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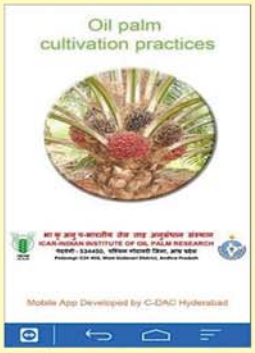
RESEARCH HIGHLIGHTS 2011-2015



ICAR-INDIAN INSTITUTE OF OIL PALM RESEARCH

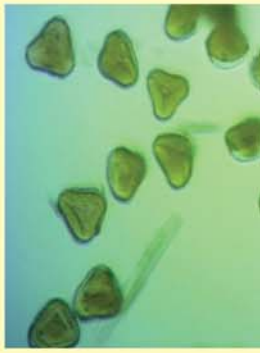
भाकृअनुप - भारतीय तेल ताड़ अनुसंधान संस्थान

ICAR - Indian Institute of Oil Palm Research

(An ISO 9001:2008 Certified Institute)

पेदवेगि - 534 450, पश्चिम गोदावरि जिला, आन्ध्र प्रदेश

Pedavegi - 534 450, West Godavari Dt., Andhra Pradesh



Research Highlights
2011-2015

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GENETIC RESOURCE MANAGEMENT

Collection of oil palm genetic resources

Survey was conducted in commercial oil palm plantations having exotic genetic material in various parts of the country for trait specific/country specific characteristics, which resulted in collection of 166 germplasm. The germplasm collected was evaluated, characterized and being maintained at IIOPR.

Twenty accessions of Sierra Leone (1994 collection) and Senegal (1993 collection) germplasm resources were imported from MPOB, Malaysia through NBPGR under the project entitled "International collaborative research project on oil palm germplasm exchange between India and Malaysia". It was reported that palms from Senegal had lipase content of <10 % (at 5ºC) which is considerably lower than that in the current planting materials of Malaysia (22 %-73 %). Sierra Leone materials have more bunch index.

Collection of oil palm germplasm

Registration of oil palm germplasm

Registration of 63 indigenously collected oil palm germplasm was completed and accession numbers were received from ICAR-NBPGR, New Delhi as IC-0610000 to IC-0610051; planted at ICAR-IIOPR, Pedavegi and IC-0599983 to IC-0599993 planted at ICAR-IIOPR, Research Centre, Palode.

Yield potential and phenotypic variation in oil palm germplasm

A total of 341 dura palms of Thodupuzha, Kerala materials were assessed for different fruit and seed characteristics. Fruit form analysis revealed that seven palms

(2 %) are teneras and the remaining palms are duras. The co-efficient of variation was high for shell weight followed by kernel weight and lowest for per cent mesocarp and kernel oil. The potentiality of unexploited dura palms (US356 US225, US147, US239, US380, US297, S285 and US375) was also studied for mesocarp content and oil per fruit (84 %). Promising palms have been identified for introgression in current breeding programme.

Genetic diversity in African oil palm germplasm in India

Twenty six accessions representing three African countries (Guinea Bissau, Tanzania and Zambia) were studied using 50 individual palms per accession. In general, mean of all the accessions exhibited high levels (0.694) of diversity. Mean diversity estimate (0.778) was highest in Tanzanian source closely followed by Zambia (0.727) and least value (0.576) was observed in Guinea Bissau. Low diversity values (<0.32) for bunch weight, shell thickness, single fruit and nut weight were noticed in Guinea Bissau compared to other sources. These findings combined with other evaluation results suggest that 'Tanzanian population' possess adequate genetic variability that is potentially useful for oil palm improvement programme in India.

Evaluation of *Elaeis oleifera* type accessions

Twenty three palms of two accessions (DOPR G 23 and 24) planted during 1992 at IIOPR, RC, Palode were evaluated for vegetative, yield and bunch quality traits as per the standard procedure. The results indicated that these palms had slow vertical growth. The highest mean Fresh Fruit Bunch (FFB) yield recorded was 158.66 kg per palm per annum, number of bunches was 7.44 per palm per annum, oil to bunch ratio was the highest at 18.31 % and height increment was lowest at 0.08 m per annum. Palm no. 6 which recorded highest FFB yield and possessed compact characteristics was selected for producing interspecific hybrids and further breeding for dwarf palms.

In *E. oleifera,* during fruit development, fertile fruits recorded substantial increase in weight, whereas, parthenocarpy fruits recorded no appreciable weight change. However, changes in fruit components were more erratic during 46 -110 Days After Anthesis (DAA) than matured phase (124 to 180 DAA) due to inherent characteristics of *oleifera*. Mass maturity (seed filling) occurred at about 148-186 DAA at which time seed moisture content declined gradually from 87.65 to 19.69 %. Oil formation in the mesocarp initiated (13.69 %) approximately at 92 DAA and peaked (67.7 %) at 186 DAA. The entire seed development period from immature to the ripe fruit took about 186 days under tropical climate of Kerala. Onset of germination was obtained at 136 DAA (16.7 %) and highest germination (90 %) was reported at 186 DAA followed by 180 DAA (81.3 %).

Fatty acid profiling of *E. oleifera* types and interspecific hybrids indicated that oil from *oleifera* palm had more oleic and linoleic acids with some exceptions in the progeny palms. Palm no 14 of Malaysia accession had highest (55.22 %) oleic acid. A known selected inter-specific hybrid planted during 1998 had highest palmitic acid (61.91 %), while Chithara 2 had the lowest content (23.77 %).

Identification of promising interspecific hybrids

Inter-specific hybridization was taken up for introgression of desirable traits, mainly dwarfness /compactness, from *E. oleifera* into *E.guineensis*. Two inter-specific hybrids ISH-1(360Eg x 13Eo) and ISH-2 (361Eg x 11Eo) were evaluated along with Dura x Pisifera (Tenera). Subsequent upon variance and heritability analysis of various growth and bunch components, a selection index was constructed by considering the most important traits of height increment, FFB yield and oil yield. Accordingly, eight palms were shortlisted; five from ISH-1 and three from ISH-2. Of the five promising palms from ISH-1, four were having annual height increment between 30 and 33 cm. Palm no. 28 recorded a bunch yield of 148.25 kg, height increment of 33.1 cm and bunch index of 0.29 which was on par with normal D x P. Palm no. 28 has also showed potential for maximum oil yield of 4.8 tonnes per ha resulting from the high mesocarp content and oil to bunch ratio. The kernel size was maximum in palm no. 34, which in turn would be useful in the development of genotypes for high kernel oil.

Dura Improvement Programme

Identification of high yielding dura palms: Yield data of dura palms were analysed for selection of high yielding duras. The enhanced selection criteria of 200 kg FFB per palm per year was applied while selecting the dura mother palms. This in-turn, is expected to ensure yield of >33 MT FFB and >6.6 MT palm oil per ha per year from the new hybrids that would be developed using these mother palms. Five year FFB yield data of ten DxD crosses in the second breeding cycle at oil palm seed garden Thodupuzha was analysed for stability parameters in order to identify consistent performing crosses. Based on stability parameter and mean yield, ThD2 was identified as the best genotype followed by ThD 5 and ThD1. From among the best families, individual palms with highest mean yield were selected for use in developing crosses. Similar exercise was carried out with dura-II population at IIOPR-RC, Palode and 43 high yielding palms were selected.

Evaluation and selection of high yielding dura palms: The performance of dura material from Palode (240D x 281D and 80D x 281D) and ASD Costa Rica (98C x 254D and 98C x 208D) planted during 2000 and 2002 respectively was evaluated. Based on the analysis of pooled data of last 5 years (2009-10 to 2013-14), eight dura palms (3 from 240D x 281D and 5 from 80D x 281D) recording FFB yield of more than 200 kg/palm/year were selected for advancing to next breeding cycle as well as

for hybrid seed production. Further, 11 dura palms (5 from 240D x 281D and 6 from 80D x 281D) recording FFB yield of more than 150 kg/palm/year were selected for hybrid seed production.

Development of DxD and TxT crosses for high yield: The high yielding mother palms were selected at three places *viz.*, OPSG - Thodupuzha, IIOPR, RC Palode and OPSG - Taraka, and fifty crosses developed were supplied for taking up a research trial at AICRP centre under UHS Bagalkot. Nursery was established and nursery evaluation of the crosses is in progress.

Development of third generation new D x P hybrids: At IIOPR, Pedavegi, 11 new oil palm DxP hybrids possessing desirable characters *viz.,* high FFB yield, slow vertical growth and tolerance to drought were developed. The dura selections made in the African germplasm (Zambia and Cameroon) and the pisifera selections (76P and 110P) among TxT progeny were utilized in developing these hybrids *viz.,* DOPR 41 to DOPR 51. These hybrids are at present under multi-location testing at AICRP on Palms centre (Vijayarai), Andhra Pradesh. Eight third generation D x P hybrids with expected annual production potential of 7 tonnes oil yield/ha have been developed and are under evaluation at AICRP, Bhavikere (Karnataka) Centre.

Identification of high yielding cold tolerant oil palm germplasm

In order to identify cold tolerant germplasm, which could serve as a source of planting materials for the North East Region, ten oil palm dura germplasm collected from Cameroon, planted during 1998, were evaluated at Mohitnagar, West Bengal for cold tolerance. Among the germplasm, CA-17 recorded the highest bunch index (0.30), highest number of bunches (8.2 palm/year), highest fresh fruit bunch (FFB) yield (108.4 kg) and highest average bunch weight (13.2 kg).

Development of dwarf oil palm

In an effort to develop dwarf and compact oil palm, selfed progeny of the Dwarf Tenera -1 from Palode was evaluated. The mean height of progenies was 165.94 cm during 7th year. Out of 58 palms, 4 palms recorded height increment less than 30 cm per annum. Palm no.31 recorded annual height increment of 19 cm and a bunch index of 0.43 against the standard value of 0.3 for normal DxP material. The mean canopy spread was 61.33 sq.m which allows 23.76 per cent extra land area as compared to currently followed spacing of 9x9x9m. Hence, a modified spacing with161 palms/ha would be possible. Yield potential of the selected progeny is 33.01 MT/ha

Palm no. 42CD, dwarf and tolerant to moisture stress

which in turn is equivalent to 6.6 MT oil per ha. With an average height increment of 30 cm per annum in the dwarf palms, the plantation height would attain around 30 ft upon reaching 30 years. The following four dwarf dura palms having tolerance to abiotic stress (drought tolerance) have been identified:

Palm No.	Height (cm)	Annual height increment (cm)	Fruit to bunch (%)	Shell to fruit (%)	Oil to bunch (%)	FFB yield (kg/palm/ year)	Average bunch weight (kg)
42CD	212 (after 14 years)	19.27	52	30.00	11.26	117	14.60
43CD	220	20.00	68	26.40	24.17	172	13.23
497CD	202	18.36	70	29.46	20.90		13.60
465CD	232 (medium dwarf)	21.09	72	31.60	13.62	159	22.70

Seasonal variation in FFB production of dura

The performance of two Palode dura cross combinations (240D x 281D and 80D x 281D) planted during the year 2000 was evaluated in terms of bunch number (BN) and bunch weight (BW) produced during different months of the year (2005 – 2012). FFB production (BN and BW) starts increasing sharply from the month of April to August and gradually decreases with the onset of winter (October onwards) up to March. FFB production was maximum (seasonal maxima) during May to August which accounted for almost 2/3rd of FFB production of the year. Seasonal minima was observed during October to March. FFB production exhibited a trend of on & off year, the trend being consistent in respect of bunch weight. Average bunch weight has shown continuous increase from 6th year to 13th year of the plantation.

Methodology for quality testing of oil palm pollen

The method of pollen quality assessment in terms of viability and *in vitro* germination was standardised. Five established dyes were screened to assess the oil palm pollen viability. Of the five dyes, 2, 5-diphenyl Tetrazolium bromide (MTT) performed better with high correlation of viability with *in vitro* germination. It did not stain dead or aborted pollen. For *in vitro* germination test, eight different media were tried. The media consisting of 2.5% - Sucrose; 100ppm - H_3BO_3 and PEG - 10 % (Mw 10,000) produced maximum germination (97.941 %) with pollen tube length of 317.88 µm and high correlation of germination with viability/staining values. Further, it is also recommended for using some type of control such as dead pollen to check the potential of the dye for pollen viability testing in oil palm.

Medium term storage of oil palm pollen

Oil palm pollen was subjected to four storage temperatures such as ambient / room temperature (RT=35± 2°C), refrigerated storage (5°C), freezer storage (-5°C) and deep freezer storage (-20°C) and significant variation was observed for viability and germination percentages. At room temperature, viability of pollen was rapidly lost and at third month of storage, it reached below 60 per cent. Similar was the case with pollen stored in refrigerated condition (5°C). In case of pollen stored in freezer (-5°C), viability was retained upto 9 months at above 60 per cent. In case of deep freezer (-20°C) stored pollen, the viability was retained above 80 per cent upto 12 months. The results were confirmed by *in vivo* fruit set studies carried out using pisifera pollen after storage. Bunch analysis data revealed that the mean maximum bunch weight (19.17 kg) was in pollen stored at -20 °C and the lowest in case of room temperature stored pollen (13.32 kg). Weight of fruits (after removing stalk and spikelet rachis) was the maximum for -20°C stored pollen (13.9 kg) followed by 11.47, 11.01 and 9.09 kg for -5°C, 5°C and room temperature storage. Per cent sterile fruits was highest (30.89) in case of room temperature stored pollen and lowest (5.47 %) in case of pollen stored at -20°C. Thus, it was observed that pollen storage in deep freezer at -20°C retained maximum viability as well as germination.

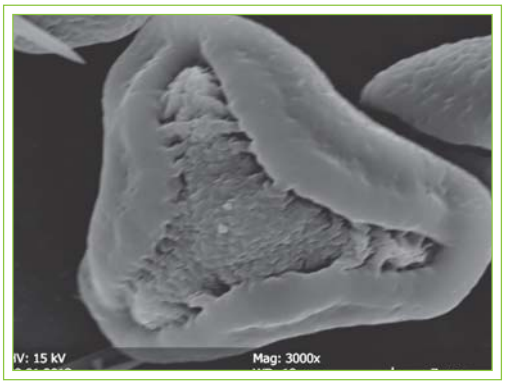
Storage of oil palm pollen in organic solvents

Studies were conducted to find out the efficacy of five organic solvents for pollen storage and significant variation was observed for viability and germination percentages. Viability was maximum for pollen stored in Diethyl ether (90.45 %) as well as in n-Hexane (88.41%) at 200 days of storage against 99 % for fresh pollen. Viability of pollen stored in chloroform and acetone were moderate and in case of Methyl alcohol, complete loss of viability was observed after initial 40 days. Similar trend was observed in case of germination also, where highest germination was recorded in pollen stored in Diethyl ether (78.98 %) and n-Hexane (78.11 %) against 94 % for fresh pollen. Same trend was observed for different intervals/period of storage. Pollen grains stored in non polar organic solvents (n-Hexane and Di ethyl ether) retained maximum viability, whereas, those stored in polar solvents, lost viability and germination very fast.

