International Journal of Oil Palm, **2** (1): 1 - 6, June 2001

REVIEW PAPER

Oil Palm Seed Production - A Short Review

P. Rethinam*, P. Murugesan, M.S. Saraswathi and K.Parimala
National Research Centre for Oil Palm, Pedavegi, West Godavari Dist.
Andhra Pradesh-534 450, India.

ABSTRACT

Complete information on oil palm seed production technology is essential to attain self sufficiency in planting material requirement. Hence a thorough review is carried out to identify the difficulties from the previous experience and thereby refining the process so that efficient seed production would be possible. This review paper briefs the various aspects of seed production namely selection of parents, preparation of male and female inflorescences for crossing, harvesting, processing and storage of seeds, seed viability tests and methods of breaking dormancy in Oil Palm with a background information on the current status of oil palm seed production in India and in the world. To assure the quality of seeds supplied to the farming community it is very much essential to bring seed production programme in India under the purview of seed certification agency.

Key words: Oil palm, seed production and certification

The oil palm (*Elaeis guineensis* Jacq.) is a native of West and Central Africa with 'natural' or 'semi-wild' grove populations of over 300 million adult palms. It is the highest oil-yielding plant per unit area. Under good management conditions, its industrial production can reach 6 tonnes of palm oil and 600 kg of kernel oil per hectare. Three fruit forms are available in *E.guineensis* . They are thick shelled *dura*, shell-less *pisifera* and thin shelled hybrid *tenera*. Four palms planted at the Bogor Botanical garden in Java, Indonesia was the main source for the subsequently developed progenies with large bunches and good fruit qualities. With the discovery of single gene inheritance (Beirnaert and Vanderweyan, 1941) *tenera* hybrids became the main planting material throughout the world (Hartley *et al.*, 1962).

WORLD SEED PRODUCTION STATUS

The estimated world production of oil palm seeds is 146 million while the estimated demand is only 120 million per annum. Indonesia, Malaysia, Costa Rica and Papua New Guinea are the major seed producing centres of the world and they have good potentials for export (Rajanaidu and Jalani, 1996). IOPRI, Bah Lias Research Station and PT Socfindo are the major seed producers of Indonesia with IOPRI contributing to 80% of the country's production (Pamin *et al.*, 1996).

Currently in Malaysia, about 13 companies are involved in seed production, the major being FELDA, Guthrie and Golden Hope which contribute to the bulk of the material produced in the country. Malaysians excel in seed production because they strictly adhere to the guidelines set by the Standard and Industrial Research Institute of Malaysia (SIRIM), which is being revised now and then (Mukesh Sharma, 1998).

Presently, part of the planting materials for India are being imported from the following sources as per the global tenders issued by the Govt. of India. The suppliers are ASD, Costa Rica, UNIPALM, Nigeria and IRHO, France. But to meet the future requirements it is highly essential to establish our own seed gardens (Nampoothiri and Ravindran, 1992).

Though the intiative to expand oil palm cultivation in India was taken a long time back, non- availability of quality planting material was one of the major constraints. Moreover, importing of oil palm sprouts is a cumbersome process as far as the companies involved in the oil palm development are concerned. So indigenous hybrid seed production of oil palm with strict control on quality is the need of the hour. In this context, the present status of oil palm seed production and related aspects are reviewed here, which will help to base the Indian seed production programme on a sound footing.

BREEDING FOR SEED PRODUCTION

The following are the major objectives in the breeding of oil palm for seed production (Kushairi *et al.*, 1997).

- Increased oil yield /ha
- Better oil quality
- Reduced height increment
- Pest and disease tolerance

Reciprocal Recurrent Selection (RRS) is the most common method of breeding adopted by the seed producing countries of the world. It involves the selection of elite *dura*s (sh^+sh^+) and *pisifera*s (sh^-sh^-) and then crossing them to produce *tenera* (sh^+sh^-) seeds (Rajanaidu *et al.*,

* Former-Chairman, Coconut Development Board, Kera Bhavan, Kochi-682011, Kerala, India & Presently Executive Director, Asia Pacific Coconut community, 3rd floor, Lina building, HR Rasuna said Kav B.7, Kuningan, Jakarta 12920, Indonesia.

