Vol. 10 (1&2), 2018

ISSN (Print) 0972-5806

INTERNATIONAL JOURNAL OF OIL PALM

An Official Publication of the
Society for Promotion of Oil Palm Research and Development

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INTERNATIONAL JOURNAL OF OIL PALM

This journal is an official publication of the Society for Promotion of Oil Palm Research and Development twice a year

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Inland: ₹2000 Foreign: US$ 50

International Journal of Oil Palm

Vol. 10 (1&2), 2018

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RESEARCH ARTICLE

Effect of fertigation on growth, yield and nutrient use efficiency of oil palm (*Elaeis guineensis* Jacq.)

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Received: 2 October, 2018 Accepted: 21 November, 2018

ABSTRACT

Oil palm is one of the biggest consumers of mineral fertilizers due to its high growth rate, biomass production and yield and therefore, demands a balanced and adequate supply of nutrients for growth and yield. Fertilizers are usually the largest variable cost in the production. A study has been taken up to standardize the fertilizer dose using drip irrigation to improve nutrient use efficiency in oil palm under sandy clay loam soils of coastal Andhra Pradesh. Six different doses of fertigation were imposed in addition to the RDF through soil application in a 13 years old adult oil palm plantation in RBD with four replications. Fertigation was given at monthly interval from 2011 to 2017 and data on growth and yield parameters were recorded. The three years pooled datafrom 2014-15 to 216-17 recorded highest number of bunches per palm (8.0) and FFB yield (23.9 t/ha) at a fertigation dose of 1200:600:1200g NPK per palm year (T_4). However, it was on par with the treatments T_2 (7.8, 23.1 t/ha), T_3 (7.3, 22.2 t/ha), T_5(7.3, 21.9 t/ha) and T_6 (7.2, 21.9 t/ha). Further, increase in fertilizer dose of NPK did not result to any significant increase in number of bunches and FFB yield in oil palm beyond the dose of T_1 indicates that T_2dose is sufficient to obtain similar yield of FFB compared to higher dose of fertilizers. Higher nutrient use efficiency was also recorded in T_2 than the higher dose of fertigation.

Keywords: Drip irrigation, fertigation, growth, FFB yield, NUE, oil palm

INTRODUCTION

Oil palm is a gross feeder and is one of the biggest consumers of mineral fertilizers due to its high growth rate, biomass production and yield and therefore, demands a balanced and adequate supply of nutrients for growth and yield. Fertilizers are usually the largest variable cost in the production. It is a proven fact that annual allocation of fertilizers at a daily dosage to individual palms, substantial improvement in yields is expected. But the method adopted has to be cost effective and also less labour intensive. Fertigation has been proved to economize water and fertilizer with a corresponding lower expenditure in cost of production and labour towards weeding, fertilization and water application (Mahalakshmi et *al.,* 2001). Fertigation which combines irrigation with fertilizers is well recognized the most effective and convenient means maintaining optimum fertility level and water supply according to the specific requirement of each crop and resulting in higher yields and better quality of fruits (Smith et al*, 1979;* Syvertsen and Smith, 1996). Fertigation is the process of application of water soluble solid or liquid fertilizers through drip irrigation system. It is the process wherein fertilizer is applied through an efficient irrigation system like drip. In fertigation nutrient use efficiency could be as high as 90 per cent compared to 40 – 60 per cent in conventional methods. The amount of fertilizer lost through leaching can be as low as 10 per cent in fertigation, whereas it is 50 per cent in the traditional system Solamalai et alet al (2005). Through fertigation, nutrients are applied directly into the wetted volume of soil immediately below the emitter, where root activity is concentrated. It is commonly accepted that the efficiency of fertilizer use can be improved when it is applied by fertigation to most crops. Therefore, fertilizers in the fertigation system are applied at lower rates compared to broadcast fertilization (Haynes 1985). Patel and Rajput (2005) reported that application through fertigation significantly increased saving of fertilizer nutrients up to 40 per cent without affecting the yield of crops compared to the conventional method of nutrient application. Similarly, Haynes, 1985 reported that fertilizer savings through fertigation can be to the tune of 25 - 50 percent. Ramachandrudu et alet al (2009) reported that 50 per cent of the RDF applied through fertigation is optimum for better growth and vigour of seedlings in oil palm.At the site of the experiment, the period from October to May is generally rainless and crops are subjected to water stress which is usually terminated with either onset of monsoon in June/July month, supplementary irrigation is given as and when required.