The *in vivo* fruit set data obtained after pollination with stored pollen indicated the same trend. Pollen stored in Diethyl ether and n-Hexane were normal with about 20 kg bunch weight. The weight of bunch was reduced to 17.4 kg in case of Chloroform and 5.86 kg for Acetone. As observed in *in vitro* studies, bunches pollinated with pollen from Methyl alcohol showed bunch failure (no fruit set). Per cent of sterile fruits was 19.41 in Diethyl ether and 14.5 in n-Hexane, whereas in case of Chloroform

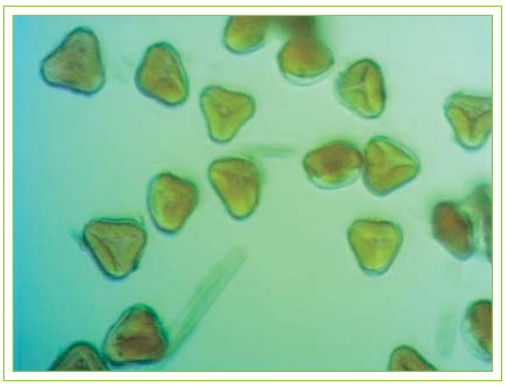
and Acetone, sterile fruits varied from 26.47 to 28.3 %. Fruit to bunch ratio was highest in Diethyl ether (67.5 %) followed by n-Hexane (59.7%) and Chloroform (53.56%). Hence, it is feasible to store oil palm pollen in Diethyl ether or n-Hexane at -5°C temperature beyond one year without considerable loss of viability or germination.

a.Compound microscopic view showing viable (stained) pollen



b.Scanning Electron Microscopic view showing broad slit filled with Exudates

Response of pollen to storage in Diethyl ether



a.Compound microscopic view showing no viable (not stained) pollen

b.Scanning Electron Microscopic view showing leaching of exudates

Response of pollen to storage in Methyl alcohol

Pollen quality in different fruit forms

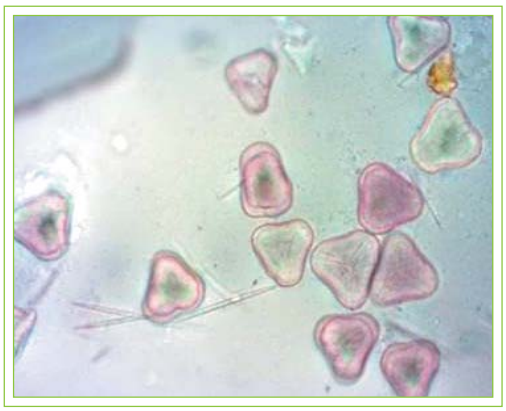
Studies were conducted on pollen quality (viability and germination) of 3 fruit forms of oil palm *viz.,* dura, pisifera and tenera. Higher viability and germination were found in pisifera followed by tenera and dura. Pollen quality in all fruit forms after 1 and 2 months of storage at -20^{0}C was found to decrease. Microscopical studies

indicated a wider slit in the centre of the pollen grain of dura compared to pisifera and tenera. The lower storage life of the dura pollen may be attributed to this character. It is proposed that the wider slit causes loss of vital exudates which may in turn trigger setting in of the process of ageing/senescence. Pollen quality of young (5 years) dura palm has got higher percentage viability as well as germination compared to 14 years old. The loss in pollen quality, however, was more in younger palms compared to older palm when stored at -20^{0}C. Cryo-storage of pisifera pollen at -196^{0}C for 10 months has no adverse effect on its quality (97.92 % viability & 92.36 % germination) and is on par with that of fresh pollen (98.17 % and 96.52 % respectively). Light microscopy as well as Scanning Electron Microscopic (SEM) studies of the cryo treated pollen from pisifera and tenera revealed no significant morphological changes.

Cryo preservation protocol for oil palm pollen

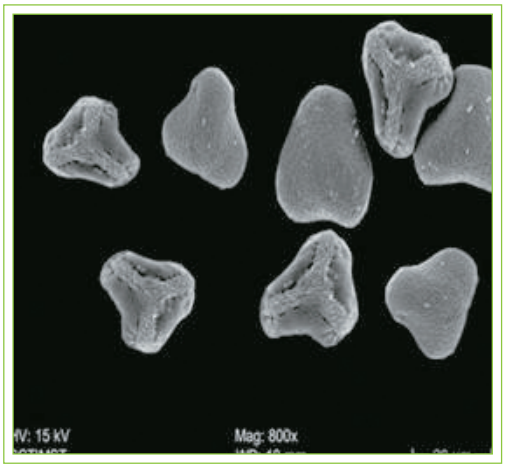
Studies were conducted to develop protocol for cryopreservation of oil palm pollen. Pollen was collected from a tenera palm, processed and placed in 5 ml cryo vials and immersed in liquid nitrogen for 1 hour. It was then thawed as per standard procedure. The viability and germination were estimated for fresh pollen before cryo treatment as well as after cryo exposure at -196^{0}C (liquid nitrogen). Both viability and germination of cryo stored pollen were retained at 79 and 74 per cent after storage against the 87 and 84 per cent for fresh pollen. No significant morphological changes were observed before and after cryo treatment under Light Microscopy or Scanning Electron Microscopy. Pollen grains stored in liquid nitrogen for one year showed no significant decline in viability or germination. *In vivo* fruit set study was conducted by artificial pollination using the cryo treated as well as normal pollen. Bunch analysis results of these bunches are in confirmity with *in vitro* findings.

a. Cryo treated pollen

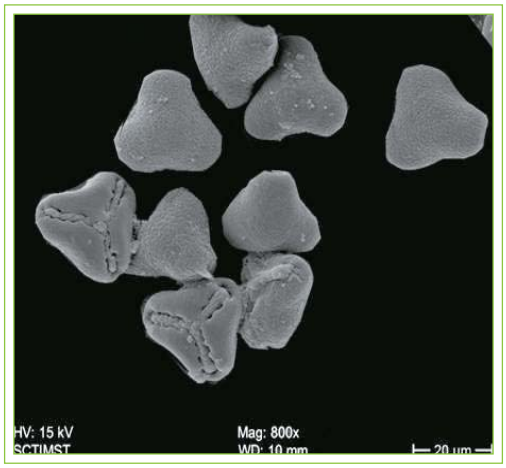


b. Normal pollen

Pisifera pollen under Light Microscope



a. Cryo treated pollen

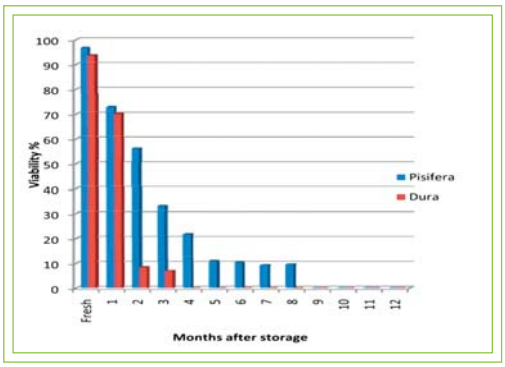


b. Normal pollen

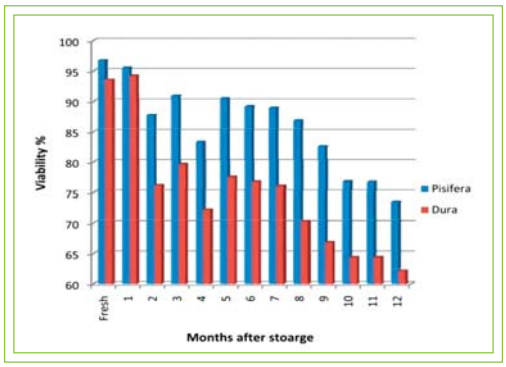
SEM photomicrograph of dura pollen

Differential longevity of dura and pisifera pollen

Dura and pisifera pollen were collected, processed and stored at different temperatures *viz.,* Room Temperature (RT) of 35±3°C, 5°C, -5 °C and -20°C for a period of 12 months. Observations on viability (MTT test) and *in vitro* germination were recorded at monthly intervals. Dura pollen retained viability for one month whereas pisifera pollen retained viability for two months at room temperature storage. At 5°C, dura pollen retained viability upto two months whereas pisifera for three months. At -4°C, dura remained viable upto four months whereas pisifera retained viability upto nine months. When stored at -20°C, both remained viable for 12 months, with pisifera retaining higher percentage of viability compared to dura. The overall viability and



Viability of Dura vs Pisifera pollen stored at Room temperature



Viability of Dura vs Pisifera pollen stored at -20°C

germination decreased with increased storage period as well as with storage temperature. Temperature above 0°C was not suitable for storage of pollen for both the fruit types. The results of the study indicated that -20°C was the best storage temperature for both the fruit forms *viz.*, dura and pisifera up to one year. In general, pisifera pollen retained viability for more time compared to dura pollen. The results were confirmed by *in vivo* fruit set studies.

Gametophytic selection (pollen) for screening germplasm against abiotic stress

The study was undertaken to understand the effect of osmotic stress (PEG) on pollen grain size, shape, germination and tube growth. The media consisting of Sucrose+ H_3BO_3 + PEG was selected for testing pollen germinability under stress. The response of pollen to osmotic stress under varying concentration of PEG 6000 (10%, 20%, 30%, 40% and 50%), with and without osmolyte ($CaCl_2$) at 40% and 50% PEG (discriminative osmotic stress) was observed in selected genotypes. These genotypes show varying response to osmoregulation and water stress, indicating the genetic variability among pollen grains for moisture stress tolerance. This varying response can be employed to infer the degree of drought tolerance of the mother palms that produce these gametophytes. Osmotic adjustment is a major strategy for drought tolerance.

Innovative seed dormancy breaking techniques

Fresh hybrid seeds were subjected to seven treatments with an objective to achieve uniform, speedy and maximum seed germination. Results showed that endocarp chipping combined with de-operculum resulted in the highest germination (88%) and took 3, 4 and 8 days to initiate germination, 50% germination and final germination, respectively. Dry heat method took 11 and 12 days to initiate and 50% germination, respectively resulted in only 66.6% germination even after 20 days incubation. Dry heat method also required extra heat treatment at 40° C for 60 days. It is inferred that chipping combined with de-operculum could be substituted with dry heat method at commercial seed production centres to break seed dormancy.

Laboratory scale seed chipping machine was developed for chipping the endocarp of seeds. Up-gradation of lab scale machine is envisaged to scaling up germinated seed supply in a short period of time.

Effect of mechanical seed scarification on germination and seedling growth

A total of six mechanical scarification techniques along with dry heat treatment were adopted to achieve speedy and uniform germination and seedling production to facilitate precise evaluation of progenies of inter specific hybrids. The results revealed that chipping endocarp (removing round piece of endocarp containing germ pore) of the nut and de-operculum (removing plate like structure present in the seed coat above the embryo in the kernel) resulted in maximum germination with uniform seedlings production. Endocarp chipping combined with de-operculum resulted in maximum germination with 50% and took 3, 5 and 7 days to initiate germination, 50% germination and final germination (50%), respectively. Dry heated seeds took 15 days time to attain maximum germination (40%) after pre heating duration of 60 days in the heating room. One set of seeds which received hammer crack in nut germpore region remained dormant even after six weeks due to ineffective scarification.

Seed quality and germination in selected oil palm hybrids

Seed quality in terms of seed physical characteristics and germination was assessed for different combinations of selected hybrids Majority of the indigenous hybrids had large proportion of small seeds and their percentage of distribution varied according to the hybrids. The different hybrid combinations recorded coefficient of variation of 11.70, 11.28 and 15.35 for seed weight, shell weight and kernel weight, respectively. Large seed group in all the crosses had high seed weight, shell weight, shell thickness and kernel weight. Though shell thickness had significant differences among crosses and size groups, the coefficient of variation recorded (6.38%) was low compared to other characteristics. Selected hybrids had low average kernel weight of 1.63, 1.05 and 0.74 g for large, medium and small seeds, respectively. High and low germination percentage was recorded in all the categories of seed groups irrespective of their sizes. All the seed physical parameters studied showed positive and highly significant correlation. Low level of variations in seed traits especially for shell thickness has been reported for indigenously developed hybrids. Variations in seed size did not affect the germination capacity of the seeds.

Standardisation of seed size

The seed size classification for the oil palm seeds of IIOPR, Pedavegi seed garden was standardised. It is <10 mm = very small, 10-15 mm = small, 15-20 mm= medium and >20 mm = big. Suitable sieves were designed for grading oil palm seeds.

Small Size

Medium Size

Big Size

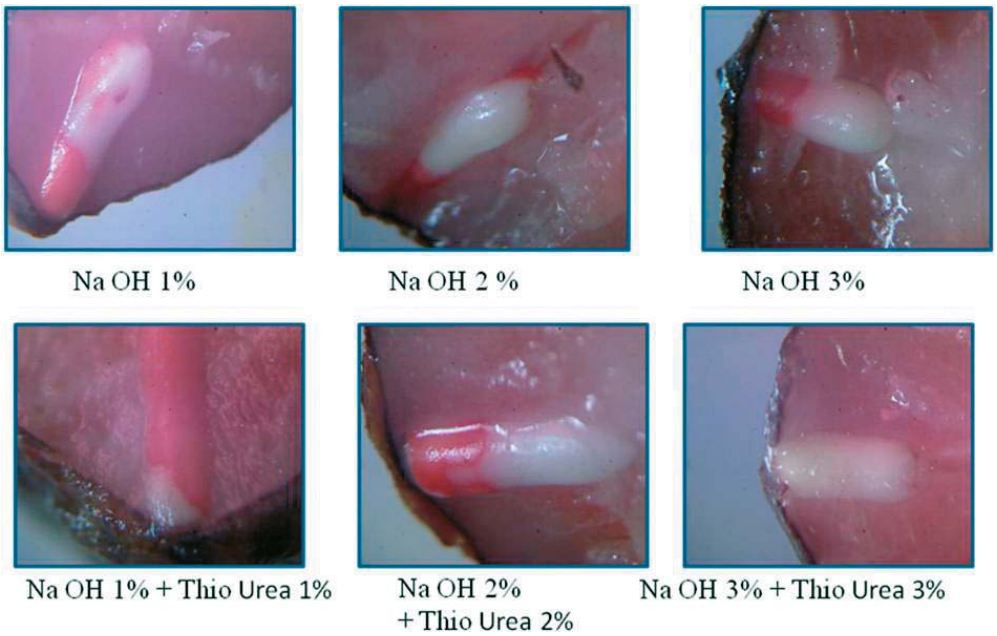
Different sieve sizes for oil palm hybrid seeds

Manipulation of seed coat permeability vis-à-vis viability

The potential of different solvents (polar & non-polar) on mesocarp degradation and in manipulating the permeability of seed operculum while maintaining the viability was investigated. A total of 13 treatments including polar and non-polar solvents individually and in combinations along with a control (water)) were used to soak the oil palm fruits for different durations (1–7 days). Viability is determined based on the visual observations with tetrazolium staining coupled with data from spectrophotometer. Treatments recording absorbance (OD) values >0.4 have been considered as potential in maintaining the viability. It was found that polar or non-polar solvents individually could retain the seed viability but were not successful in mesocarp degradation. Soaking in water (control) was found to be effective in both mesocarp degradation as well as in retaining the seed viability. Soaking in water resulted in softening of mesocarp which was evident from the microscopic observation of tissues. All the treatments consisting of combination of polar and non-polar solvents were found to be ineffective except 'Hexane:Iso-propanol (in the ratio of 3:1)' which has shown the absorbance of (OD) 0.405 indicating that they are just viable.

Effect of chemicals on degradation of operculum in the seed

A total of eight different chemicals (capable of dissolving cellulose and hemicelluloses) with different concentrations and combinations with GA3 and Thio-urea, along with water were used for soaking the fresh seeds (DxP) with the aim to dissolve the operculum. Magnesium sulfate, Potassium nitrate, Potassium dihydrogen phosphate and Potassium sulphate were not effective in the disintegration of operculum and in maintaining the viability of the embryo. Sodium hydroxide (1-3 %) alone and in combination with Thio urea (1-3%), however, was able to disintegrate the operculum completely and retain the viability of embryo upto 10 days. The seed processing period could be shortened from 110 days to 25-30 days.