1997). Owing to its increased oil production than that of the parents, *teneras* have become the only commercial planting material all over the world.

ORIGIN OF PARENTAL PALMS FOR SEED PRODUCTION

a) *Dura* mother palms

All over the world the mother palms used for seed production are mainly derived from the Deli *dura* palms. High intensity of selection of *dura* in the past has resulted in a very narrow genetic base. The Deli *dura* populations are derived from the four Bogor seedlings planted in Java, Indonesia in the year 1848 (Jogoe, 1952) . The Deli *dura* has gone a full cycle due to its popularity among the seed producers. The Deli *dura* seeds were imported from Sumatra in 1927 for planting in Guthrie, Chemara and Layang Layang Johore. After intense selection by Chemara at Ulu Remis Estate, 20 families were sent to Golden Hope and two families were sent to Dami in Papua New Guinea in 1968. After further selection, new planting materials from these Deli *dura* mothers palms were sold to Indonesian plantations. The situation of exploiting Deli *dura* exclusively may not be critical yet but in terms of sustainability, it is important to widen the genetic diversity of *dura* palms.

b) *Pisifera* pollen palms

The genetic base of the pollen palms is not as narrow as the Deli *dura* as there appears to be some diversity in their origins. However, on close examination, it can still be traced to a few selections in Africa. For example, the origin of the AVROS population can be traced to the famous single *tenera* palm "Djongo" (=the best) at Yangambi, Zaire. Again the planting material has gone a full cycle after reaching Indonesia following intensive selection. For example, from the selfs in Zaire, the material was sent to Sumatra in 1922, which gave rise to the famous SP 540. Further selfing and introgression with female fertile *pisifera* resulted in the TxP crosses planted at Indonesia and sent to Banting in Malaysia in 1957. The AVROS BM 119 material as sib crosses, was sent to Dami OPRS, Papua New Guinea in 1968. After further selection, the hybrids from the AVROS pollen crossed with Deli *dura* were sent to Indonesia for planting. Even the NIFOR origin can be traced only to a few palms in Africa.

SELECTION OF PARENTS

The selection of elite *duras* and *pisiferas* is vital for the production of high yielding hybrids. Parental selection based on vegetative characters like high leaf area ratio (LAR), leaf magnesium content (LGM) and low vegetative dry matter production (VDM) was found to be more efficient in contributing to the increased yield and harvest index of the off-spring because of their fair level of heritability (Breure and Bos, 1992). As far as the reproductive characters are concerned, number of bunches, weight of single fruit, percentage of mesocarp and kernel per fruit are given the maximum weightage because of high heritabilities (Meunier *et al.*, 1979).

SELECTION OF *DURA*

Selection is made based on the performance of DxP progenies. The minimum standards required for the *dura* parent palms are the following:

FFB yield minimum	- 170 kg/palm/year (high yielding areas)
	- 130 kg/palm/year (low yielding areas)
Mesocarp to fruit ratio	- 55%
Shell to fruit ratio	- 35%
Oil to dry mesocarp ratio	- 70%
Oil to bunch ratio	- 16%

SELECTION OF *PISIFERA*

In the first stage it is based on the performance of the TxT progenies and in the second stage it is based on the performance of DxP progenies. It needs greater importance, as their potential cannot be assessed directly as that of the dura parents since they are mostly abortive. Only sterile *pisiferas* are capable of transmitting the thin shell to their progenies. Hence selection based on fruit setting and progeny testing is emphasised. The minimum standards required for the *tenera* in the progeny test are as follows:

FFB yield	- 170 kg/palm/year (high yielding areas)
	- 130 kg/palm/year (low yielding areas)
Oil to bunch ratio	- 24%
Kernel to bunch ratio	- 3%

Parents of unknown pedigree and performance should not be used for commercial DxP seed production.

