *dura* × *pisifera* combinations have been reported (Corley, 1982). Therefore, it is imperative to field test as many crosses as possible and identify the best ones.

In India, hybridisation work was initiated at the Central Plantation Crops Research Institute, Research Centre, Palode, Kerala in 1975 using *dura* parents of Malaysian origin available at Oil Palm Station, Thodupuzha, Kerala with four pollen samples imported from Nigeria. Eleven such *dura* × *pisifera* combinations were planted in 1976 at the Research Centre, Palode, under rainfed conditions. The yields obtained are given in Table 1 and 2.

The final yield in oil palm is the palm oil, which is generally 20 per cent of the fresh fruit bunches (ffb). Under ideal conditions such as in Malaysia, 6 to 8 metric tonnes of palm oil is obtainable from one hectare. Table 2 shows that there is considerable variation between hybrids in terms of yields. The crosses 65 D × 30.103 P, 92 D × 30.3154

Table 1 : Performance of oil palm hybrids - Number of fruit bunches

Hybrids		1986	1987	1988	1989	1990	Average
		(per palm per year)					
1.	65 D × 30.103P	7.0	6.3	4.7	7.0	6.5	6.2
2.	271 D × 30.4336P	6.2	5.7	2.8	6.2	6.5	5.5
3.	139 D × 24.3087P	4.9	4.8	3.1	4.9	5.8	4.7
4.	156 D × 30.4336P	3.7	3.9	3.3	3.7	4.1	3.7
5.	61 D × 30.4336P	5.2	6.2	2.9	5.2	7.2	5.3
6.	125 D × 30.103P	6.8	6.1	5.4	6.8	7.3	6.5
7.	108 D × 30.4336P	6.0	5.1	3.6	6.0	7.0	5.5
8.	92 D × 30.3154P	5.6	6.8	2.8	5.6	6.4	5.4
9.	269 D × 30.4336P	4.8	6.1	2.3	4.8	4.9	4.6
10.	187 D × 24.3087P	4.1	4.7	2.9	4.1	4.8	4.1
11.	120 D × 30.103P	6.7	6.5	4.4	6.7	6.5	6.2

Table 2 : Performance of oil palm hybrids - Yield of fresh fruit bunches

Hybrids		Yield of ffb (kg.)						*Oil yield MT/ha/ year
		1986	1987	1988	1989	1990	Average	
		(per palm per year)						
1.	65 D × 30.103P	164.1	87.1	86.3	94.4	141.6	124.8	4.6
2.	271 D × 30.4336P	146.4	71.5	47.4	68.5	141.3	111.8	4.1
3.	139 D × 24.3087P	98.7	61.2	52.9	54.7	116.0	89.1	3.2
4.	156 D × 30.4336P	60.8	53.7	27.0	29.1	84.0	63.6	2.4
5.	61 D × 30.4336P	138.5	77.4	42.3	55.9	155.2	116.4	4.3
6.	125 D × 30.103P	125.7	77.0	85.6	73.8	137.0	113.7	3.8
7.	108 D × 30.4336P	123.0	72.9	67.3	64.6	139.8	110.7	3.9
8.	92 D × 30.3154P	124.7	91.0	49.8	104.7	161.2	127.2	4.5
9.	269 D × 30.4336P	107.2	69.4	28.6	39.8	101.1	81.4	3.0
10.	187 D × 24.3087P	63.3	48.8	36.8	40.5	85.4	66.6	2.4
11.	120 D × 30.103P	159.2	98.3	87.1	75.4	148.1	128.4	4.5

*Estimates based on highest yield of ffb.

P and 120 D × 30.103 P performed much better than the others indicating the suitability of these hybrid combinations for commercial planting. If these hybrids are planted under better management, under irrigated conditions yields above 5 mt can be expected since these crosses have shown a potential to give 4.5 mt of oil per hectare in certain years (Nampoothiri *et al.*, 1992).

Another interesting observation is a sudden boost in yield in 1986 (Table 2). This could mainly be due to the introduction of the pollinating weevil *Elaeidobius kamerunicus* to the plantation in 1985. This was followed by a drastic reduction in yields. Such decline in yield, after a boost in production, consequent to weevil introduction has been reported by Weng (1985). An application of 20 per cent additional fertilisers, as recommended by Suwandi *et al.* (1984), restored the yields by 1990.

With a view to having more high yielding combinations for commercial seed production, several trials have been laid out to compare the yield performance of over 100 combinations in various centres. Forty crosses are under field testing in Andhra Pradesh, Karnataka, Mulde and Tamil Nadu under multilocation trials.

5.3 Clonal Propagation

Vegetative propagation offers scope for producing uniform progenies which are similar to their parents. Though we have very high yielding elite palms giving above 300 kg of ffb per year, it is not possible to maintain the yields in progeny especially since yield of ffb has low heritability.