Effect of chemicals on oil palm seed operculum and embryo

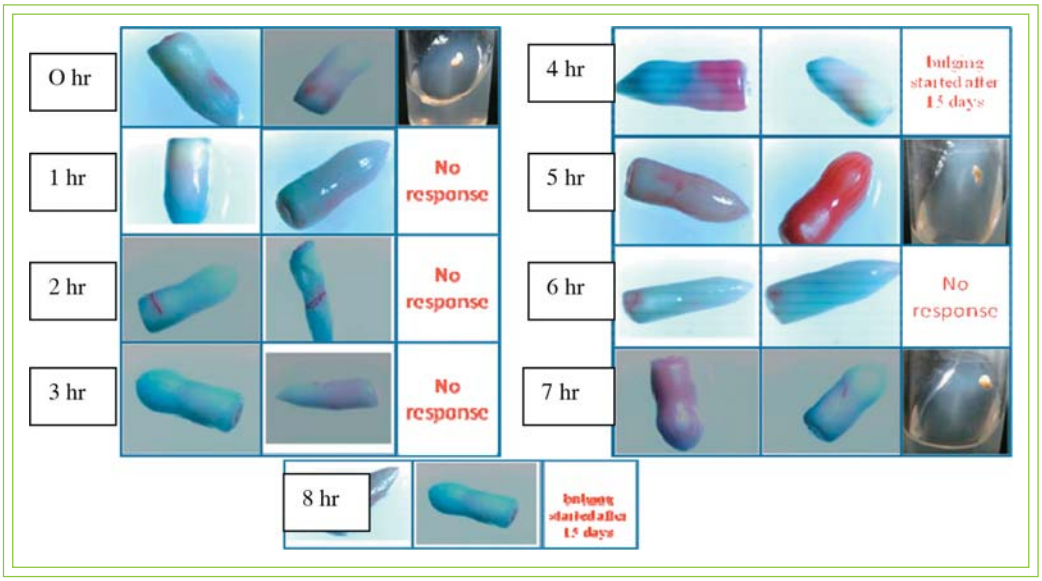
Effect of low temperature storage on seed viability

Studies on the effect of low temperature (-4, -20 -40, 23^{0}C and ambient temperature/uncontrolled room temperature) storage for different durations (15, 30, 45, 60, 75 and 90 days) indicated loss of seed viability (measured through tetrazolium staining) when stored at sub-freezing temperatures (-4^{0}C, -20^{0}C and -40^{0}C) irrespective of the storage duration. Storage at 23^{0}C or ambient temperature did not affect the viability even after 90 days. It appears that low temperature storage (at sub-freezing temperatures) is not suitable for oil palm seed. The biochemical reactions like fall in the levels of sugars and proteins and the acceleration of lipid peroxidation, however, appears to commence after 60 days of storage. Fresh oil palm seed can be stored upto 90 days at 23^{0}C without any loss in viability

For long distance transport of germinated seeds, a paste was formulated to apply as a coat near the neck portion where plumule and radical differentiate in the germinated seed without affecting their establishment in the nursery.

Method to conserve zygotic embryos

Oil palm zygotic embryos, which were desiccated in silica gel for 4, 5 and 7 hours with the moisture content of 11.48 %, 10.36 % and 9.35 % respectively had shown viability after exposure to liquid nitrogen for an hour, in tetrazolium salt test as well as bulging in the modified MS medium.



Effect of cryo-preservation on the viability of embryo through Tetrazolium test (TZ) and *in vitro*

Labour saving machineries for hybrid seed production

The existing de-pericarping machine was modified for seed processing. The remnants over the seeds were removed during the second de-pericarping *i.e.*, on 5th day of water soaking, which saves 4 days during seed processing.

Modified depericarping machine

Novel method for hybridization in oil palm

To aid in hybridization process of oil palm, a novel method was standardized for controlled pollination through pollinating weevil without climbing the tree. The pollinating weevils (*Elaeidobius kamerunicus*) were cleaned to make them devoid of pollen and sent through a controlled device with desired pollen to effect pollination in a controlled environment. Number of pollinating weevils, their pre-treatment, pollen quantity etc were standardized. The size of the FFB formed through this method is on par with the FFB formed through existing pollination method.

Abnormally germinated seeds need not be rejected

Abnormality through physical appearance of germinated seeds in terms of disproportionate size of radicle and plumule does not have any impact on growth of seedlings as evident from the experiment conducted by using 10 categories of germinated seeds having disproportionate size of radicle and plumule, which are normally rejected as abnormal. No significant differences were observed statistically between the aberrantly germinated and normally germinated seed sprouts with respect to their seedlings growth parameters recorded after 22nd and 30th week after planting in the nursery. Relative growth rate (RGR) and compound growth rate (CGR) calculated based on the dry matter accumulation in the seedlings also did not show any significant differences. Hence, it is concluded that the physical appearance of germinated seeds in terms of disproportionate size of plumule and radical does not have any impact on the growth of the seedlings. Sorting / rejection of abnormal germinated seeds can be avoided during supply of germinated seeds; instead, culling could be effectively done at nursery stage.

Aberrantly germinated seed sprouts in oil palm

Supply of basic planting material for establishment of new seed gardens

Planting material (mother palms) was developed and supplied for establishment of four new seed gardens to augment indigenous hybrid seed production and meet planting material requirement. The new seed gardens were established at Taraka and Kabini in Karnataka and at Morampudi and Gopannapalem in Andhra Pradesh. D x D and T x T crosses were effected for the proposed seed garden in Mizoram and the sprouts were supplied.

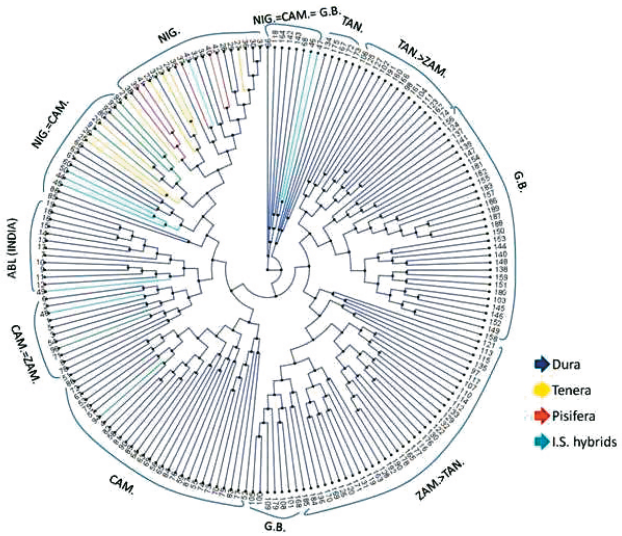
Establishment of new seed garden (dura block) at Palode with third cycle crossed resources

Eight cross combinations of advanced dura parental materials (D20 × D23, D20 × D35, D36 × D36, D48 × D48, D48 × D61, D47 × D61, D80 × D85 and D84 × D61) were planted in the new block as a seed garden. These materials were developed from Thodupuzha and African germplasm materials after evaluation and selection of mother palms in the seed garden and field gene bank planted at Research Centre, Palode during 1992 and 1998, respectively. This dura block has CRBD design with eight treatments of five replication and 15 seedlings per replication. It is to be noted that present Palode materials has undergone 3 cycles of selection and expected to have high productivity. Individual palms of Tanzania and Zambian sources with high productivity in terms of five years consecutive FFB yield with best bunch quality characteristics were also included in the dura improvement and seed garden.

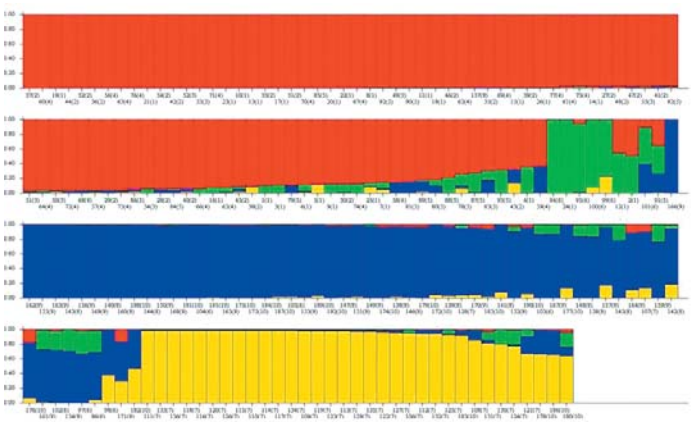
Genetic diversity of oil palm germplasm collections of India

Molecular characterization of 192 *ex situ* oil palm germplasm collections revealed the amount of genetic diversity of populations and genetic relatedness among natural oil palm populations from different African countries. Overall, 45 SSRs were polymorphic across the entire population, with a total of 120 amplified alleles, and an average of 2.7 alleles per microsatellite. Four clusters were noted in the neighbor-joining tree. The SSRs clearly grouped all the *Dura* into a major cluster than from *Tenera* and *Pisifera*. The populations of West and Central Africa (Nigeria, Cameroon and Guinea Bissau) are more similar to each other than to populations from East Africa (Zambia and Tanzania). The distinctiveness of these accessions was verified in the neighbor-joining tree where the accessions from Tanzania, G.B., Zambia formed separate cluster and different from Cameroon and Nigeria. The clustering pattern identified at molecular level indicates a high rate of genetic exchange that was attributed mainly to the dispersal of seeds. Ancestry shown in red was traced to Cameroon and Nigeria while green for Nigeria in the chart. Ancestry coloured as Blue and yellow, belonged to accessions of Tanzania, Zambia and G.B. Oil palm materials

from Africa represent a useful genetic resource for expanding the genetic base of the currently planted oil palm varieties.



Neighbor-Joining (NJ) depicting relationships estimated across 192 oil palm germplasm collections of IIOPR, Pedavegi



Shared ancestry as revealed by population structure analysis across 192 diverse oil palm collections of IIOPR, Pedavegi

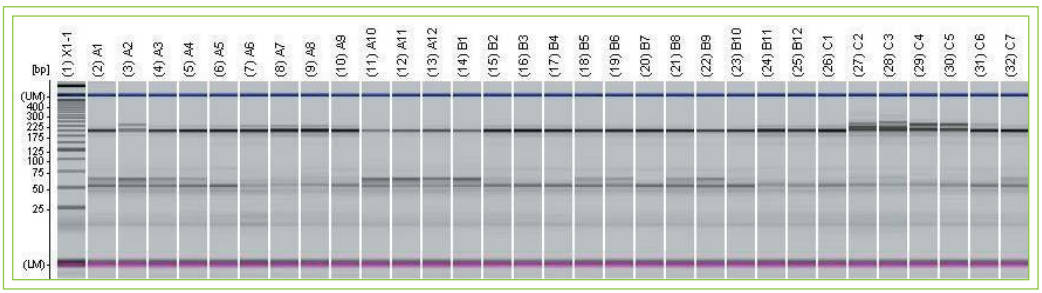
Genetic diversity analysis among Zambian accessions

Genetic diversity among nine Zambian accessions (27 palms) was studied using 11 SSR primers. UPGMA cluster analysis using simple matching coefficient revealed a total of 160 alleles with an average of 14.5 alleles per primer out of which 150 were

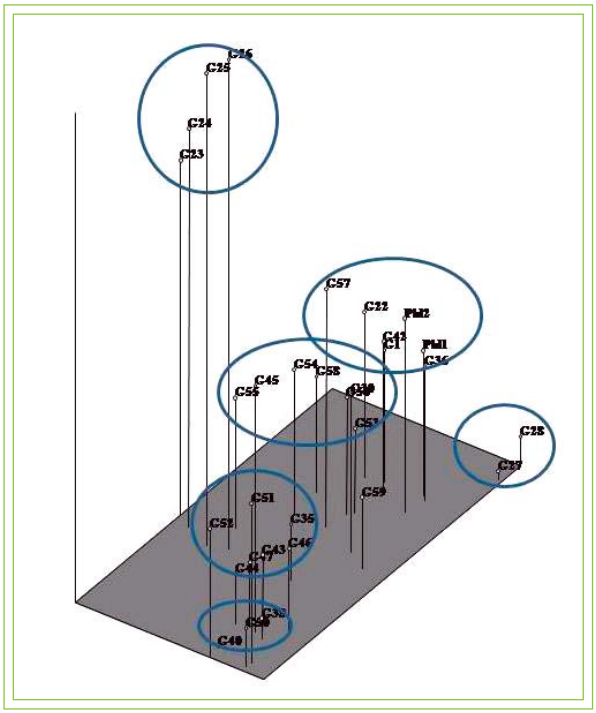
polymorphic. Maximum similarity (0.90) was observed between ZS2-215 and ZS2-216 while maximum dissimilarity was recorded between ZS5-497 and ZS8-263 (recorded least similarity of 0.56). The UPGMA based dendrogram showed three major clusters with 71% similarity. This information is highly beneficial in breeding programme where the palms with least similarity can be utilized in bringing divergent alleles together and thereby heterosis.

Molecular characterization of selected oil palm germplasm (Palode)

Molecular characterization of 31 germplasm accessions with 9 SSR primer pairs (specific to oil palm for diversity and relatedness) indicated that the total number of alleles per primer pair varied from six (sMo00129, sMo00128, mEgCIR3890, sMo00130, mEgCIR0268, mEgCIR0905, sMo00020, sMo00154,) to seventeen (mEgCIR3399). It produced a total of 107 alleles from the two oil palm species, *Elaeis oleifera* and *Elaeis guineensis* Jacq. Among the 9 primer pairs, mEgCIR3399 gave the highest number of alleles (17) and sMo00129 produced the lowest number (6) of alleles. Cluster analysis, based on UPGMA, was performed in order to realize the extent of similarity/dissimilarity between the oil palms. The dendrogram showed the two major clusters at 0.09 similarity coefficient. Cluster I contains 4 samples (G23, G24, G25, G26), all are *Elaeis oleifera* and cluster II contains the 25 samples all are *Elaeis guineensis* including the reference palms (G1, G22, G27, G28, G35, G44, G53, G54, G56, G59, G30, G36, G38, G40, G42, G43, G45, G46, G47, G50, G51, G52, G55, G57, G58, PLD1, PLD2). Maximum similarity was seen between G27 and G28 (0.96) and minimum similarity (0.07) is seen between many offspring. The major two clusters are again subdivided into further clusters. It showed the maximum diversity between the species of oil palm which was followed by diversity within the species.



SSR profiling of oil palm in automated electrophoresis (MultiNA) system using Primer mEgCIR0268FR. X1- 25bp Ladder A1 to C1 *Elaeis guineensis* Jacq, C2, C3 Parents C4 to C7 *Elaeis oleifera*



3D Principal Coordinate Analysis (PCA) of genetic identity among 31 oil palm genotypes

There were six distinct groups based on 3D Principal Coordinate Analysis of genetic identity as given below.

I. G23, G24, G25 and G26.
II. G57, G22, G42, G1, G36 and reference palms Pld1 and Pld2.
III. G55, G45, G54, G58, G30,G56 and G53;
IV. G40, G50, G38
V. G52, G51, G35, G44, G47, G43 and G46
VI. G27 and G28.

Group I consisted of all *oleifera* accessions, whereas *E. guineensis* accessions formed the remaining five groups. Second group consisted of Pld 1 and Pld 2 along with Dwarf identified from Nigerian collection indicating the common ancestry of these genotypes. G27 and G28 were the accessions belonging to Dura-III population and hence close resemblance is in expected line. G59 remained diverse from the above groups. In short, the high genetic diversity was observed in oil palm natural populations which indicated that these materials are good sources of new genes for introgression into the current breeding materials for oil palm improvement.

Development of a tissue culture protocol for oil palm regeneration

A protocol for complete cycle of regeneration from somatic embryos of immature inflorescence was developed. Regeneration Media (Modified Y3 media) with an exhaustive list of chemicals (plant growth regulators, antioxidants, minerals, etc), culture conditions (Temp, light & RH) and procedure for hardening (growing media consisting of sand: soil: vermicompost (1:1:1), two developed leaf stage and time of transfer should be during or just after the monsoon) were standardized for each stage of culture (callus induction, somatic embryogenesis, shooting, rooting, plantlet development, hardening, etc). It is a callus mediated somatic embryo regeneration using combinations of plant growth hormones. Fidelity testing of plantlets developed from tissue culture using SSR markers is also worked out. Three plantlets (ramets) from tissue culture (Nos. 34, 36 & 37) were successfully hardened (mist chamber to shade net house, secondary nursery and 25% shade-net house) and finally planted in the field (on 24.01.2014). Two plantlets (ramets) from tissue culture (No. 38 and No. 40) were successfully hardened from mist chamber to shade net house and were field planted in August 2015. Normal flowering (male and female inflorescence) was observed in the tissue cultured palms during December 2014 and 2015. The oil palm tissue culture protocol developed has low conversion ratio (embryogenic callus is ranging from 3.5 to 10.4 % only) and there is large genotypic variation in the response to *in vitro* media.

Somatic embryogenesis from spear leaf explants of oil palm

Somatic embryogenesis in oil palm from spear leaf explants of mature Pisifera was observed for the first time in India. Spear leaf explants from a mature (12 years old) pisifera palm inoculated on modified Y3 media showed callus induction after 45 days of inoculation. Somatic embryo formation was observed after three sub-cultures and the fully developed somatic embryos were separated and cultured on fresh media after 6-7 months of initial inoculation.

Commercialization of Oil Palm Tissue Culture Technology

IIOPR is taking concerted efforts towards commercialization of the IIOPR developed tissue culture technology through M/s. AgrInnovate India Limited, New Delhi to ensure that the benefits reach the stakeholders at the earliest. It is expected that the commercialization process will supplement efforts being taken for achieving self sufficiency in indigenous oil palm planting material production.