PREPARATION OF MALE INFLORESCENCE

A week before anthesis, the spathes enclosing the inflorescence are removed with a level head chisel and the spikelets are surface sterilized with 40% formaldehyde diluted in the ratio of 1:10. Then it is bagged with a pollen proof cover fitted with inspection windows and should be properly labelled. The inflorescence is detached from the palm along with the bag at the time of anthesis. The inflorescence is dried in a dehumidifier for 5h. The pollen is collected by shaking the inflorescence thoroughly, and then the pollen is sieved through a 70 mesh sieve. For the

effective usage of pollen, it is diluted with good talc in the ratio of 1:5 / 1:20 (Turner and Gillbanks, 1974).

POLLEN STORAGE

Pollen could be stored for several months without any loss of viability either in a desiccator containing silica gel or calcium chloride (Hardon and Davies, 1969; Benard and Noiret, 1970) or in a deep freezer at -18° to -20° C or in a refrigerator at + 5° C (Devreux and Malingranx, 1960; Henry, 1959). The use of differently stored pollen has its impact on both germination and early seedling growth (Hartley, 1988).

Poor pollen viability and germinability might also be attributed to the lower fruit set and bunch failure often encountered in some of the matured gardens of oil palm. Hence, this area needs critical investigation.

POLLEN VIABILITY TEST

Pollen viability is tested by making them germinate either on a solid (Taillez and Valverde, 1971) or liquid medium with sucrose. It can also be tested using a 1% triphenyl tetrazolium chloride stain with which viable pollen alone becomes purple (Mok, 1972). Pollen showing viability less than 60% is always discarded. But it has been shown by Broekmans (1957) that the actual germination on stigma is higher than on the artificial medium. Hence, good fruit set can be obtained even if the viability of pollen is as low as 10% as shown by the laboratory tests. Persons showing symptoms of pollen allergy should never be entrusted with pollen collection, processing and storage works (Lietch, 1970).

PREPARATION OF FEMALE INFLORESCENCE

This preparation is similar to that of male inflorescence but here the bags used are made of either terylene or cloth having thick white polythene windows of convenient sizes to facilitate observation. The polythene windows should have punched holes, which could be closed with adhesive tapes after insertion of the pollination tube.

CONTROLLED POLLINATION

Bagged female inflorescence is kept under constant watch for flower opening. On the first day of opening, the hole of the window is opened and pollen is blown inside with the help of a pollinator and then closed with the adhesive tape. The type of pollinator used varies with the palm age and to some extent with the labour availability. The pollinating equipment, which is practically in vogue, is of hand puffer type. It consists of a test tube carrying a cork at the open end. The cork is fitted with two L- shaped glass tubing stoppered with cotton wool. Pollination is carried out by opening the glasstubes and inserting one of the tubes into the punched holes on the window of the bag and blowing the pollen available in the test tube through the other tube. The bag is shaken well after pollination so as to help the pollen to reach all the opened female flowers. Pollination is repeated for three consecutive days so that all the flowers receive the pollen at the correct receptive stage. While inspecting the inflorescence 7 - 10 days after pollination, if there is any damage on the bag that particular cross is discarded. The bag could be removed three weeks after pollination when the flower tip turns black.

Occurrence of *dura*, *pisifera* and sterile palms in the *tenera* plantations is a serious problem being faced by the oil palm industry throughout the world. This is mainly due to faulty crossing technique being adopted in the seed production centre. Hence, strict quality control measures and scrupulous culling in the nurseries must be followed in all stages of the seed production and nursery programmes.

HARVESTING OF CROSSED BUNCHES

Fruit maturity is attained normally in $5^1/_2$ - 6 months after pollination. The ripened bunches after harvest are bagged to prevent any loss of loosened fruits and to prevent damage to the fruits and then brought to the processing site.