Not much work has been done on oil palm to standardize the dose of fertilizer and method of application of fertigation for sustainable production and enhance the nutrient use efficiency. Hence, a study has been taken up to standardize the fertilizer dose using drip irrigation to improve the nutrient use efficiency.

MATERIALS AND METHODS

Afield experiment was laid out during 2011 on an existing 1997-98 oil palm plantation planted at 9m hexagonal method at ICAR-IIOPR, Pedavegi, Andhra Pradesh, India to study the effect of fertigation on oil palm using supplementary irrigation through drip methodin sandy clay loamsoils. The experimental site is located at 16^0 43'N and 81^0 09'S at a mean sea level of 13.41 m. The average rainfall is 1014 mm distributed over 45-65 days.Low rainfall during 2014 and 2015, less number of rainy days coupled with higher temperatures and pan evaporation during summer months from April to June were recorded continuously during 2014-15 and 2015-16 (Table 1).

SOILS OF THE EXPERIMENTAL SITE

Soil samples were collected from the experimental site and analysed for physic-chemical properties. The soil of the experimental site isa sandy clay loam. The soil was neutral in reaction with low in organic carbon and low in available nitrogen, highin available phosphorous and medium in available potassium (Table 2). There is no significant variation in the experimental site among the physic-chemical properties of the soil at the time of laying out the experiment.

Table 2: Physico-chemical characteristics of the experimental filed (Mean)

Properties	Values
pH	7.12
Electrical conductivity (dsm^{-1})	0.022
Organic Carbon (%)	0.44
Available nitrogen (kg ha^{-1})	198
Available phosphorous (kg ha^{-1})	52.3
Available potassium(kg ha^{-1})	284.6
Soil type	Sandy clay loam

Table 1: Monthly meteorological data recorded at ICAR-IIOPR, Pedavegi, West Godavari Dist., Andhra Pradesh during April, 2014 - March, 2017.

Month	2014-15			2015-16			2016-17		
	Mean Max. Temp.(^{0}C)	Rainfall (mm)	Pan Evaporation (mm/day)	Mean Max. Temp.(^{0}C)	Rainfall (mm)	Pan Evaporation (mm/day)	Mean Max. Temp.(^{0}C)	Rainfall (mm)	Pan Evaporation (mm/day)
April	36.18	0.00	4.25	40.00	10.00	4.10	39.2	0.00	4.25
May	38.03	79.15	4.02	40.82	7.80	4.06	40.10	0.00	4.40
June	38.53	9.00	3.51	33.70	155.00	2.60	35.68	94.00	3.47
July	33.68	293.75	2.87	35.76	56.00	3.69	33.58	207.00	3.29
Aug	33.25	129.25	3.36	33.60	178.30	3.15	33.05	173.00	3.37
Sept	33.20	116.50	3.06	32.79	16.00	2.94	33.00	152.00	3.33
October	33.80	56.70	4.93	33.68	0.00	3.00	32.49	148.00	3.48
November	31.84	20.75	2.31	31.70	0.00	2.34	31.51	17.00	2.58
December	39.67	0.00	2.57	30.51	0.00	2.12	33.33	0.00	2.60
January	29.70	0.00	2.49	33.08	0.00	2.45	30.66	0.00	2.61
February	29.69	0.00	2.86	33.34	0.00	2.90	30.94	0.00	3.09
March	34.60	0.00	3.41	39.2	0.00	3.10	33.95	0.00	3.86

The experiment was conducted in a Randomized Block Design with seven treatments and four replications. Each treatment comprising of nine palms planted at 9m hexagonal method accommodating 143 palms per hectare.Treatments comprising of T_1-300:150:300g NPK through fertigation, T_2-600:300:600g NPK through fertigation, T_3-900:450:900g NPK through fertigation, T_4-1200:600:1200g NPK through fertigation, T_5-1200:600:1800g NPK through fertigation, T_6-1200:600:2700g NPK through fertigation, T_7-120:600:1200g NPK (RDF) through soil application (Table 3).