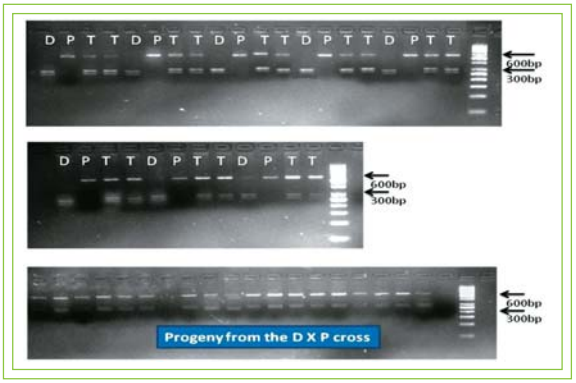
Standardization of media for *in vitro* culturing of zygotic embryos

Zygotic embryos (ZEs) excised from open pollinated dura, tenera and DxP were inoculated in five different media to study the germination and plant growth. The result shows that the germination of ZEs from tenera was highest (71.0 %) than dura

(69.0 %) and DxP (60.0 %) which were on par with each other. Among the media, MS recorded lowest germination of ZEs (57.2 %) than other four media which were on par *i.e.*, ½ MS (71.1 %), MS + Activated Charcoal (61.1 %), Y3 (71.1 %) and N6 (72.8 %). The germination of ZEs from DxP was lowest (40.0 %) in MS while dura recorded highest (81.7 %) in Y3 medium. At the end of three months after inoculation of ZEs, the plant fresh (107.8 mg) and dry (14.2 mg) weight of dura was highest than tenera and DxP hybrids which were on par with each other. The plant fresh and dry weights (mg) were highest in MS+AC (115.4 & 15.1) and N6 media (98.7 & 13.3) whereas, the MS media recorded lowest plant fresh (76.6) and dry (10.0) weight which were on par with ½ MS and Y3 media. In conclusion, the germination and subsequent plant growth of ZEs were highly affected by both genotypes and culture media.

CAPS marker to identify dura, pisifera and tenera fruit forms

E. guineensis has three fruit forms, dura (thick shelled), pisifera (shell less), and tenera (thin shelled) - a hybrid between dura and pisifera. The tenera hybrid yields far more oil than dura and pisifera and is the basis for commercial palm oil production in all of Southeast Asia. Identification of suitable molecular markers to differentiate the three fruit form will be useful to diagnose the fruit form at seedling stage instead of waiting for 4-5 years by traditional means. It is also useful in certification of high yielding seed production by selective breeding of DxP crosses, where contamination through natural pollination with small quantities of tenera or dura pollen can occur. The markers can also be used for determination of pisifera genotypes from the progeny of the TxT or TxP crosses to maintain required pollen parent population in the seed gardens. With this aim, eight gene specific primer pairs (EST-SSRs) from genes like oil palm MADS box transcription factor21 like, *Arbidopsis thaliana* agamous like MADS box AGL11, AGL5, AGL1 mRNA sequences were developed. One cleaved amplified polymorphic site (CAPS) marker was identified which can differentiate the dura, pisifera and tenera fruit forms. The

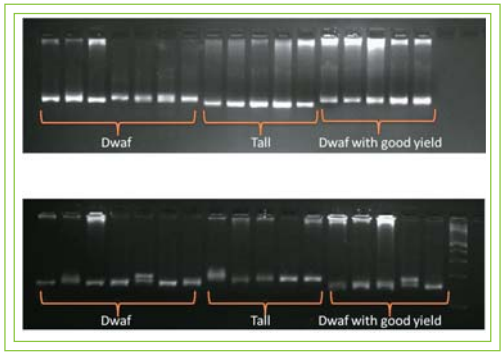


Differentiation of dura, pisifera and tenera oil palm genotypes using CAPS marker

CAPS marker produced two alleles (280 and 250 bp) in dura forms, three alleles in tenera forms (550, 280, and 250 bp) one allele in pisifera form (550 bp).

Identification of SSR markers linked to short stature of oil palm

Shorter stature of oil palm plant facilitates easy harvesting and extends economic yield period of the palm. Plant height is an important yield associated trait, and the benefits of cultivating short palms have led to an effort to introgress a reduced vertical growth trait into high yielding varieties in current breeding schemes. Bulk Segregant Analysis (BSA) was done with 400 SSR markers (both genomic and genic) among three bulks of DNA. A total of 50 SSR markers were able to find polymorphism between the bulks of dwarf, tall and dwarf with good yield. Two SSR markers (mEgCIR0059 and mEgCIR3328) were identified to be linked to the short stature of oil palm. These two SSR markers can be effectively used to identify the dwarf plants from tall plants.



Identification of SSR markers linked to virescence character of oil palm

Fruit colour is an important trait in terms of fruit harvesting and, therefore, oil yield. The majority of oil palms produce either nigrescence or virescence fruit type. virescence fruits are green when unripe, and change to orange when the bunch matures, reflecting degradation of chlorophyll and accumulation of carotenoids. The virescence trait is governed by the VIR gene. A set of ten genic SSR markers were developed which spans the microsatellite repeats of VIR gene of oil palm and its homologous sequences in other crops. A total of 400 SSR markers (genic and genomic) were used for identification of markers polymorphic between the two bulks and 30 SSRs were identified as polymorphic between the bulks. Twenty polymorphic SSR markers were found polymorphic between the virescence and nigrescence bulks through bulk segregant analysis (BSA).

Genetic diversity study among tissue culture plants in the field

The clonal fidelity of the five tissue culture plants (TC1, TC2, TC3, TC4 and TC5) was done using a set of 50 highly polymorphic SSR markers. The results showed that a considerable amount of variation existed among all the selected tissue culture plants. Out of the 50 SSRs, 28 were found to be polymorphic, whereas remaining 22 SSRs were monomorphic. The percentage of polymorphism observed was 56 %.

PRODUCTION SYSTEM MANAGEMENT

Effect of biofertilizers on growth and vigour of oil palm seedlings

Experiment undertaken to study the effect of biofertilizers on growth and vigour of oil palm seedlings indicated best results for various growth, physiological, biochemical and microbiological parameters, nutrient status in potting mixture and seedlings under integrated application of biofertilizers+chemical fertilizers followed by combined use of all the biofertilizers, individual biofertilizers especially *Glomus aggregatum*, 100 % recommended dose of fertilizers (RDF) in comparison with control. Among integrated treatments, highly significant results were manifested with biofertilizers+25% RDF. The study indicated that consumption of inorganic/chemical fertilizers can be reduced significantly (up to 75 %) with the usage of biofertilizers but minimal dose of chemical fertilizers is compulsory for exploiting the best possible benefits from biofertilizers. Significant improvement in many of the key parameters was noticed under combined use of various types of biofertilizers when compared with individual biofertilizers except *Glomus aggregatum* and 100% RDF. Among individual biofertilizers, *Glomus aggregatum* showed outstanding performance which was better than 100 % RDF and it was equally effective when compared with combined use of biofertilizers in most of the parameters. Integrated use of biofertilizers with 25% of recommended dose of chemical fertilizers is recommended for commercial application in oil palm nurseries in India.

Prominent growth of oil palm seedlings under biofertilizers + 25% RDF

Nutrient management in oil palm nursery

An experiment was conducted to find out the optimum dose of nutrients by using various levels of NPK for better growth and vigour of oil palm seedlings. Treatments used were NPK @ 30:38:25g (T_1), NPK@ 22.5:28.5:18.75g (T_2), NPK@15:19:12.5g, (T_3) NPK@ 7.5:9.5:6.25g (T_4) and the control (T_5). Among the treatments, T_1 recorded the maximum seedling height (143.52cm), leaf area (3157.98cm^2), petiole width (1.80cm), stem girth (29.14cm), root volume (244cc) and dry biomass (532g). Highest N, P, K and Ca levels in potting medium were recorded in T_1 while the lowest levels

were observed in the control. Similarly, the maximum concentration of N, P, K, Ca, Mg, Fe, Mn, Cu and Zn in leaf samples was estimated in T_1 whereas the minimum levels were noticed in the control. Therefore, it can be inferred from the results that NPK @ 30:38:25g/seedling/year has emerged as the most promising nutrient dose in improving the growth and vigour of oil palm seedlings and the same is recommended for commercial application in oil palm nurseries in India.

Effect of organic manures on growth of oil palm seedlings

An experiment was conducted to study the influence of various conventional organic manures along with palm oil mill effluent (POME) sludge on growth and vigour of oil palm seedlings. Tank silt and vermicompost (T_1), pig manure (T_2), goat manure (T_3), poultry manure (T_4), farm yard manure (T_5), palm oil mill effluent sludge (T_6) mixed in 2:1 ratio on v/v basis and combination of farm yard manure + poultry manure (T_7) and vermicompost + poultry manure (T_8) mixed in 2:0.5+0.5 ratio on v/v basis were used as potting mixture. Results were compared with T_9-tank silt with recommended dose of nutrients (30g N, 38g P and 25g K-T_9) and T_{10}-only tank silt.

All organic manures showed significant improvement in seedling growth and dry matter production over the control. However, the best results for key parameters like seedling height (168.78 cm), number of leaves (19.66), leaf area (5211.76 cm^2), stem girth (34.52 cm) and total dry matter (696.12 g) were observed with POME sludge. Among the treatments, higher level of OC, Fe, Mn and Cu in potting mixture and nitrogen, phosphorous and potassium in leaves were recorded with POME sludge. Similarly, the cost of production of seedlings with POME sludge was worked out as quite cheaper (CBR-1:1.72) when compared with other organic manures particularly with FYM (CBR-1:1.37). Therefore, palm oil mill effluent sludge which is available in abundance at palm oil mill can be used in lieu of conventional organic manures as it was most effective in improving the growth and vigour of oil palm seedlings.

Effect of palm oil sludge (POS) on growth and vigour of oil palm seedlings

Trial was taken up to study the effect of palm oil sludge (POS) or decanter cake on growth of oil palm seedlings and also determine an optimum dose of POS for oil palm nursery. The solid content of POS sludge mixed with tank silt was 5, 10, 15 and 20 % respectively. Tank silt with recommended dose of nutrients (30 g N, 38 g P and 25 g K) applied at monthly interval was used as a control. All levels of POS exhibited significant improvement in seedling growth and dry matter production over the control. However, the best results for key parameters like seedling height (185.34 cm), number of leaves (19.50), leaf area (6130 cm^2), stem girth (38.23 cm), number of primary roots (35.25), root volume (415.22 cc) and total dry biomass (873.75 g)

were observed with 90 % tank silt + 10 % POS. Higher level of organic carbon in potting mixture and nitrogen and phosphorous in leaf were recorded with tank silt + POS mixtures as compared with control. The cost of production of seedlings with 90 % tank silt + 10% POS had been worked out as quite cheaper (CBR-1:1.52) when compared with control (CBR-1:1.28). Therefore, POME sludge @10 per cent in potting mixture can be an ideal substitute for chemical fertilizers and the same is recommended for commercial oil palm nurseries in India.

Influence of palm oil mill effluent (POME) sludge on growth of oil palm seedlings

Experiment was carried out to study influence of palm oil mill effluent (POME) sludge on growth of oil palm seedlings and standardize optimum dose for producing good quality seedlings. POME sludge was mixed with tank silt at 5 levels *i.e.*, 5% (T_1), 10% (T_2), 15% (T_3), 20% (T_4) and 25% (T_5). Other treatments were T_6-with recommended dose of nutrients (30g N, 38g P and 25g K) applied at monthly interval and T_7-with tank silt alone (Control). The best results for important characters like seedling height (125.82 cm), leaf area (2074 cm^2) stem girth (23.80 cm), number of primary roots (25.5) and total dry biomass (371.24 g) were recorded with 20% POME sludge (T_4). This treatment was significantly superior to T_6 (RDN) with respect to seedling height, leaf area and dry matter production. But treatment T_4 was found on par with T_6 for stem girth and petiole depth. Therefore, based on the results obtained so far POME sludge @ 20 per cent in potting mixture can be a good substitute for chemical fertilizers and the same is recommended for commercial oil palm nurseries in India.

Effect of palm oil mill effluent (POME) on growth of oil palm seedlings

Experiment was conducted to study effect of palm oil mill effluent (POME) on growth and vigour of oil palm seedlings. POME was applied to potting medium individually @ 2, 4, 6, 8, 10 and 15 % and results were compared with the RDF and the control. Among the treatments, the best results for important parameters like seedling height (151.40 cm), number of leaves (18.50), number of leaflets (61), leaf area (3666 cm^2), stem girth (27.87cm), number of primary roots (31.50) and total dry matter (449.75 g) were recorded under 10% concentration of POME. Results were slightly better than RDF though they did not differ significantly. More organic carbon and Ca were estimated with 10% POME while P and K in RDF in potting medium. Results were found non significant for P and K in leaf among the treatments but higher level of N and Ca was observed under RDF and 10% POME, respectively. Among the treatments, more bacterial and fungal population was recorded with 10% POME whereas actinomycetes count was noticed higher in RDF. The present results indicate

that POME @10 % is a good substitute for conventional practice and the same is recommended for commercial application in oil palm nurseries in India

Influence of cattle urine on growth of oil palm seedlings

Experiment was carried out to study influence of cattle urine on growth and vigour of oil palm seedlings. Buffalo urine was applied @2, 4, 6, 8, 10 and 15% to potting medium and results were compared with the RDF and the control. Among the treatments, the best results for important parameters like seedling height (148.98cm), number of leaves (16.25), number of leaflets (59), leaf area (2745.70cm^2), stem girth (27.40cm), number of primary roots (33.75) and total dry matter (425.50g) were recorded under 10% concentration of buffalo urine. However, results were found non significant between 10% buffalo urine and RDF for above characters. More organic carbon and Ca were estimated with 10 % buffalo urine whereas higher P and K in RDF in potting mixture. The treatment RDF recorded the highest level of N in leaf whereas better levels of K and Ca in leaf were noticed under 10% buffalo urine.

Studies on inter cropping in bearing oil palm gardens

Experiment was started in 2007 to identify suitable and profitable inter crops in grown up oil palm garden planted in equilateral triangular system with 9m x 9m x 9m spacing. Cocoa, heliconia, red ginger, banana, bush pepper, black pepper, long pepper and cut foliage plants *viz.*, asparagus, fish tail fern, dracaena, cordyline, philodendron and dieffenbachia have been introduced in grown up oil palm garden. Average light infiltration in oil palm garden was about 21.2 per cent during last 5 years.

Higher FFB yield of main crop (oil palm) was recorded in all inter cropped plots compared to solo crop. Among the inter crops, maximum FFB yield (23.12 t/ha) was recorded in oil palm+cocoa combination whereas the minimum FFB (16.32 t/ha) yield was obtained with oil palm alone. Microflora *i.e.*, bacteria, fungi and actinomycetes has been found more in inter cropped area when compared to the control. Among the inter crops, there was tremendous improvement in microbial population in cocoa plot. Organic Carbon, P and K levels were recorded higher in palm basin as compared with inter space in all the treatments. Among the treatments, significant improvement in OC, P, K and Ca in soil was noticed in inter space of oil palm+cocoa. Higher root density of oil palm was observed in inter cropped area (13.29 kg/cu. m) except red ginger as compared with mono cropped area (10.78 kg/cu.m). Among the inter crops, the highest oil palm root density (18.79 kg/cu.m) was noticed in bush pepper while the lowest density was in red ginger (8.07 kg/cu.m).

Higher cost benefit ratio has been worked out for bush pepper (1:3) when compared with oil palm alone (1:2). Inter cropping in oil palm has been found more profitable when compared to oil palm alone. Crops like heliconia, red ginger, cocoa, bush pepper, banana, long pepper, guinea/napier grass and cut foliage plants have

been identified as suitable and the same are recommended for oil palm gardens in Andhra Pradesh. Among cut foliage plants, fish tail fern (*Nephrolepis falcateforma*), ti plant (*Cordyline terminalis*), asparagus and phylodendron have been emerged as most promising inter crops for grown up oil palm gardens. It can be concluded from results that interaction between oil palm and inter crops was complementary when compared to solo crop.