PROCESSING

The harvested bunches are taken out of the bags. The spikelets are cut from the peduncle and the individual fruits are removed from the spikelets by hand picking. In earlier days, depericarping was done manually either with a knife or through retting. Then the seeds are extracted by pounding the fruit with sand in a wooden mortar to remove the adhering mesocarp. Currently mechanical depericarpers are in use (Gray and Bevan, 1966; Bevan *et al.*, 1966) which consists of hexagonal cages revolving at 30 rpm. The walls are made of expanded wire metal mesh and water is fed to the cage to keep the fruit wet. The fibre removed from the seed is hosed off the mesh by pressure hoses.

SEED STORAGE

Seeds thus extracted are cleaned, well dipped in a solution of Emisan (0.1%) or Thiram (0.2%) for 20 min., dried in shade for a period of two days and then packed in polythene bags. It remains good for a period of one year without any loss in viability under ambient conditions (Rees, 1962a,1965). However storage at high temperature was found to impair germination (Kim and Luan, 1988). Presently they are stored in air-conditioned atmosphere at a temperature of 20- 22°C and humidity of 60 percent (Hartley, 1988).

In earlier days, oil palm seeds were said to be orthodox in behaviour as the seeds survived even when desiccated to a moisture content of 10 % (Rabechault *et al.*, 1967; 1969; Grout *et al.*, 1983;). This was further supported by Rees (1965) who indicated that viability can be maintained for 15 months even when water content was reduced to 15

% of it's fresh weight. Subsequently, King and Roberts (1979) classified oil palm seeds in the recalcitrant group since drying damaged the seeds. Oil palm seeds are said to be of intermediate kind as per the reports of Roberts (1973) and Ellis *et al.* (1991).

Storage behaviour/viability of oil palm seeds under Indian condition needs to be investigated in view of the extremely different climate unlike other traditional oil palm growing countries.

SEED DORMANCY

Oil palm seeds have an inherent dormancy period. The dormancy is due to blocking 'operculum' in the embryo which prevents the germination of fresh seeds. The seeds of oil palm requires a temperature treatment at a critical moisture content to overcome its dormancy and for uniform, rapid and maximal germination (Hartley, 1988).

METHOD OF BREAKING SEED DORMANCY

Giving high temperature treatment initially at a low moisture content of 17 - 18 % and subsequently raising the moisture content to 22% for breaking the dormancy and to initiate germination is termed as dry heat treatment (Rees, 1962). In case of wet heat treatment high temperature treatment is given when the seeds are having a moisture content of 21 - 22 % (Rees, 1962; Bull, 1966). The advantage of dry heat treatment over the wet heat method is avoidance of brown germ disease (Bull, 1966). Germination is completed within 95 days under wet heat treatment as against 120 days in dry heat method (Hartley, 1988). For the seeds of '*dura*' type, it is necessary to bring the seed to 17% to 18% moisture content (dry basis) and keeping them in an enclosed polythene bag for a period of 40-60 days at a temperature of 38- 40°C (Mok, 1970). Rees (1962) found that the *dura* seeds dry heated for 80 days germinated well after 25 days storage under ambient conditions.

The above said methods to break dormancy seem to be highly cumbersome and time consuming. If we are successful in reducing the period for breaking the dormancy by applying some physical/chemical methods, it would be greatly helpful in hastening the germination process.

SEED GERMINATION

The factors *viz.*, size of the fruit, position, age of the palm and season did not affect the germination of oil palm seeds. Seeds are collected from mature fruits after removal of the pericarp. Seeds are then dried in shade for 1-2 days and used for propagation (Hartley, 1988).

Marynen and Bredas (1955) in an investigation on the germination of oil palm seeds observed that packing in charcoal and fungicidal treatment of the seeds was harmless but unnecessary.

GERMINATION OF *PISIFERA* SEEDS

Germination is difficult because they tend to dry out rapidly and are susceptible to fungal and bacterial infection. But a method developed in Malaysia (Arasu, 1970) has given germination ranging from 5-52%. The percentage of fertile seed varied between parents and between bunches but rarely exceeded 60. The depericarped seeds are washed, rinsed in 0.05% sodium hypochlorite solution and then germination was initiated following the wet heat method.