Fertigation treatments were imposed at monthly interval and it has been carried out using injecting pump. All precautions were taken to run the normal water before fertigation to verify the discharge of drippers and also after fertigation to avoid precipitation in drip pipes. For large scale field operations, water soluble solid fertilizer sources are less expensive than liquid formulations and hence, water soluble solid fertilizers viz., urea, DAP(Diammonium Phosphate) and MOP (Potassium Chloride) were utilized for experimentation**.** All cultural practices including weeding, micronutrient application and application of irrigation water were done as per the recommendation of ICAR-Indian Institute of Oil Palm Research. High irrigation water application efficiency associated with negligible deep percolation in drip irrigation systems makes it ideal for fertigation in oil palm.

IRRIGATION WATER REQUIREMENT

The quantity of water applied as irrigation has been given as follows. The method of calculation devised by the institute based on the evaporation rates prevailing at the experimental area has been used to estimate potential-evapotranspiration (PE).

Potential-evapotranspiration (PE) = Pan evaporation × Crop factor

Crop factor 0.7 is considered for an adult oil palm.

Penman's estimate of evaporation and crop factor been used to estimate Potential-evapotranspiration and estimate water requirement for adult oil palm.Water holding capacity of 70% of the field capacity has been taken into consideration to estimate the water requirement per palm per day.

RECORDING OF OBSERVATIONS

Various growth and yield parameters were recorded as per the time schedule framed using standard operating procedures.The height of the palm was recorded in meters at quarterly interval and expressed as per palm per year. The difference in height between two successive years is expressed as height increment in centimeters. Number of leaves produced per palm were recorded on quarterly basis and expressed as per palm per year. The first opened leaf was marked with red color at the beginning of the first quarter and the first opened leaf in the next quarter was marked with yellow color, thus the number of leaves between the two markings indicated the number of leaves produced during that particular quarter.

Number of Fresh Fruit Bunches (FFBs) per palm were recorded in every harvest and expressed on yearly basis as number of fresh fruit bunches per palm per year. Total FFB weight was recorded per palm in each harvest and all harvests of the palms in the treatment is expressed as kilograms per palm per year. Average yield of fresh fruit bunches per palm in each treatment was multiplied with number of palms per hectare and expressed in tonnes.

Nutrient use efficiency was calculated for each treatment which is the ratio of FFB yield of oil palm in t ha-1 and total nitrogen(N), phosphorous(P) and potassium fertilizers applied in t ha-1.

Nutrient use efficiency= FFB Yield (t/ha) /Total nutrient as N,P and K

The data thus arrived was subjected to statistical analysis as per the procedure outlined by Panse and

Table 3: Recommended dose of fertilizer for oil palm (RDF)

Age of the palm	N(g/palm)	P_2O_5(g/palm)	K_2O(g/palm)	$MgSO_4$(g/palm)	Boron (Borax)(g/palm)
1st Year	400	200	400	125	25
2nd Year	800	400	800	250	50
3rd Year	1200	600	1200	500	100

Sukhatme (1985). The data on yield components recorded during the last three years *i.e*., 2014-15, 2015-16 and 2016-17 were pooled and analysed. Critical differences (CDs) were worked out at probability pd"0.05 using the ANNOVA wherever the results were significant. The non-significant treatment differences were denoted at NS.

RESULTS AND DISCUSSION

Effect of fertigation on growth of oil palm

Among the growth parameters, number of leaves per palm and height increment did not express any significant difference among the treatments and also no specific trend has been observed with dose of fertigation (Table 4).