Standardized the cropping system with red ginger and heliconia in grown up oil palm gardens under irrigated conditions. Red ginger and heliconia are shade tolerant cut flower crops which can come up well even under dense shade of oil palm gardens. Both the crops have been found compatible with oil palm. They are perennial in nature and can be cultivated as inter crops in grown up oil palm gardens for 4-5 years and replanted in the system again. Red ginger and heliconia provide the income to farmers round the year and average net profit expected from each crop is about Rs.40,000/ha/year.

Oil palm-cocoa, oil palm-red ginger+heliconia, oil palm-cocoa, oil palm-bush pepper+long pepper, oil palm-banana, oil palm-cut foliage plants, oil palm-cut foliage+long pepper are the probable cropping systems suitable for oil palm gardens in India.

Cocoa in oil palm (Inset -cocoa pod bearing)

Heliconia in oil palm (Inset-heliconia flower)

Red ginger in oil palm (Inset-red ginger flower)

Long pepper on oil palm stem

Studies on mixed farming in irrigated oil palm plantations of A.P

A seven year old oil palm plantation with equilateral triangular planting (9 x 9 x 9 m spacing) was integrated with fodder crop, dairy, poultry and vermi-composting unit. Guinea grass variety Co1was planted in inter space in four rows with 60 x 45cm spacing. Oil palm was integrated with 2 murra buffaloes and 25 local poultry birds. Guinea grass variety Co1 has established well in the system and yield level (8-18 t/ha) was on the increasing trend due to physiological adaptation under the dense shade which varied from 74-82 per cent during the last five years. Legumes like stylosanthes, fodder cow pea, horse gram and fodder green gram (pillipesara) could not establish well.

A view of mixed farming system (Inset - Dairy and poultry alogn with vermicompsoting unit)

The noteworthy observation of the system is the performance of poultry birds without additional inputs except the cost of birds purchased at the beginning. There was tremendous improvement in yield of oil palm over a period of five years (26.67 t/ha) when compared with the control (23.55 t/ha) plot. Microbial population i.e., bacteria, fungi and actinomycetes in inter cropped area was more as compared to mono cropped plot in the system. Macro (OC/N, P, K and Ca) contents in soil and leaf collected from the intercropped area and mono cropped area of the farming system were more or less equal. Higher cost benefit ratio has been worked out for mixed farming system (1:3.28) when compared with sole crop of oil palm (1:2.90) and a farmer can earn an additional income of Rs.60,000/ha/year from the system. Based on the results obtained and observations made so far, oil palm based integrated farming system with fodder crop (Guinea and Hybrid Napier grass), dairy (2buffaloes) and back yard poultry (25 Giriraj birds) has been found most suitable and profitable for Andhra Pradesh.

Identification of shade tolerant and high yielding fodder crop varieties as intercrops for grown up oil palm gardens

Fifteen varieties of Guinea grass and four varieties of Hybrid Napier were evaluated in 8 year old oil palm plantations planted at equilateral triangular spacing (9m x 9m x 9m). Incidence of light in the garden during the study period ranged from 18-24 per cent. Grass varieties were planted in four rows in inter space (25 % of total area) at 60 cm x 45 cm spacing. Intra/columnar space of the garden is left vacant for the free movement of farm workers and ease of garden operations round the year.

Promising grass varities %2c DGG-1 & DHN - 6 in oil palm

Among all the varieties, Hybrid Napier grass varieties DHN-6 (36.15 t/ha) and KKM (34.18 t/ha) and Guinea grass varieties BG-1 (38.38 t/ha), DGG-1 (28.67 t/ha) and Co3 (32.25 t/ha) have been found shade tolerant and high fodder yielding varieties. Better crude protein content was noticed in Reversedale (12.64 %), Co1 (12.54 %), DHN-7 (11.86 %) whereas less lignin content was recorded in BGG-1 (8.13 %), Tanzania (8.21 %) and Reversedale (8.29 %). Higher cellulose content was observed in DHN-6 (41.23 %), GG-1(40.88 %), Co-3 (40.12 %), Hamil (40.12 %) and Tanzania (40.10 %). Dharwad Guinea grass (DGG-1), which is of short stature and grassy nature can be a very good option for oil palm gardens as grazing is very common in oil palm gardens in Andhra Pradesh. Based on the results obtained so far, BG-1, DGG-1, Co3, DHN-6 and KKM varieties can be grown as inter crop in grown up oil gardens and they may provide solid base for the success of integrated farming system in oil palm.

Recycling of oil palm waste through cost effective and innovative techniques

One month old oil palm leaf shreds mixed with 25 % buffalo dung slurry were used for vermi and milli composting. Two worms per kg of biomass were released and the time taken for complete composting was 165 days with both the composting agents. Fresh oil palm leaves (150 kg) were cut into 1 m pieces and mulched in the basin itself and then applied 25 % (37.5 kg) buffalo dung slurry over the leaves. This is cost effective and sustainable technique for effective conversion of on farm biomass in oil palm gardens wherever microjet or basin system of irrigation is followed.

Milli-compost (Inset - domestication of millipede and millipedes)

In-situ composting in palm basin by millipedes (Inset - millipedes inside leaf petiole)

Nutrient status of milli-compost (2.58 % N, 0.26 % P, 0.54 % K and 2.58 meq Ca) can be compared with nutrient status of vermi-compost (2.39 % N, 0.27 % P, 0.58 % K and 2.13 meq Ca). Standardized the methodology for domestication and multiplication of millipedes.

Suitable method for disposal of oil palm trunk at replanting

Oil palm needs to be replanted after 25 - 30 years because of declined FFB production and also difficulty in harvesting of tall palms. Pot culture studies conducted with fifteen different combinations of microbial cultures and chemicals indicated that *Pleurotus florida* in combination with urea @ 0.25 % can be effectively used for composting shredded trunk pieces. The compost became suitable for application within 6 months (C:N = 20:1) and its performance was comparable with that of FYM when applied on cowpea as a test crop. Although the consortium of microbes could compost the trunk biomass at faster rate, the rate of nutrient release was poor in this treatment. Density of trunk in terms of fresh and dry biomass varied at different heights and it was more at upper portion of the trunk. Density of fresh biomass ranged between 812 to 1265 kg/m^3 and dry biomass ranged between 144 to 328 kg/m^3.

Control - after 6 months

Control – after 12 months

P.florida – after 6 months

P.florida – after 12 months

Bioethanol production from oil palm trunk sap

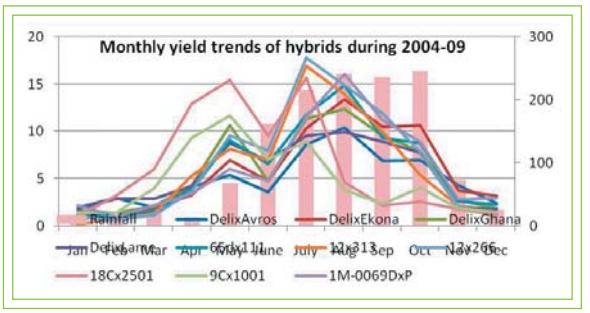
The potential of oil palm trunk sap was estimated for converting it into bioethanol using microbial cultures. On an average, 150 to 180 litres of sap could be extracted from a single palm (inner trunk) at 25 years of age. The sap is acidic in reaction with a pH ranging between 4.22 to 5.77 and specific gravity of 1.07-1.08. The total sugar content was around 87 mg/ml at felling and it rose to 155 mg/ml after one month of storage with glucose as the dominant one indicating its suitability for bioconversion. Among the two microbial cultures evaluated, *Saccharomyces cereviceae* (yeast) was found more effective in converting sugars into ethanol.

Extraction of sap from inner part of oil palm trunk

Bioethanol produced from trunk sap

Influence of weather parameters on FFB yield

The fresh fruit bunch (FFB) yield data of 10 oil palm tenera hybrids planted during the year 2000 under irrigated conditions at ICAR-IIOPR was analyzed for a period of 6 years (2004-09) and it was correlated with the weather parameters of the location. In general, it was observed that FFB yields are higher during third quarter of the year (July-September) and the yield data has shown a regular trend of up and down, year after year. Very low yields were recorded in the first quarter of the year irrespective of cross combination. Correlations with weather data revealed that rainfall and maximum temperature prevailing at 24 months before harvest have got a high degree of correlation with FFB yields. The ecological conditions which affect earlier phases of inflorescence and flowering appear only in the yields 18-24 months afterwards.



Estimation of K by simple and inexpensive water extraction method

Since K in plant tissue is not bound to organic complexes and it is extractable by water, a study was carried out to extract K from oil palm leaf tissue by water extraction method. The results were compared with other established methods like 1 N ammonium acetate (NH_4OAc) extraction, 0.5 N hydrochloric acid (HCl) extraction and diacid digestion. The proposed water extraction method consists of shaking of 0.5 g finely ground oil palm leaf tissue with distilled water at 1:60 ratio (sample to water w/v) for a period of 20 minutes in a reciprocating shaker, filtration of the content and measurement of K concentration in filtrate by flame photometer. The results of analysis of 30 oil palm leaf samples collected from various production systems under different soil types and management practices for K concentration revealed the close agreement of water extraction method with other established methods. The mean value of K extracted by water extraction method was within 1 to 10 per cent of the K extracted by other established methods. Water extractable K was significantly correlated with K extracted by other methods and it could be predicted by other methods. The values of standard error and coefficient of variation for K extracted by different methods were very low, which indicated that the water extraction method was comparable with other established methods.

Derivation of DRIS norms and establishment of optimum leaf nutrient concentrations of oil palm plantations in various states

Karnataka: Soil properties and leaf nutrient concentration were assessed in 42 oil palm plantations in the state of Karnataka. Soil properties varied widely. DRIS norms were established for different nutrient expressions and it was used to compute DRIS indices. As per DRIS indices, the order of requirement of nutrients in the region was found to be K> P > nitrogen (N) > B > Mg. Optimum leaf nutrient ranges varied from 2.24 to 2.97 %, 0.08 to 0.14 % and 0.78 to 0.91 % for N, P and K respectively, from 0.74 to 1.53 %, 0.25 to 0.98 % and 0.72 to 1.09 % for Ca, Mg and S respectively and from 5.71 to 31.0 mg kg^{-1}, 7.42 to 12.9 mg kg^{-1}, 33.6 to 58.6 mg kg^{-1}, 82.5 to 681 mg kg^{-1} and 82.8 to 936 mg kg^{-1} for B, copper (Cu), zinc (Zn), manganese (Mn) and iron (Fe) respectively. On the basis of DRIS derived sufficiency ranges, 57, 24, 62, 3, 3, 9, 7, 5, and 26 % leaf samples were having less than optimum concentration of N, P, K. Ca, Mg, S, B, Cu and Mn respectively. The optimum ranges developed can be used as a guide for balanced fertilizer application.

Goa: Soil properties and leaf nutrient concentration were assessed in 64 oil palm plantations in the state of Goa. DRIS norms were established for different nutrient expressions and it was used to compute DRIS indices. As per DRIS indices, the order of requirement of nutrients in the region was found to be P >Mg > K > nitrogen (N) > B. Optimum leaf nutrient ranges as per DRIS norms varied from 1.64 to 2.79%, 0.36 to 0.52 %, 0.37 to 0.75 %, 0.89 to 1.97 %, 0.35 to 0.63 %, 0.89 to 1.50 %, 3.10 to 13.9

mg kg^{-1}, 7.50 to 32.2 mg kg^{-1}, 35.0 to 91.1 mg kg^{-1}, 206 to 948 mg kg^{-1}, 895 to 2075 mg kg^{-1} for N, P, K, Ca, Mg, S, B, copper (Cu), zinc (Zn), manganese (Mn) and iron (Fe) respectively. On the basis of DRIS derived sufficiency ranges, 14, 5, 11, 6, 6, 6, 8, 2, 3, 6 and 16 per cent leaf samples had less than optimum concentration of N, P, K, Ca, Mg, S, B, Cu, Zn, Mn and Fe respectively. The optimum ranges developed can be used as a guide for balanced utilization of fertilizers.

Gujarat: Soil fertility status and leaf nutrient concentration were assessed and yield limiting nutrients were identified in twenty six oil palm plantations in Surat district of Gujarat. Soil pH, electrical conductivity (EC), organic carbon (OC), available potassium (K) (NH_4OAc-K), available phosphorus (P) (Olsen-P), exchangeable calcium (Ca) (Exch. Ca) and magnesium (Mg) (Exch. Mg), available sulphur (S) ($CaCl_2$-S) and hot water soluble boron (B) (HWB) content in surface (0-20 cm depth) and subsurface (20-40 cm depth) soil layers varied widely. DRIS norms were established for different nutrient expressions and it was used to compute DRIS indices. As per DRIS indices, the order of requirement of nutrients in the area was found to be K > nitrogen (N) > B > P > Mg. Optimum leaf nutrient ranges as per DRIS norms varied from 2.63 to 2.85%, 0.16 to 0.18%, 0.56 to 0.88%, 0.34 to 0.84% and 9.10 to 32.5 mg kg^{-1} for N, P, K, Mg and B respectively. On the basis of DRIS derived optimum ranges, 65, 31, 35 and 8 per cent leaf samples had less than optimum concentration of N, P, K and B respectively. The optimum ranges developed could be used for efficient nutrient management.

Mizoram: Soil fertility status and leaf nutrient concentration were assessed and yield limiting nutrients were identified in oil palm plantations of Mizoram. Soil pH, electrical conductivity (EC), organic carbon (OC), available potassium (K) (NH_4OAc-K), available phosphorus (P) (Bray's-P), exchangeable calcium (Ca) (Exch. Ca) and magnesium (Mg) (Exch. Mg), available sulphur (S) ($CaCl_2$-S) and hot water soluble boron (B) (HWB) content in surface (0-20 cm depth) and subsurface (20-40 cm depth) soil layers varied widely. Diagnosis and Recommendation Integrated System (DRIS) norms were established for different nutrient expressions and it was used to compute DRIS indices. As per DRIS indices, the order of requirement of nutrients in the state was found to be B > K > Mg > P > nitrogen (N). Optimum leaf nutrient ranges as per DRIS norms varied from 1.91 to 2.95%, 0.46 to 0.65%, 0.63 to 1.00%, 0.48 to 0.88% and 9.41 to 31.0 mg kg^{-1} for N, P, K, Mg and B respectively. On the basis of DRIS derived optimum ranges, 32, 9, 27, 12 and 12 per cent leaf samples had less than optimum concentration of N, P, K, Mg and B respectively. The optimum ranges developed could be used as a guide for routine diagnostic and advisory purpose for efficient fertilizer application.

Mapping spatial variability of leaf nutrient status of oil palm plantations

Spatial variability of leaf nutrients in oil palm plantations located in Goa, Karnataka, Mizoram and Gujarat states of India were examined for implementation of site-specific fertilization programme. Georefrenced leaf samples were collected randomly for the oil palm plantations. The leaf nutrients concentration was assessed

and analysed statistically and geostatistically. The concentration of leaf nutrients like N, P, K, Ca, Mg, S and B in oil palm plantations varied widely at different locations. Leaf P concentration was positively and significantly correlated with S concentration at Goa, Karnataka and Gujarat. Positive and significant correlation between leaf Ca and Mg concentration was recorded at Mizoram and Gujarat. Geostatistical analysis of leaf nutrients exhibited different distribution pattern at different locations. This study revealed the necessity of determining spatial variability of nutrient status of oil palm plantations before planning a differential fertilizer programme. Thus, saving of nutrients could be achieved by adopting site-specific nutrient management strategy.

Evaluation of spatial variability of soil properties in plantations of Goa

Spatial variability of soil properties like–acidity (pH), salinity (Electrical Conductivity (EC)), organic carbon, available K, available P, exchangeable Ca^{2+}, exchangeable Mg^{2+}, available S and hot water soluble B were assessed in surface (0-20 cm) and subsurface (20-40 cm) soil layers of oil palm plantations in south Goa and north Goa districts of Goa. A total of 128 soil samples were collected from 64 oil palm plantations of Goa located at an approximate interval of 5-7 km and analyzed. Soil was acidic to neutral in reaction. Other soil properties varied widely in both the soil layers. Correlations between soil pH and exchangeable Ca^{2+}, between soil EC and available K, between available P and available S and between exchangeable Ca^{2+} and exchangeable Mg^{2+} in both the soil layers were found to be positive and significant (P = 0.01). Geostatistical analysis revealed different spatial distribution pattern for the measured soil properties. Best fit models of measured soil properties were spherical, linear, exponential, circular and Gaussian with weak to strong spatial dependency. The results revealed that site-specific fertilizer management options needed to be adopted in the oil palm plantations owing to variability in soil properties.