Tissue culture work was, therefore, initiated at CPCRI in 1985. Plantlets were produced from tender leaf explants of seedling tissues and successfully field planted (CPCRI, 1987). Successful clonal propagation from seedling tissues has been reported from Bhabha Atomic Research Centre also (Thomas and Rao, 1985). However, usefulness of large scale multiplication of seedlings is limited. It is, therefore, necessary to standardise the methods of propagation using adult palm explants. Although, techniques for commercial production of clonal plantlets from adult palm have been developed in Malaysia and Cote d' Ivoire, this has not so far been achieved in India.

6. BREEDING FOR SPECIAL FEATURES

6.1 Dwarfness

Shorter palms are preferable in terms of easier harvesting and likely better longevity. Two main sources considered for dwarfness are 'Dumpy' *Deli* from Serdang and a dwarf selection from Pobe. However, it has not been possible to combine the high yield and dwarfness in hybrid combinations so far. Since variations in height is observed between lines, the efforts are now towards selecting comparatively shorter parents.

The most important source for dwarfness is the American oil palm, *Elaeis oleifera*. The palms have extremely low annual height increment with a tendency for procumbency.

The inter-specific crosses are fertile and the isolation barrier is so weak as to allow reasonable pairing giving mostly 16 bivalents (2n = 32) in meiosis (Hardon and Tan, 1969). F_1 hybrids are less than intermediate between the parents in height. However, because of the shy bearing, increased percentage of parthenocarpy, shell thickness and low oil recovery, commercial plantings have not yet been possible. Trials involving back crosses are under way in many countries. 'Super compact palms' being developed by ASD, Costa Rica is of special interest in this regard. Both *E. oleifera* and dumpy palms have been introduced to India only recently and the work in this direction is at its infancy.

6.2 Disease Resistance

Vascular wilt disease caused by *Fusarium oxysporum elaeidis* is very serious in African countries. Resistance breeding involves identification of tolerant progenies and screening the progenies in the nursery for which techniques have been perfected. Though no crosses are available, which are resistant, evidence have been accrued to indicate that parents which consistently gave crosses with a high degree of tolerance can be advantageously used in producing tolerant progenies (Rajagopalan *et al.*, 1978; Meunier *et al.*, 1979b). Agencies which sell seeds claim that only tolerant progenies are distributed for commercial planting.

Lethal bud rot of unknown etiology causes serious damage in Central and South America. Planting of *E. guineensis* × *E. oleifera* is the best known method of combating the disease. No control measures are available for spear rot disease noticed in certain parts of India. Resistance breeding is the only long lasting solution. None of the germplasm accessions as a whole is found to be resistant so far. Efforts are on to identify individual palms which are tolerant/resistant to the disease for use in further resistance breeding.

6.3 Drought Tolerance

Although oil palm can withstand drought conditions to a great extent, its performance is seriously affected when there is moisture stress. Differences in the severity of drought symptoms between different progenies have been reported suggesting the possibility of selection for drought resistance or tolerance. Several physiological tests have also been developed for screening parents and progenies. The seeds of these combinations which have been selected based on field performance under severe drought conditions such as in Republic of Benin are likely to fare better under conditions of moisture stress. But so far, nowhere a drought resistant/tolerant hybrid has been realised for commercial cultivation.

6.4 Oil Quality

An oil rich in unsaturated fatty acid (particularly with less palmitic and more linoleic acid) giving a large liquid fraction would be of high economic value (Corley,1982). Attempts are made to improve the quality of oil in *Elaeis guineensis* by using *E. oleifera* which has a lower melting point (20 to 22°C), an iodine value above 80 and higher unsaturated acids (up to 80 per cent). The F_1 hybrid is intermediate between the parents. Further selections are necessary before the hybrid derivatives can be commercially exploited.

7. SEED PROCESSING

Generally, the bunches fully ripen within six months after pollination. The fully ripened fruits are separated and depericarped to extract the seeds. Seeds are treated with emisan (0.1 per cent) solution for 20 minutes or any other suitable fungicide to control the external microflora. The seeds are dried in shade to attain a moisture percentage of 18 per cent. Such seeds can be stored in polythene bags up to a period of 6 months without loss in viability.

8. SEED GERMINATION

The oil palm seed consists of an outer shell covering the kernel. The embryo lies embedded in the endosperm below the functional germpore. The ovule is tricarpellary and usually only one of them develop. Under natural conditions, germination is sporadic and may take several months which is not adequate for establishment of plantations where a high percentage of germination is desired in a short period.

Fig. 4 : Germinated oilpalm seeds.

The method now adopted is to soak the seeds in water for five days with a daily change of water. Thereafter, the seeds are spread out and dried in shade for 24 hours. The dried seeds are put in polythene bags, closed tightly using rubber bands and placed in germinator at 40°C for 80 days. The seeds are then soaked in water for five days changing the water daily and dried for two hours. The seeds are placed back in bags and kept at room temperature. The germination commences in 10-12 days (Fig. 4). A germination percentage of 90-95 per cent in obtained by adopting this method.

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