Table 4: Height and number leaves per palm as influenced by fertigation

Treatment	Height increment (cm)	No. of leaves/ palm/year
T_1	49	31.9
T_2	45	31.5
T_3	48	31.8
T_4	53	29.9
T_5	44	30.6
T_6	42	29.3
T_7	43	29.4
CD(p=0.05)	NS	NS

Effect on yield characteristics

Effect of different fertigation doses on oil palm during the years 2014-15, 2015-16 and 2016-17 (Table 5&6) revealed that the bunch number per palm and FFB yields were higher in all the treatments during the year 2014-15 and the values were gradually decreased towards 2016-17. This may be attributed to the low rainfall coupled with high temperatures and pan evaporation for a longer period.

The three years pooled data (Table 5&6) in the study with different fertigation doses in oil palm recorded significant difference among the treatmentsfor number of bunches per palm and FFB yield. The bunches were in the range of 6.2 to 8.0 per palm.Except T_1-300-150-300g NPK which recorded the lowest number of bunches per palm (6.2) all other treatments were recorded significantly superior performance over the control T_7-1200-600-1200g NPK through soil application. Narsimha Rao et al*,* (2011), Sanjeevraddi et al. (2016), also reported similar results in oil palm.Although palms applied with 1200:600:1200g NPK (T_4) through fertigation recorded highest number of bunches per palm (8.0) followed by T2-600:300:600g NPK per palm (7.8), T_3-900:450:900g NKP(7.3), T_5-1200:600:1800g NPK (7.3)and T_6-1200:600:2700g NPK (7.2) per palm, they are not significantly different from each other indicates the lower dose of fertilizer at T_2-600:300:600g NPK is beneficial to obtain higher number of bunches per palm than applying higher doses of fertilizers. Haynes(1985) reported that fertilizer savings through fertigation can be to the tune of 25 - 50 percent in trickle irrigated crops.

Similarly, significant difference was recorded among the treatments for FFB yield per hectare and the yield was in the range of 18.0 to 23.9 t/ha. Highest FFB yield was recorded in T_4(23.9 t/ha) through fertigation, however, it was on par with the treatments T_2(23.1 t/ha), T_3(22.2 t/ha), T_5&T_6 (21.9 t/ha) indicating that the FFB yield increased with increase in number of bunches per palm.While the lowest FFB yield (18.4 t/ha and 18.0 t/ha) were recorded in T7 and T1 treatments respectively, during the same period.

Further, increase in fertilizer dose of NPK did not result in significant increase in number of bunches and FFB yield in oil palm beyond the dose of T_2 indicating that T_2 is sufficient to obtain the equal yield of FFB than higher dose of fertilizers. This may be due to supply of nutrients and water at the active root zone of oil palm which has a shallow root system. Mahalakshmi et al. (2001) also observed that the fertilizer savings through fertigation are presumably because of fertilizer and water are applied to soil where active roots are concentrated in banana.

Nutrient use efficiency

The fertigation at 600:300:600g NPK/ palm/year (T_2) has been found ideal dose to obtain higher FFB yield (23.1 t/ha) which is on par with the higher dose of fertilizers. Nutrient use efficiency has been estimated as 269.2kg FFB/ha kg of nitrogen and potassium and 538.5 kg FFB/ha/kg of phosphorous at T_2 than other treatments (Table 7.)

Table 5: Number of bunchesper palm as influenced by fertigation in oil palm

Treatments	2014-15	2015-16	2016-17	Mean
T_1	7.6	6.0	5.2	6.2
T_2	8.7	8.4	6.1	7.8
T_3	8.7	6.1	7.0	7.3
T_4	8.8	8.0	7.3	8.0
T_5	9.2	6.4	6.4	7.3
T_6	8.0	7.1	6.5	7.2
T_7	7.5	4.8	5.9	6.2
CD(p=0.05)	NS	2.0	1.2	1.3

Table 6: FFB yield as influenced by fertigation in oil palm (t/ha)

Treatments	2014-15	2015-16	2016-17	Mean
T_1	19.4	18.1	15.9	18.0
T_2	25.8	23.8	20.5	23.1
T_3	27.4	18.6	21.6	22.2
T_4	27.7	23.6	21.4	23.9
T_5	26.5	19.1	20.8	21.9
T_6	25.8	21.2	19.9	21.9
T_7	20.3	16.0	17.9	18.4
CD(p=0.05)	NS	5.1	3.6	3.7