Assessment of distribution variability of soil properties in Karnataka

Distribution variability of soil properties like pH, electrical conductivity (EC), organic carbon (OC), available potassium (K) (NH_4OAc-K), phosphorus (P) (Olsen-P), exchangeable calcium (Ca) (Exch. Ca) and magnesium (Mg) (Exch. Mg), available sulphur (S) ($CaCl_2$-S) and hot water soluble boron (B) (HWB) were assessed in oil palm plantations of Mysore, Mandya and Hassan districts of Karnataka. The mean values of soil pH, EC(dS m^{-1}), OC (g kg^{-1}) NH_4OAc-K (mg kg^{-1}), Olsen-P (mg kg^{-1}), Exch. Ca (mg kg^{-1}) , Exch. Mg (mg kg^{-1}), $CaCl_2$-S (mg kg^{-1}) and HWB (mg kg^{-1}) were 6.94 ± 1.19, 0.53 ± 0.47, 11.6 ± 5.60, 179 ± 107, 92.9 ± 50.6, 820 ± 326, 159 ± 58.9, 21.8 ± 14.9 and 5.81 ± 2.53 respectively in surface (0 to 20 cm) soil layers. Geostatistical analysis revealed that surface soil properties had circular, Gaussian, spherical, and exponential best fit models and were influenced by intrinsic, extrinsic and both intrinsic and extrinsic factors. The wide spatial variability of soil properties warrants site specific nutrient management for higher oil palm production.

PHYSIOLOGY, BIOCHEMISTRY AND POST HARVEST TECHNOLOGY

A faster indirect method of estimating leaf area index in oil palm

Leaf Area Index (LAI) indicates leafiness of a crop and is the ratio of total upper leaf surface of crop divided by surface land area on which crop grows. However measurements of LAI in oil palm are usually done by direct methods, which are destructive, time consuming and expensive. A faster indirect method of measuring LAI in oil palm has been developed for oil palm. LAI was measured with the help of Li-Cor Plant Canopy Analyzer. LAI was determined in individual palms by taking one above canopy observation in open area followed by eight under canopy observations at 2 m distance from palm. The LAI in whole plant canopy was measured diagonally between six palms by taking five transects. For each transect, one above canopy observation in open sky is taken followed by six equidistant observations below canopy. The direct method was also done by taking direct measurements on a sample of leaflets and leaves and LAI determined. Comparison of indirect measurement of LAI with direct one indicated a strong correlation (R2 = 0.98) between them. Hence the present indirect method of estimating LAI using plant canopy analyzer is faster, amenable to automation and allows for a larger number of spatial samples to be obtained over that of traditional direct method.

Effect of source manipulation on yield in oil palm

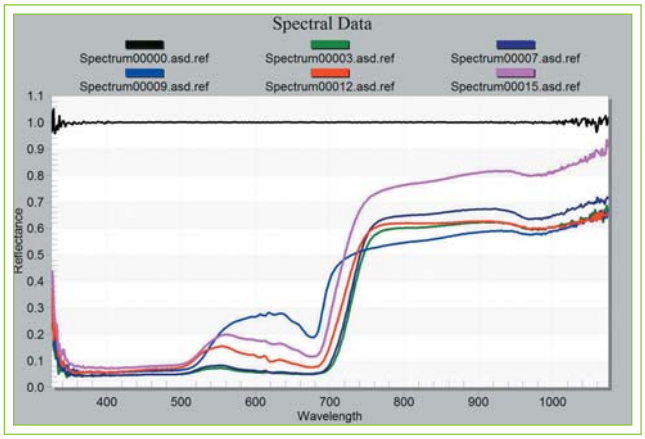
The source was manipulated in oil palm by pruning fronds up to 9, 17, 25, 33 leaves and its effect was studied on biochemical characters and yield. When fronds were pruned from 9th frond onwards, yield was zero. The bunch number was maximum when fronds were pruned from 25th frond onwards, which was closely followed by 17th frond. The bunch weight was maximum when fronds were pruned from 33rd frond onwards followed by 25th and 17th fronds. The lowest bunch weight was recorded when fronds were pruned from 17th frond onwards. Among the different treatments, highest FFB yield was obtained when fronds were pruned from 25th onwards followed by 33rd frond and 17th frond. This indicates that pruning of fronds in oil palm directly affects the FFB yield and bunch weight. Glucose and sucrose were the dominant fractions in petiole while starch and sugars accumulated more in trunk. Highest percentage of glucose, sucrose and starch accumulated in palms whose bunches were cut completely, while sugars were highest in control palms.

Effect of sink manipulation on yield in oil palm

The source was manipulated in oil palm was done by removing floral buds @ 25, 50, 75, 100 % and its effect was studied on biochemical characters and yield. The number of bunches and bunch weight were highest, when 25 percent sink were removed followed by 50 and 25 percent removal. The lowest number of bunches and bunch weight were recorded when 75 percent sinks were removed. Sugars were found highest in palms, whose fronds were cut from 33rd onwards, while sucrose and starch accumulated more in control palms. In general, glucose accumulated more in the petioles, while sucrose, starch and sugars accumulated more in the trunk in all the treatments.

Detection of nutrient deficiencies using Spectroradiometer

Different nutrient deficiency symptoms like magnesium, boron, N/K imbalance and potassium were evaluated by analyzing the foliage using field portable Spectroradiometer through spectral reflectance image measurement and the spectrums obtained were correlated with nutrient concentration in the leaves. Generally healthy green vegetation reflects about 40- 50 % of energy in the near infra red region (700-1100 nm) with the chlorophyll in plants absorbing up to 80-90 % of energy in the visible (400-700 nm) part of the spectrum. Because dead or unhealthy vegetation reflects a greater amount of energy than healthy vegetation in the visible spectrum and reflects less energy in the near infra red region, this characteristic is utilized as a measure of crop performance.



Spectral reflectance of different nutrient deficient palms

Detection of stress in oil palm with the help of Infrared thermometer

Standardized the stress detection process in oil palm by measuring canopy temperature difference with the help of infrared thermometer. The canopy temperature difference (CTD) is the difference between leaf temperature and ambient temperature. The canopy temperature difference was 2 to 3°C in the leaf breaking palms, while it was 1°C in the normal palms. Transpiration rate in the palms affected with leaf breaking increases due to closure of stomata with the onset of any stress

(may be disease, soil moisture deficit, atmospheric drought, etc.). Protein contents were lower in palms affected with leaf breaking while proline contents were very high. No definite trend was observed with respect to superoxide dismutase contents.

Role of Vapour Pressure Deficit in stomatal control

Gas exchange observations in oil palm with leaf breaking symptoms revealed that closure of stomata was noticed when vapour pressure deficit (VPD) increased from 1.2 kPa. The stomatal conductance and photosynthetic rate was severely reduced when the VPD reached 2.0 kPa. Photosynthesis in oil palm was significantly limited when VPD was more than 4.0 kPa (when air temperature is 38°C and relative humidity below 40 per cent). VPD values of 5.0 kPa were observed during the dry days at Pedavegi.

Carbon sequestration potential of oil palm

Destructive sampling of eleven oil palm hybrids (16 years old palms) belonging to different sources was taken up for estimation of standing biomass and carbon contents. The total biomass and carbon content ranged from 354.9 to 764.7 kg/palm and 138.9 to 305.4 kg/palm respectively. The total biomass (764.7 kg/palm) and carbon contents (305.4 kg/palm) were found to be highest in Deli x Ghana while, lowest levels were found in 128 x 31323. Quantified the potential of carbon sequestration in oil palm plantations grown under irrigated and rainfed conditions in Andhra Pradesh. The annual carbon sequestered by oil palm was 11.73 and 5.51 t ha-1 y-1 under irrigated and rainfed conditions respectively. The standing biomass of a ten year old oil palm plantation was of the order of 59.62 and 36.53 t ha-1 under irrigated and rainfed conditions.

Seasonal changes in oil formation and fatty acid composition

Oil content and fatty acid composition in three oil palm hybrids *viz.,* Malaysia, Deli x Ghana and Deli x Nigeria were analyzed in rainy and summer seasons. Seasonal variations in fruit weights (4.9 – 13.6 g), oil content (69.3 – 81 %) and moisture content (30.2 – 43.9 %) were observed. Saturated fatty acids like myristic (0.67 – 1.32 %) and palmitic (41.9 – 49.6 %) showed high levels during summer season, while stearic (3.67 – 4.86 %) increased during rainy season. Unsaturated fatty acids like oleic (36.5 – 44.1 %), linoleic (5.58 – 8.57 %) and linolenic (0.22 – 0.56 %) also increased during summer season and decreased during rainy season. The study confirms that oil content and fatty acid composition is strongly influenced by temperature and rainfall during rainy and summer seasons.

Effect of fruit ripening on fatty acid composition, oil and moisture contents

Changes in fatty acid composition, oil content and moisture content were analyzed in four adult oil palm tenera hybrids *viz.*, Malaysia, Palode, Deli x Ghana and Deli x Nigeria grown under irrigated conditions. During different developmental stages from anthesis to maturity during the 12, 14, 16, 18, 20 weeks after anthesis (WAA), analysis was carried out. Fruit weight increased from 12th to 20th week (5.1-10.6 g) in all the hybrids. Oil content increased from 22 to 79 oil/dry mesocarp % while moisture content decreased (34.3 %) from 12th to 20th week. Six fatty acid profiles *viz.,* myristic (0.5 - 4.3 %), palmitic (34.1 - 50.9 %), stearic (2.8 - 6.4 %), oleic (3.0 - 6.4 %), linoleic (7.8 - 11.5 %) and linolenic (0.3 - 3.3 %) were identified by standardizing the GC parameters. The method standardized was rapid with a total analysis time of 7 minutes and environmentally friendly, and accuracy was good for raw-material quality control.

Phenological growth stages of adult oil palm hybrids

The different phenological growth stages of adult oil palm hybrids grown in India under irrigated conditions were coded using the *Biologische Bundesantalt, Bundessortenamt and Chemische Industrie* General Scale. The duration between unfolding of 70 per cent spear leaf to bunch maturity in the hybrids ranged from 447.9 to 485.2 days and the duration from anthesis to maturity ranged from 145.8 to 153.7 days. Wide variation in the degree days from spear leaf development to bunch maturity were also observed among the hybrids ranging from 6320.2 to 6937.3. Among the hybrids, United plantations hybrid possessed the shortest duration and lowest degree days from spear development to bunch maturity. The study would help in estimating thermal time required for completion of different phenological stages, which could be used for yield forecasting models and studying climatic analogues in oil palm.

Improved sickles for harvesting oil palm

Different profiles of sickles were designed, fabricated and tested in oil palm plantations of Andhra Pradesh and Kerala. Based on the field evaluation trials, six sickles *viz.,* DOPR-1, DOPR-2, DOPR-3, DOPR-4, DOPR-5 and DOPR-6 were found better. Based on intensive field trials with different skilled harvesters to harvest bunches from different heights, two sickles *i.e,.* DOPR-1 and DOPR-5 manufactured with stainless steel were found promising.

Motorized sickle for harvesting in medium tall palms

Two models of oil palm harvesting tools *viz.,* back pack mounted and trolley mounted were developed and tested in oil palm plantations. Based on the initial trial it was observed that, using the back pack model the operator could harvest comfortably up to a height of 5-6 m and it has better adoptability and flexibility. The average number of bunches harvested per hour is about 15. The number of palms harvested would depend on various factors like efficiency of operator, number of matured bunches per plant, orientation of bunches and height of palm.

Height adjustable hydraulic lift platform for harvesting in tall palms

Height adjustable hydraulic lift platform was designed and fabricated for harvesting bunches from tall palms. The maximum platform working height is 4.5 m and minimum is 3.3 m. Safe load on the platform is 1000 kg. Maximum height of palm that can be reached with pole is 10.5 m. Power required for hydraulic system is taken directly from Tractor Hydraulic PTO. Whole trolley is moved by the tractor from one station to another in the field. By using this platform, a harvester can harvest bunches on both sides while moving in between the oil palm plantations. A person with average skill can reach up to a height of 4.54 m, and with 20 ft (6.1m) pole attached to sickle, he can reach a height up to 36 ft to harvest bunches.

Ablation tool

The ablation tool developed at IIOPR consists of a long handle of 1 inch GI pipe, B class of 152.4 length. On one end of this pipe a “U” shaped holder made of 1 inch flat with thickness of 5mm ± 1mm and of 19 cm length is welded which has a width of 2 cm at the welding point, and gradually widened to 5.2 to 5.7cm at the outer end. A sharp pointed nail of 6.5 cm length and 5-8 mm diameter is welded on to the centre of the “U” holder. In the traditional method of removing the inflorescence, at least 2.4 leaves are cut to remove one inflorescence, where as with the developed tool there is no harm to the leaves. The efficiency of the ablation tool is 125 inflorescence /hectare.

PLANT HEALTH MANAGEMENT

Studies on preferential difference of rhinoceros beetle incidence on Arecaceae palms

The per cent incidence and infestation of rhinoceros beetle on both oil palm and coconut observed at monthly intervals revealed that the pest causes more damage to coconut than oil palm. The major symptom on oil palm is a permanently marked hole in the petiole of the leaf with the presence of chewed up fibres in these holes. This is not seen in case of coconut. The correlation studies between per cent infestation and the chemical composition of the palm fibres indicates more lignin content in coconut compared to oil palm, whereas oil palm is having more á cellulose and hemi cellulose contents. In spite of this reason, the pest was found to prefer coconut causing more damage compared to oil palm plants. The symptoms of damage reveal that the pest is attacking only the leaf silhouette in case of coconut, where as it prefers to attack the petiole portions in oil palm. This could be the reason for low incidence and infestation on oil palm as the petiole portions are having more lignin compared to leaf silhouette.

Studies on population dynamics of bagworm (*Metisa plana*)

Bagworm incidence and its infestation were found very less to severe depending upon the weather factors. Prevalence of high temperatures of more than 45°C during summer months followed by incessant rains during rainy season caused uncongenial conditions for the pest build up. The incidence and infestation was found more in plantations raised in black cotton soils and middle aged palms with more than 15 years old. This was found further aggravated with flood irrigation practices which created congenial conditions for the pest becoming endemic to the area. Pest incidence was found more on 32nd frond and less on 17th frond. However the average incidence was found on par with 25th frond confirming the earlier results carried out in different oil palm growing countries to fix the critical leaf for taking observations on bagworms.

Studies on life history of bag worm

The life stages of psychid (bag worms) were studied in plant growth chamber at congenial conditions for the pest growth i.e. 28°C temp and 58-84% RH with day and night conditions using light source. It was observed that on an average 100-150 eggs are laid by the wingless female in the cocoon. The egg stage lasted for 7-10 days. The first instar larvae after hatching from eggs were found naked without any cocoon. Immediately after hatching these were found feeding on the mother's bag and thereby

formed its own bag. Sometimes these were found cutting the leaf tissue as bits instead of scrapping as a part of preparation of bag. In general the first five instars only scrape the leaf tissue where as the later stages prefer to make holes on the leaf lamina and feed . The pest completed its life cycle in an average of 102 days.

Eggs of bagworm

Larvae of bagworm

Studies on natural enemies of bag worm

Bag worms were parasitized by three parasitoids in the field condions. *Goriphous bunoh* and *Brachymeria* sp. were recorded parasitizing on pupae of bagworm. D*olichogenidea metesae was* recorded as larval parasitoid causing moderate incidence. The average per cent parasitism on bagworm was observed to be in the range of 39.2 to 65.23 per cent during the month of November while minimum (15.83%) was observed during December. *Brachymeria* sp. was causing 20.8 per cent parasitism. Presence of prominent hole on the down side of the bag was found indication for the parasitism of the pupae.

Adult of *G bunoh*

Studies on bio efficacy of insecticides on bag worm

Bioefficay studies conducted on bag worm using chemical insecticides and microbial organism *viz.,* carbofuran, imidachloprid, thiomethoxim, chlorantraniliprole and *Beauveria bassiana* under laboratory conditions indicated that chlorantraniliprole was effective in causing heavy mortality of the pest compared to microbial organisms and control at 7 days after treatment. The per cent mortality was observed varying between 82.0 to 92.0 per cent with highest in the chlorantraniliprole treatment

followed by carbofuran. In a field trial it was found that granular application of carbofuron proved effective in bringing out 100 % mortality of the pest population followed by chlorantraniliprole (99.0 %) at 4 days after application. The microbial agent *Beauveria bassiana* was proved ineffective in causing knockdown effect on pest. As the soil application was found effective and easy to operate in tall plantations, this proved a successful treatment compared to aerial spraying.