GERMINATION OF *E.OLEIFERA* SEEDS

Satisfactory germination has been obtained with the seeds of 22% moisture content by initial adoption of dry heat method for 15 days. Then the seeds were soaked in warm water at 43°C for 15 minutes. This was followed by the wet heat treatment for 65 days.

SEED VIABILITY

The fruit size and position do not have any consistent impact on viability. Viability deteriorates gradually, sometimes alarmingly with the length of storage. Dunnett's 't' test showed that seeds stored at 30°C had shown an alarming reduction of moisture than the seeds stored at lower temperature. At 22°C the viability of seeds was maintained for 24 weeks (Rees, 1965) and at 20°C for 32 weeks (Mok, 1970). The high temperature of 30°C impaired the germination of seed after 10 weeks of storage. The seeds lost moisture rapidly to reach 11.7% in 59 weeks. In contrast, non-heated seeds maintained good viability for 18 weeks at 34°C (Rees, 1965). Low temperature causes a rapid decline in seed viability (Mok and Hor, 1977).

SAMPLE SIZE FOR SEED VIABILITY TESTING

Sample size can be determined using the following formula given by Cochran (1953):

$$n = \frac{t^2pq}{d^2}$$

Where 'n' is the number of seeds to be sampled (sample size)

't' is the value of the normal deviate corresponding to the desired confidence level

'p' is the per cent viable seed

'q' is the per cent non-viable seed

'd' is the level of precision or margin of error

Generally, the viability of commercial oil palm seeds is in the range of 85 to 100% but more often above 90%. The viability was found to be influenced more by the moisture levels. A sample size of 20-40 seeds was adequate for a 1% precision at 95% confidence. The level of viability or germination is largely determined by the sample size taken for testing viability (by chemical staining) or germination. A sample size of 400 seeds was found to be satisfactory for experimental work as well as commercial

seed testing giving 45% precision at 95% confidence.

PROGRESS OF SEED PRODUCTION PROGRAMME IN INDIA

Indigenous production of *tenera* hybrids was initiated in the country at National Research Centre Oil Palm, Regional Station, Palode (formerly: Central Plantation Crops Research Institute, Research Centre), Kerala during 1974 at Thodupuzha (Nampoothiri *et al*., 1992). Seed production in India mostly started with the *dura* population available at Thodupuzha, Kerala which were planted during 1961 by the Dept. of Agriculture, Govt. of Kerala.

SELECTION OF PARENTS

Forty three *dura* palms were selected based on yield and other characters during 1983-84 to form a large mother palm population and more than 11 *pisifera* having sterile characters were selected as pollen parent during the same period. Using the above parents, an average of 0.3 million seeds per annum were produced until 1996 (Nampoothiri and Pillai,1999). The selected individual palms from both *dura* and *tenera* population were either selfed or *interse* crossed. The selfed and *inter-se* crossed material were distributed to places *viz.*, Rajahmundry, Lakshmipuram (Andhra Pradesh), Taraka (Karnataka), Thodupuzha and Palode (Kerala) for further evaluation and limited seed production has been initiated.

In the seed garden at Lakshmipuram 44 *dura* palms were selected based on four years consecutive FFB yield average of 150 kg/palm/year mostly from 120 and 65 *dura* self families. Sixty pisifera palms were identified from 266Tx266T populations. Seed production has just been started using the pollen obtained from Palode as well as *pisifera* selected *in situ* .

PROGENY TESTING

Crossing programme was initiated utilizing 20 selected high yielding *dura* palms mostly from 65 and 120 and six *pisifera* palms to find out good combining ability for seed production (Rethinam and Murugesan, 1998). Although we have a large assemblage of both *dura* and *pisifera*, many of those are underutilized or not properly evaluated. Thus by using available population there is a need to have comprehensive progeny testing programme covering all the selected palms to further improve the breeding programme so as to have an increased yield from the best out of the best. In due course of time, India would be able to compete with other seed producing countries.