Table 7: Nutrient use efficiency as influenced by fertigation

Treatments	N Use efficiency (FFB kg ha^{-1} kg of N)	P Use efficiency (FFB kg ha^{-1} kg of P)	K Use efficiency (FFB kg ha^{-1} kg of K)
T_1	419.6	839.2	419.6
T_2	269.2	538.5	269.2
T_3	172.5	345.0	172.5
T_4	139.3	278.6	139.3
T_5	127.6	255.2	127.6
T_6	127.6	255.2	127.6
T_7	107.2	214.5	107.2

CONCLUSION

Fertigation with NPK 600:300:600g NPK/palm/year at monthly intervals coupled with irrigation based on Potential Evapotransiration (PET) are recommended for higher FFB yield over recommended nutrient application of 1200:600:1200g NPK/palm/yearthrough soil.

ACKNOWLEDGEMENTS

Authors wish to thank the Director, ICAR-IIOPR, Pedavegi for facilitating to accomplish the task.

REFERENCES

Gnanamurthy P, Manickasundram P (2001). Fertigation in high value crops-a review. *In:* Advances in Integrated Nutrient Management System for Sustainable Crop Productivity and Soil Fertility, October 4.24,2001, Tamil Nadu Agricultural University, Coimbatore, pp 110-116.

Haynes RJ (1985) Principles of fertilizer use for trickle irrigated crops. *Nutrient Cycling in Agroecosystems.*6(3): 235-255.

Mahalakshmi M, Kumar N, Jeyakumar P, Soorianathasundaram, K. (2001). Fertigation studies in banana under normal system of planting. *South Indian Hort.,* 49: 80-85.

Narsimha Rao B., Suresh K, Ramachandrudu K, Mary Rani KL (2011). Influence of fertigation on growth and yield of Oil palm. *Intr. J. Oil Palm*. 8(1&2):13-16.

Neelam P, Rajput TBS (2005). Effect of subsurface drip irrigation on onion yield.*Indian J. Agric. Sci.,***75 (1)**:725-730.

Panse VG, Sukhatme PV (1985). Statistical Methods for Agricultural Workers. Indian Council of Agricultural Research Publication

Ramachandrudu K, Suresh K, Sekhar G, Suneetha V. (2009). Effect of fertigation on growth and vigour of oil palm seedlings.Int. J. Oil Palm6(2): 25-28.

Sanjeeva Raddi GR, Maheswarappa HP, Chandravathi B, Patil DR (2016). Effect of fertigation on yield and economics of oil palm (*Ealisguineensis* Jacq.).*J.Farm Sci.* 29(2): 200-202.

Smith MW, Kenworthy AL, Bedford CL (1979).The Response of Fruit Trees to Injection of Nitrogen through a Trickle Irrigation System. J. *Amer. Soc. Hart. Sci.,* 104: 311-313.

Solamalai A, Bhaskar M, Sadasakthi A, Subburamu K (2005). Fertigation in high value crops - A review. Aric. Rev., 26(1):1-13.

Syvertsen JP, Smith ML (1996). Nitrogen Uptake Efficiency and Leaching Losses from Lysimeter-grown *Citrus* Trees Fertilized at Three Nitrogen Rates. J. Am. *Soc.* Hort. *Sci.,* 121: 57-62.

RESEARCH ARTICLE

Skill gap in cultivation practices of oil palm (*Elaeis guineensis* Jacq.)

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Received: 10 June, 2018   Accepted: 18 July, 2018

ABSTRACT

Oil palm is grown commercially under irrigated conditions in India since 1990-91. Though the farmers are aware and adopt the practices, they could not adopt the correct skill in oil palm. A study was taken to find out the skill gap in cultivation of oil palm. A pre tested interview schedule was used to collect the data from 31 farmers. Most of the farmers (71%) are in low skill category. Skill gap ranged from 14.25 to 69.60 percent in the practices *viz.,* ablation, plant protection measures, planting of seedling, weed management, utilization of oil palm wastes, pruning of leaves, pit preparation, selection of seedling for planting, mulching, fertilizer management, basin Management, irrigation management, land preparation and management, selection of suitable inter crops and harvesting of oil palm Fresh Fruit Bunches (FFB).