Studies on different methods of pesticide application for management of leaf eating caterpillars

Studies on the efficacy of different methods of insecticide application *viz.,* stem injection, root feeding and soil application against oil palm leaf web worm and bagworm indicated that stem injection method using imidacloprid @10ml per palm recorded highest change over control followed by soil application of phorate granules @ 100 g./palm. Injecting the insecticide to the stem using used saline pouches was found effective and easy method for controlling the lepidopterous pests of oil palm. Moreover, they are safe for the pollinating weevils.

Stem injection unit

Studies on life history of oil palm leaf webworm *Acria meyricki*

The life history of oil palm leaf webworm, *A.meyricki* was studied. Each female laid about 62.5 eggs in confined condition. The incubation period was about 4.7 days. The percentage of egg hatchability was about 95.6 per cent. The larvae were greenish in colour with whitish dorsal line in the middle of the body. The larval stage passed through 6-7 instars in a period of about 20.7 days. After the larva was full grown, it

Eggs of leaf webworm

Larva of leaf webworm

stopped feeding and reduced in size and entered to pre-pupal stage, which lasted for 1 day. The pupal stage lasted for about 5.8 days. Adult lived for about 5.4 days on an average. The total life period from egg to adult stage was ranging from 30.0 to 44.0 days.

A method for mass rearing of leaf webworm

Newly emerged adults were sexed and confined to transparent perforated plastic jars having blotting paper strip smeared with thin layer of non-absorbent cotton. The set up were maintained at 27±0.5 °C constant temperature and 55.0-60.0 per cent RH in BOD incubator. The blotting paper strip with non absorbent cotton was acted as substrate for egg laying. The adults laid eggs in between the cotton fibres. After egg laying such strips were cut into smaller strips. Those strips were loosely sand witched between nursery oil palm leaf bits in specimen tubes. The newly hatched larvae move to oil palm leaf bits and start feeding.

Mass rearing unit of leaf webworm

Studies on seasonal activity of leaf webworm in relation to weather factors

The incidence of leaf webworm normally commences from October. The population increases slowly and peak population is observed during January, February and March and start declining in April. It was found that larval population was significantly negatively correlated with weather parameters like maximum temperature (r=-0.36), minimum temperature (r=-32), mean temperature (r=-34) and relative humidity(r=-54). Non significant correlation was observed with rainfall. Pupae were not significantly influenced by maximum temperature, minimum temperature and mean temperature, but significantly with relative humidity(r=-41).

Studies on natural enemies of leaf webworm

The larvae of leaf web worm were found parasitized by two biocontrol agents. They were identified as *Apanteles hyposidrae* (Braconidae: Hymenoptera) and *Elasmus brevicornis* (Elasmidae: Hymenoptera) by National Bureau of Agriculturally Important Insects, Bangalore. The parasitization by *A. hyposidrae* was ranging from 8.33 to 71.08 per cent and parasitization by *E. brevicornis* was ranging from 23.92 to 31.42 per cent. Apart from these, pupae were found parasitized by *Brachymeria albotibialis* (Chalcididae: Hymenoptera) to an extent of 79.8 per cent in oil palm gardens. These parasitoids are the new record on this pest.

Adults of *Apanteles hyposidrae*

Adults of *Brachymeria albotibialis*

Management of leaf webworm

Field trials conducted against leaf webworm using various chemical insecticides indicated that triazophos 40 EC (1.25 ml/l), cypermethrin 10 EC (0.5ml/l), and profenophos 50 EC (1.0 ml/l) effectively controlled the pest even on the first day after spraying. The insecticides triazophos and cypermethrin continued to be effective in controlling the pest up to 14 days after spraying. Profenophos kept the pest population under check effectively up to 10 days. Insect growth regulators *viz.*, buporofein and novaluron did not result in satisfactory control. In another pesticide evaluation trial, insecticides *viz.,* deltamethrin (1ml/litre of water), thiodicarb (0.5 ml and 1.0 ml/litre of water) effectively reduced the larval population even at one day after spraying and protected the palm from pest infestation for about a month.

A scaring device for management of avian pest menace of oil palm

Avian pests like common myna, *Acridotheres tristis* Linn., the jungle crow, *Corvus macrorhynchos* Wagner and House crow, *Corvus splendens* Villot, parakeet, *Psittacula eupatria* (Linn.) cause considerable damage in isolated oil palm gardens. Protecting ripened oil palm fruit bunches from them is a tough job as some of the currently available methods seem unsuitable or impractical or uneconomical. Hanging the visual scarring devices namely compact disk (CD) and digital video disk (DVD) furnished with images like predator's eye on non reflective side designed in the present investigation were found protecting the fruit bunches significantly. The disks or devices having predator eye image on yellow or red background offered excellent protection (100.0 %) compared to black background (92.7 %). These devices could easily

Scarring device

be installed, have no negative impact on the environment and economical as the unwanted CDs or DVDs are used.

Studies on seasonal activity of oil palm pollinating weevil and fruit set

The number of pollinating weevils *E.kamerunicus* per spikelet was less than 10.0 during April, May and June. No weevils were found developing during May 4th week to June 2nd week in some oil palm gardens. During that period the maximum and minimum temperature reached to more than 35°C and 33°C respectively and relative humidity dropped to less than 55.0 per cent. However, pollinating weevils were found developing on old oil palm plantations at low numbers where the micro climate prevalence might have played a major role in sustaining the weevil population. It is assumed that as soon as the weather conditions are congenial the weevils disperse from the old plantations and start building up in the young gardens. At the onset of monsoon the temperature dropped down and humidity increased, which cause congenial conditions for the weevil multiplication and development. Beginning from July the weevil population slowly increased. October, November and December months were seemed to be ideal for the development of the weevil. It was found that flowers which were pollinated during April 2nd Fortnight to June 1st Fortnight 2013 showed comparatively less Fruit set at harvest time and it was ranging from 55.29 to 79.70 per cent. This might be due to less activity of pollinating weevil during severe summer months. The per cent age of fruit set was more than 80.0 per cent when flowers pollinated during other than summer months.

Effect of pesticides on the emergence of pollinating weevils from male inflorescences

To assess the impact of various pesticides on the development and emergence of pollinating weevils from male inflorescences, a total of 17 pesticides were used at recommended doses, and observed that the pesticides fipronil, acetamiprid, thiamethoxam, monocrotophos, L-cyhalothrin, cypermethrin and deltamethrin caused more than 75 per cent population reduction. Other pesticides *viz.*, buprofezin, glyphosate and carbendazim caused less than 50 per cent population reduction. *Bacillus thuringiensis* HD-1 and B.t.HD-7 were found to be safe to apply in the field as they caused little reduction of weevil population (less than 13.0 %).

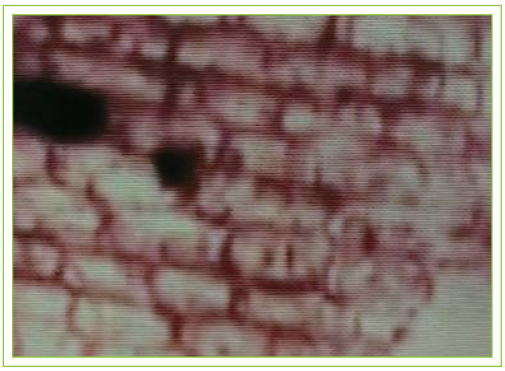
Survey and identification of diseases

Basal stem rot, Bud rot, Bunch rot, Pestalotia blight, orange spotting and red rust were observed in oil palm plantations of farmers and experimental plots of IIOPR. Diseases like early leaf disease, leaf spots, leaf rot were observed in nursery. Fungal and bacterial cultures of most of the oil palm diseases have been isolated and being maintained. Various isolates of *Botryodiplodea theobromae, Glomerella cingulata,*

Culvularia lunatum, Pestalotia palmarum, Ganoderma lucidum, bud rot bacterial isolates etc., are being maintained.

Isolation of michorrhiza from oil palm roots

Association of micorrhizal is observed with oil palm. Formation of mycelium, H-shaped branching of hypha (*Glomus* sp), simple vesicles, lobed vesicles (*Acaulospora* sp), arbuscules and peletons were observed under microscope.

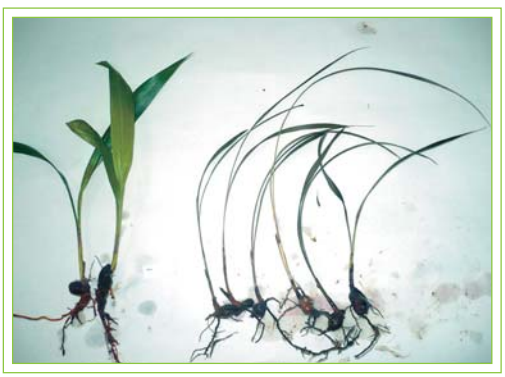


H – shaped branching formed by *Glomus* sp

Massive intracellular growth of arbuscules/ peletons

Etiological investigations on bud rot in oil palm

Through koch's postulates: Five bacterial isolates from bud rot affected palms affected palms were isolated. They were named as BRI-1, BRI-2, BRI-3, BRI-4 and BRI-5.These isolates were studied for their colony and cultural characteristics previously. Further, morphological characteristics are also studied through grams staining. The pathogenic studies were conducted in *in vitro* and *in vivo.* The isolate BRI-5 has developed the bud rot symptoms in hydroponics as well as in pot culture. The *invitro* study was repeated and the same isolate was reisolated.



Proving pathogenecity in *in vitro* Right: diseased; left: control

Proving pathogenecity in *in vivo;* left: diseased; right: control

Through molecular studies: DNA of the bud rot isolates were extracted and amplified in PCR with universal primers. With the set of universal primers (5'-AGATTACCGCGGCKGCTG-3', 3'-CCGTCAATTCTTTAGTTT-5') produced a band of 500bp. The DNA of all the samples of bud rot isolates BRI-1, BRI-2, BRI-3, BRI-4 and BRI-5 were isolated using culture lysates. The protocol of PCR amplification was done by using a set of Erwinia genus specific primers (5'- TAAAGGGTCTATCATGCG- 3'; 3'-CCTTCACCATACATAATTTGGA-5'), 500bp band was produced which is provisionally confirming the BRI-5 as *Erwinia* sp. The amplicons were sent for sequencing, based on the sequencing data, the DNA was further amplified to confirm the genus and species of the reisolated microorganism. Blast analysis identification as *Erwinia chrysanthemi* with 99% G+C homogeneity. Association of *Bacillus pumilis* with bud rot was also recorded.

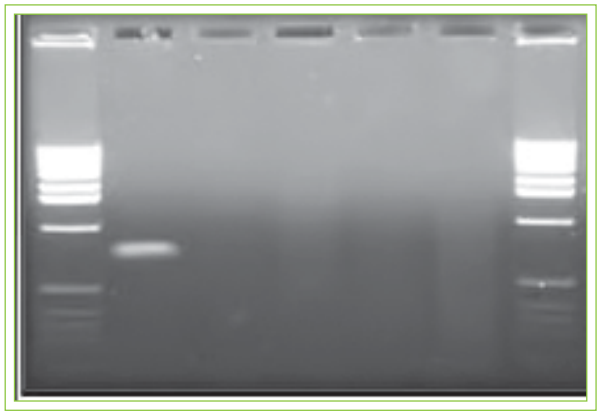
Amplification of DNA of BRI-5 isolate with universal (lane 1 and 2) and Erwinia (lane 3 and 4) specific primers

Survey of basal stem rot disease in oil palm

A survey on incidence of Basal Stem rot in AndhraPradesh was done in Visakhapatnam, East Godavari, West Godavari, Krishna, Khammam, vizianagaram Districts. Kuchimpudi, Pedavegi, laxmipuram, medinaraopalem, Venkataramanna-gudem, talla gokavaram villages in west Godavari; Rajamundry and kadiyapu lanka in East Godavari; Nujividu, M N palem in Krishna district; Aswaraopet and Naaramvarigudem in Khammam district; parvathipuram in vizianagaram district; J D peta in Vizag district were surveyed. The incidence varying from 2.9 % to 52.85 %.

Validation of Ganoderma specific primers for diagnosis of basal stem rot

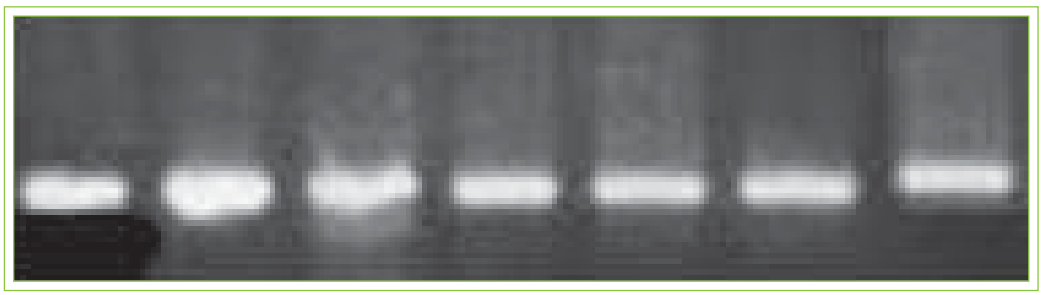
The ganoderma specific primers gan-1 and gan-2 that are already validated are used for their specificity confirmation. All the 35 samples were amplified in PCR reaction and the specificity is confirmed. The ganoderma specific primers gan-1 3'-TTG ACT GGG TTG TAG CTG-5'and gan-2 5'-GCGTTACATC GCAATACA-3' that are already validated in other crops are proved specific for oil palm Ganoderma also. The set of primers are proved non specific to other oil palm fungi like *Schizophyllum sp, Marasmius palmivora, Glomerella cingulata, Colletotrichum, Pestalotia palmarum* and other saprophytes like *Fuasrium, botryodiplodia theobromae*.



Gan-1 and gan-2 primers are specific to *Ganoderma lucidum*, not to other fungi of oil palm. Lane 1: *Ganoderma lucidum*; lane 2: *Phellinus noxius*; Lane 3: *Marasmius palmivorus*; Lane4: *Glomerella cingulata*; Lane 5: *Pestalotia palmarum*

Molecular diagnosis of basal stem rot

A methodology for PCR amplification of Oil palm Ganoderma DNA was standardised with a recipe of primers each of 1ul, taq polymerage 0.25ul, taq buffer 5ul,dntps 1ul, template 1ul. The correct tissue to be sampled for diagnosing the Basal stem rot is identified. Samples from 25 BSR affected palms were taken from four locations of the palm like root, basal stem, upper stem and leaf. Among the tissues basal stem tissue is recorded highest Colony forming units of *Ganoderma lucidum* in all the 25 palms. This result is supported by ganoderma specific primers.



Detection of *Ganoderma lucidum* from basal stem tissue

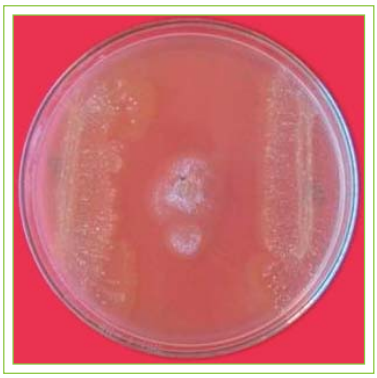
Management of basal stem rot

Using Trichoderma sp: Eight basal stem rot palms were selected and confirmed the BSR infection through culturing on ganoderma selective medium. From each palm Trichoderma spp were also isolated namely tv-1, tv-2, tv-3, tv-4, tv-5, tv-6, tv-7 and tv-8 and tested their efficacy on Ganoderma. Among them the tv-8 isolated has shown

the highest mycelia inhibition of ganoderma. Trichoderma is mass multiplied on FYM, and applied to the palm basins 5kg per basin. This is done at 2 months interval. Number of upright leaves, bending leaves, brackets were recorded at monthly intervals. Number of upright leaves is increased, number of bending leaves is decreased. No new brackets were observed in treated palms. The population of ganoderma in treated palm basins is reduced where as in control palms no change in the population is recorded. Hence, the technology of application of *Trichoderma viride* that was multiplied on FYM can be recommended to farmers for management of basal stem rot of oil palm caused by *Ganoderma lucidum.* The isolate TV-8 was highly antagonistic with 90 % inhibition of mycelial growth against *Ganoderma lucidum* among all native and commercial *Trichoderma viride* formulations.