CONCLUSION

In India there is vast scope to expand the area under oil palm cultivation not only in irrigated areas but also in wasteland with sufficient water source. In view of the increasing demand for vegetable oil in the country the efforts taken up by the government to develop the future oil palm industry and interest being shown by small holders, the demand for quality seed will be increasing. So, adequate production of quality seeds is needed to meet the future domestic requirements. Consequently, utmost care is warranted in all the stages of production for which oil palm seed production in India should be immediately brought under Seed Certification agency to monitor and assure the quality of the seeds supplied to the farming community.

REFERENCES

Arasu,N.T. 1970 A note on the germination of pisifera oil palm seeds. *Malay. Agric. J.,* **47**: 524.

Beirnaert,A. and Vanderweyen,R. 1941. Contribution a l ' etude genetique et biometrique des varieties d' *Elaeis guineensis* Jacq.Publ. INEAC *Ser. Sci.* 27.

Benard, G. and Noiret, J.M. 1970. Le pollen de palmier a nuile. Recolte, preparation, conditionment et utilisation pour la fecondation artificielle. *Oleagineux*, **25**:67.

Bevan, J.W.L., Fleming, T. and Gray, B.S. 1966. *Planting techniques for oil palm in Malaysia.* Incorporated Society of Planters, Kuala Lumpur, 156 p.

Breure, C.J. and Bos, I. 1992. Development of elite families in oil palm. *Euphytica,* **64**:99-112.

Broekmans, A.F.M. 1957. Studies on the factors influencing the success of controlled pollination of oil palm. *J.W.Afr. Inst. Oil Palm Res.*, **2**:133.

Bull, R.A. 1966. The production of oil palm seedlings for field planting. *Planter*, **42**:248-272.

Cochran, W.G. 1953. *Sampling technique.* John Wiley and Sons, New York,p. 50 - 56.

Devreux, M. and Malingranx,C. 1960. Pollen d' *Elaeis guineensis* Jacq. Recherches sur les methodes de' conservation. *Bull. Agric.* Congo belge, **5**:543.

Ellis, R.H., Hong, T.D., Roberts, E.H. and Soetisna, U. 1991. Seed storage behaviour in *Elaeis guineensis. Seed Sci. Res.*, **1**:99-104.

Gray, B.S. and Bevan, J. W. L. 1966. Seed selection. In: *The Oil Palm in Malaysia.*, Min. Agric. Co-op.,Kuala Lumpur, p. 195-198.

Grout, B.W.W., Shelton, K. and Pritchard, H.W. 1983. Orthodox behaviour of oil palm seed and cryopreservation of the excised embryo for genetic conservation. *Annals of Botany,* **52**: 381-384.

Hardon, J.J. and Davies, M.D. 1969. Effects of vacuum drying on the viability of oil palm pollen. *Exp. Agric.*, **5**:59.

Hartley, C.W.S. 1988. *The oil palm,* 3rd edition, Longman, London.

Hartley, C.W.S., Menendez,T. and Smilde, K.N. 1962. Report on a visit to oil palm estates, research centers

and a settlement scheme in Malaya, West African Instt. for oil palm Research, 73 p.

Henry, P. 1959. Prolongation de la viabilite du pollen chez *Elaeis guineensis*. *Cr. hebd. Seanc. Acad. Sci.*, **98**:722.

Jogoe,R.B. 1952. Deli oil palms and early introduction of *Elaeis guineensis* to Malaysia. *Malay. Agric. J.*, **35**: 4-11.

Kim, M.C. and Luan, H.Y. 1977. The storage of oil palm seed after high temperature treatment. *Seed Sci. and Technol.*, **5**:499-508.

King, M.V. and Roberts, E.H. 1979. The storage of recalcitrant seeds: Achievements and possible approaches. International Bureau for Plant Genetic Resources.

Kushairi,A., Jalani,B.S., Ariffin,D. and Rajanaidu,N. 1997. Seed Production and export of Malaysian oil palm planting material. *The Planter*, **73**(853): 185-200.

Lietch, T. 1970. Practical experience in pollen collection and drying on a small scale. *Planter* **46**:216-219.

Marynen,T. and Bredas. 1955. La germination des graines d' *Elaeis*. Bull. Inf., INEAC, **4**:156.

Meunier, J., Gascon, J.P. and Noiret, J.M. 1979. Heredite des characteristics du regime d' *Elaeis guineensis* Jacq. En Cote d' Ivoire. Heritabilities-aptitude a' la combination. *Oleagineux*, **35**:377-382.

Mok, C.K. 1970. Studies on the germination of oil palm *Elaeis guineensis* Jacq. seed. Masterate thesis, University of Malaya, Kuala Lumpur, Malaysia.

Mok, C.K. 1972. The tetrazolium test for evaluating the viability of oil palm. *Proceedings of the International Seed Testing Association*, **37**:771-778.

Mok,C.K. and Hor,Y.L. 1977. The storage of oil palm (*Elaeis guineensis*) seed after high temperature treatment. *Seed Sci. & Technol.*, **5**:499-508.

Mukesh Sharma. 1998. Reprint. In: *Guide on oilpalm seed production prepared for the officers from India under UNDP Training programme.*

Nampoothiri, K.U.K. and Pillai,R.S.N. 1999. Crop improvement in oil palm-present status and future strategies. In: *Oil Palm Research and Development* (Eds. Rethinam,P. and Suresh,K.), N.R.C. for Oil Palm, Pedavegi, West Godavari District, Andhra Pradesh, p. 17-24.

Nampoothiri, K.U.K. and Ravindran, P.S. 1992. Breeding. In: *Oil Palm production technology.* (Eds. Nair,M.K. and Nampoothri, K.U.K.) C.P.C.R.I., Kasaragod, p.21- 32.

Nampoothiri, K.U.K., Pillai,R.S.N. and Ravindran,P.S. 1992. Evaluation of certain oil palm hybrids under rainfed conditions. *J. Plant. Crops*, **20** (Suppl.): 166-169.

Pamin, K., Tri Hutomo and Razak Purba, A. 1996. Supply and demand of oil palm planting materials. In: *Proceedings of the ISOPA/IOPRI seminar, Pekanbaru.*

Rabechault, H., Guenin, G. and Ahee, J. 1967. Absorption de l'eau par les noix de palme (*Elaeis guineensis* Jacq. var. *Dura* Beec.) 1. Hydration des differentes parties de graines amenees a teneurs globales en eau determinees. Cah. Orstom, *Ser. biol.*, **4**:31.

Rajanaidu,N. and Jalani, B.S.1996. Worldwide production and performance of DxP planting materials. Presented in the seminar on Sourcing of oil palm planting materials for local and overseas joint ventures. ASGARD Information Services, Subang Jaya, Malaysia.

Rajanaidu, N., Jalani, B.S. and Kushairi, A. 1997. Genetic improvement of oil palm. In: *The crop improvement for the 21st century*, p.127-137.

Rees, A.R. 1962. High temperature pre-treatment and the germination of the seed of the oil palm (*Elaeis guineensis*). *Ann. Bot.*, **26**: 569-581.

Rees, A.R. 1965. Some factors affecting the viability of oil palm seed in storage. *J. Nigerian Inst. Oil Palm Res.*, **4**: 317-324.

Rethinam, P. and Murugesan, P. 1998. Oil Palm Breeding for seed production. In: *Annual report 1998-99*, National Research Centre for oil palm, Pedavegi, India, p.13-18.

Roberts, E.H. 1973. Predicting the storage life of seeds. *Seed Sci. & Tech.*, **1**:499-514.

Taillez, B. and Valverde, G. 1971. Sensibilite aux ouragans de differents types de croisements de palmier a huile. *Oleagineux*, **26**:753.

Turner,P.D. and Gillbanks,R.A. 1974. *Oil palm cultivation and management*, Incorporated Society of Planters, Kuala Lumpur, Malaysia.

Venugopal, R. 1996. Policy issues related to reverse investment in oil palm industry. Presented in the seminar on Sourcing of oil palm planting materials for local and overseas joint ventures. ASGARD Information Services, Subang Jaya, Malaysia.