Antagonistic activity of tv-8 isolate against basal stem rot pathogen

Using *Pseudomonas fluorescens:* Five *Pseudomonas fluorescens* isolates were isolated from the rhizosphere of oil palm. Antagonistic activity of 5 P. fluorescens isolates was tested through dual culture technique against the Ganoderma lucidum, the causal agent of Basal stem rot disease. Pf-3 was superior among the five by forming an inhibition zone of 10mm. The isolate was mass multiplied on nutrient broth and applied to the oil palm seedlings at 2 months interval with a concentration of 1 X 10^8 cfu/ml. The soil was pre-inoculated with *Glucidum* multiplied on jowar grain. Seedlings were observed for growth and biometric readings were being taken. PF-3 effectively reduced the PDI of the disease by recording the 12.76 as compared to control which recorded 100 PDI. PF-3 treated seedlings showed more height, number of leaves, dry weight and root spread as compared to control.



Antagonistic activity of pf-3 pseudomonas fluorescens isolate against basal stem rot pathogen

Identification of indicator plants for basal stem rot

Identification of indicator plants for basal stem rot is going on. Seeds of nine crops were sown in pots preinoculated with Ganoderma inolculum. The nine crops were, jowar, maize, ragi, red gram, blackgram, green gram, brinjal, tomato, bhendi. The same were sown in the ganoderma infested soil to check the infection. Germination percentage was calculated. In the pot culture bhendi recorded the lowest

germination percentage of 9%, where as in field conditions bhendi and green gram recorded minimum germination percentage of 13 and 17.

Identification of indicator plants to basal stem rot disease in pot culture- bhendi

Identification of indicator plants to basal stem rot in field conditions- bhendi and green gram

Effect of bio priming for management of basal stem rot

The microbes to be used as bio primers were isolated from the oil palm rhizosphere. *Trichoderma viride, Pseudomonas fluorescens, Bacillus subtilis, Azatobacter* sp and *Azospirillum* sp were isolated on respective specific media. Their antagonistic activity was tested against *Ganoderma lucidum* in Dual culture. Among all, *P. fluorescens* was superior with 10 mm of inhibition zone. The bacteria were not cross compatible. In cross compatibility studies, *P. fluorescens* was found superior, which suppressed the growth of other bacteria. However all the isolates along with consortia were used for bio priming of oil palm sprouts. Oil palm sprouts were treated with the above bacterial isolates at a 1 X10^6cfu/ml, and coated with talc and shade dried. These primed sprouts were planted in pots that were pre-inoculated with *Ganoderma lucidum*. The isolates were applied to the pots containing the oil palm seedlings as drench. Growth of the seedlings and PDI of basal stem rot is being calculated.

In the bio-priming pot culture experiment, combination of *P. fluorescens* + *T. viride* proved effective with 23.56 PDI as compared to control with 100PDI. The same treatment took 8 weeks of incubation period for onset of symptoms. Highest dry matter production was recorded with consortium (*P. fluorescens* + *T. Viride* + *Azatobater* sp + *Azospirillium* sp) treatment which could also significantly reduce the PDI.

Effect of bio priming of oil palm sprouts against basal stem rot disease

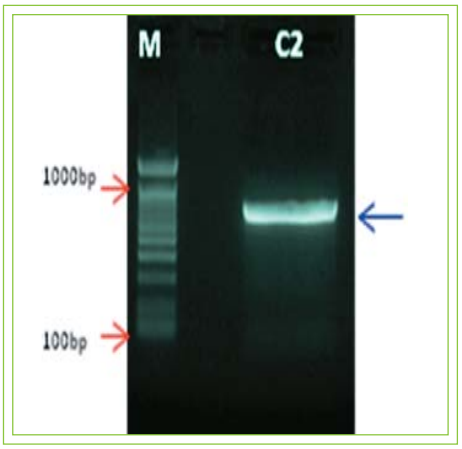
Etiological investigations on orange spotting disease of oil palm

Orange spotting samples were collected and associated microbes were isolated. A fungal isolate named as GNFD is very frequently isolated from all the collected diseased samples. The isolate was studied for its morphology, conidial length was 16.2 um, conidial width was 6.4 um, septhate, hypha occasionally septate conidia, oblong to cylindrical in shape. The isolate was mass multiplied on PD broth, challenge inoculated on oil palm seedlings and were observed for symptoms development. Symptoms were observed on the inoculated seedlings at around 2 weeks after inoculation as minute specks with yellow halo, subsequently increased in size. The isolate GNFD is re-isolated from the diseased samples taken from challenge inoculated seedlings. The isolate was characterized at molecular level. DNA was isolated and ITS

Minute specks and orangespotting development on challenge inoculated seedling

Orange spotting disease development on challenge inoculated seedlings

region was amplified in PCR in 20 µl of reaction mixture containing PCR buffer, 1X; $MgCl_2$, 3 mM; dNTP mix, 0.25 mM; *Taq* DNA polymerase, 0.05 U; primer, 1 pmol and template DNA, 50 ng, with the ITS4 and ITS6 oligo primers having a sequence of 5'-TCCTCCGCTTATTGATATG-3' and 5'-GACACTCAAACAGGTGTACC-3'. This yielded a band of approx 500bp band. The sanger sequencing results showed that the amplicon sequence has 99 % similarity with *Glomerella cingulata* whose imperfect stage is *Colletotrichum lindemuthianum*.



Molecular identification of GNFD isolate – causal organism of orange spotting disease

Management of orange spotting

The orange spotting disease incidence is slowly accelerating season by season, especially during monsoon season. Orange spotting affected palms shows, copper or bronze spotting in older fronds and petioles, gradually the center of the spot become dark and the surroundings will be orange in colour. Bases of leaflets will shred and start drying become brittle and breaks easily. A technology was developed for management of orange spotting disease through the stem injection of carbendazim 12% + mancozeb 63% @ 3% or benomyl @ 2% or triademorph @1% concentrations.

A field trial was conducted and a strategy was derived for management of orange spotting and leaf blight disease. All diseased leaves have to be pruned. Two or three stem injections and sprayings with hexaconazole/ chlorothalonil/ triademonph @ 1% and spraying @ 0.1% have to be imposed to suppress the disease spread and development further. For each treatment fungicide has to be changed to avoid development of resistance to the fungicides.

Seed treatment of oil palm seeds

A methodology seed dip treatment was developed to avoid seed diseases and contamination during heating and germination process. Seed dip can be done with methyl alcohol @10%, Difenocoazole 0.3%, Chlorothalonil @ 0.3%, triademorph @ 0.3% or captan @ 0.5% concentrations.

TRANSFER OF TECHNOLOGY

Officers training programmes

IIOPR organized training programmes to officers on Oil Palm Production Technology, Oil Palm Hybrid Seed Production, Plant Protection in Oil Palm, Nursery Management in Oil Palm, Soil and Leaf Nutrient Management in Oil Palm. A total of 55 training programmes were conducted where in 782 officers, consisting of officials of state department of Agriculture/Horticulture, staff of oil palm processing units, scientists of ICAR/SAU/KVK participated.

Officers training programmes organised

Year	No. of Programmes	No. of officers participated
2011	10	243
2012	9	139
2013	11	146
2014	9	19
2015	16	235
Total	**55**	**782**

North East officers training

Farmers training programmes

Training programmes were organised to farmers on recommended oil palm cultivation practices. A total of 138 programmes were conducted to 4921 farmers. Farmers representing from Andhra Pradesh, Maharashtra, Chhattisgarh, Gujarat, Odisha, Goa, Karnataka and Mizoram participated.

Farmers training programmes organised

Year	No. of Programmes	No. of farmers participated
2011	18	942
2012	25	553
2013	29	948
2014	25	1039
2015	41	1439
Total	**138**	**4921**

Farmers training on harvesting

State level officers training programmes

Seven state level officers training programmes were organised on oil palm production technologies to 184 officers belonging to Telangana (22), Karnataka (24), Tamil Nadu (30), Chhattishgarh (26), Odisha (24), Mizoram (25) and Arunachal Pradesh (33).

State level training programme organsied at Raipur, Chhattisgarh.

Capacity Building Programmes to officers of North Eastern states

Orientation training on State Agriculture/ Horticulture department officials from the states of Assam (14), Meghalaya (5), Arunachal Pradesh (11) and Nagaland (13) were trained on oil palm production technologies.

Farmers Fields Schools

Farmers field schools were organised in two villages of West Godavari district of Andhra Pradesh and two villages of Kolasib district of Mizoram. Farmers field school on Fertilizer management, Irrigation management, Pest and disease management were organised in Andhra Pradesh. Farmers field school on Supplementary pollination in oil palm and Fertilizer management in oil palm were organised in Mizoram.

Block Demonstration

Block Demonstration on 'Fertilizer management in oil palm plantations' was implemented in Kolasib District, Mizoram in an area of 100 ha. Recommended doses of fertilizers were distributed and skill demonstrations on method of fertilizer application in oil palm plantations were organized.

Dissemination of technologies through ICT

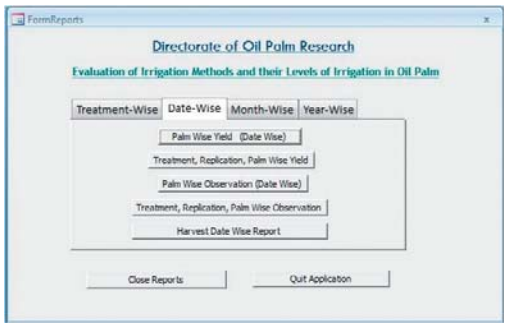
Oil Palm Kisan Mobile Message Services through SMS/Voice messages: Data base consisting of 22,352 unique mobile numbers of oil palm growers from 13 states were collected. Ninety two contents on oil palm production technologies were developed for text and voice message. 1,079 SMS were sent to 19.27 lakh mobiles and 876 voice messages were sent to 23.60 lakh phones.

Video Conference: Video conference was conducted to disseminate oil palm production technologies to different stakeholders. 129 participants were connected over 8 locations in 6 video conference sessions .

Software developed for experiments on oil palm carried out at ICAR-IIOPR.

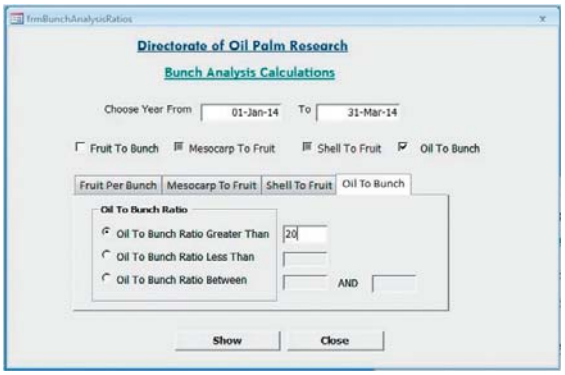
Irrigation management: Software was developed in MS Access with modules of data management and reports.

Nutrient management: Software was designed and developed in MS Access with VBA code for recording and retrieving the data.

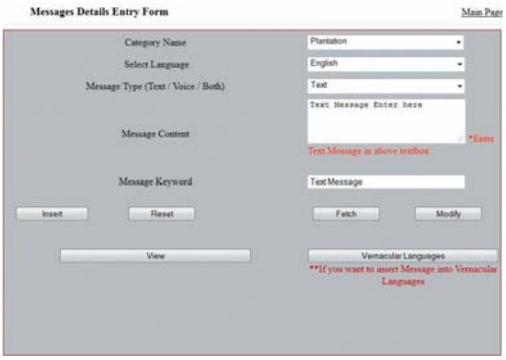


Bunch analysis: The software was designed and developed in MS Access using the visual basic for applications to record the data of various characters and to retrieve information in the form of various reports for the selected period. This helps the breeders in selection of parental material in oil palm breeding programme.

Hybridization data management in oil palm seed gardens: Software was developed forhHybridization process of oil palm seed gardens using visual basic.net for front end and SQL server for backend.



Oil palm kisan mobile message services: The software was designed and developed to maintain the data on content of oil palm and oil palm grower contact and plantation details using ASP.NET as front end and SQL Server 2008 as back end using embedded SQL queries to retrieve and update data. The software application was useful in handling the voluminous data in the implementation of the project.



CDs on Oil Palm

Three menu driven software CDs on oil palm were developed on different aspects of oil palm with the help of text and images using VB.Net which are as follows :

- E-Manual on Oil Palm Cultivation explains about climate requirements, variety, planting, irrigation, fertilizer, cultural practices, disorders, pests and diseases.

- Diseases of Oil Palm and their Management explains about, oil palm seed diseases, nursery diseases and diseases in main field. By clicking on the selected disease, information is displayed about various symptoms and management practices.

- CD on Nutrient Disorders in Oil Palm and their Management explains about deficiencies / disorders in oil palm. By selecting the deficiency / disorder, information about causes, symptoms and control measures is displayed. Video clips were also used for explanation.

Mobile Apps on Oil Palm

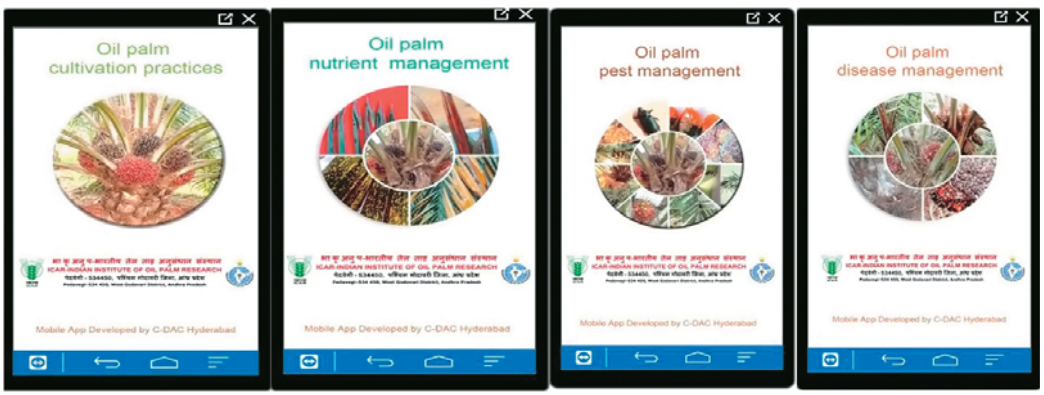
Four mobile apps viz., Oil Palm-Cultivation Practices, Oil Palm-Nutrient Management, Oil Palm-Pest Management and Oil Palm-Disease Management were developed in English language. All the apps included text and pictures wherever necessary to explain the technologies.

The mobile app Oil Palm-Cultivation Practices explains the recommended practices for oil palm cultivation in India. The climatic requirements for oil palm cultivation in India, cultivated variety, planting season, planting, population, spacing requirements, cultural practices, management of oil palm plantations during juvenile period and adult plantations are explained.

The mobile app Oil Palm-Nutrient Management explains the symptoms of nutrient deficiencies in oil palm and their management. Symptoms of nutrient deficiencies viz. Nitrogen, Potassium, Phosphorous, Boron, Magnesium, iron, copper, Zinc, Manganese and other disorders in oil palm were explained along with management practices. Short video segments were included in the app to explain the symptoms and management practices to adopt.

The mobile app Oil Palm-Pest Management explains the symptoms of pest infestation in oil palm and their management. Symptoms of pest infestation viz., Rhinoceros beetle, Scales, Mealy bugs, Slug caterpillar, Bag worm, Chafer beetles, Termites, Leaf webworm, Birds, Rats and wild animals in oil palm were explained along with the management practices to be followed.

The mobile app on Oil Palm-Disease Management explains symptoms of disease infection in oil palm and their management. Symptoms of disease infection viz., Basal stem rot, Bud rot, Stem wet rot, Orange spotting, Bunch rot, Upper stem rot, Spear rot, Fruit rot, Crown disease, Crown fracture, Bunch end rot and Bunch failure in oil palm were explained along with their management practices to adopt by the farmers. All the four mobile apps are placed in Google Play Store for public.



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