Key words: Oil palm, adoption, skill gap.

INTRODUCTION

Oil Palm is being cultivated commercially in an area of 2,70, 000 ha in identified potential states in India since 1990-91, of which the state of Andhra Pradesh has 1,60, 000 ha. Government is providing subsidies and other benefits to the farmers to promote Oil Palm cultivation. However, the area expansion is at slow pace due to various factors. One among the main problems as it exists today is that of transfer of fruitful technologies and their skills pertaining to various practices of oil palm cultivation among the growers. It has also been observed that even if the farmers have technical know how, they resist adoption as they are unskilled in utilization of technology in their oil palm plantations apart from other constraints faced by them in adoption. No specific effort has been made to know the extent of skill gap in oil palm cultivation. Keeping this point in view a study conducted with an objective "to find out the skill gap in cultivation practices of oil palm".

MATERIALS AND METHODS

The present study was undertaken in three districts in Andhra Pradesh *viz.* Krishna, East Godavari and West Godavari districts. Among these three districts one village was selected at random. Thus from 3 villages 31 farmers were selected at random for the study. The data were collected by personal interview with the help of interview schedule developed for the study. Fifteen package of practices containing 33 skills were measured in five point rating scale *i.e.* very highly skilled (5 score), highly skilled (4 score), moderately skilled (3 score), skilled (2 score), less skilled (1 score) and unskilled (0 score). After collecting the data, the mean scores obtained and technological gaps were worked out. Based on the percentage gaps, the ranks were assigned to each practice.

RESULTS AND DISCUSSION

Results from the table 1, revealed that majority of the farmers are in low skill category indicating that they are not practicing the correct techniques in adoption of oil palm cultivation practices. The findings from the table 2, showed that skill gap is existing in the practices in that order *viz.,* ablation, plant protection measures, planting of seedling, weed management, utilization of oil palm wastes, pruning of leaves, pit preparation, selection of seedling for planting, mulching, fertilizer management, basin Management, irrigation management, land preparation and management, selection of suitable inter crops and harvesting of oil palm Fresh Fruit Bunches (FFB).

Table 1: Categorization of farmers based on their Skill in oil palm cultivation

Category	No. of farmers	%
Low	22	71
Medium	9	29
High	—	—
Total	31	100

The results indicated that the highest skill gap was 69.60% in ablation, though farmers are aware of the practice, they don't practice recommended technique of ablation. A gap of 67.73% was found in Plant protection measures, as many of the farmers are not practicing correct technique of pesticide/fungicide application. The gap in Planting of Seedling was 66.80%, this may be due to non practicing recommended technique of planting, skill gap of 66% was noticed in weed management, since farmers are not practicing correct method of application. Gap in utilization of oil palm wastes was 65%, as many of the farmers either through the oil palm wastes or burn. Gap of 62.80% was found in pruning of leaves, as many farmers are cutting the leaves excessively. Gap in pit making for planting was 60%, it is observed that many farmers don't follow the recommended method of pit making. The gap in selection of seedling for Planting was 58.40%, most of the farmers are taking less aged seedlings for planting. Gap in mulching was 58.20%, as many of the farmers don't do proper mulching. Skill gap of 49.04% was found in fertilizer management, since farmers are not following recommended method of application. The gap in basin management was 43.20%, irrigation management was 42.24%, land preparation and management was 33.86%, selection of suitable inter crops was 22.60 and harvesting of oil palm fresh fruit bunches was 14.25% respectively. The lowest gap observed in harvesting, since this skill has got direct impact on yield, farmers are cautious about harvesting of oil palm bunches.

Skill gap with respect to oil palm cultivation ranged from 14.25 to 69.60 percent, though majority of oil palm farmers are in high knowledge category (61%) and medium adoption category (53%) in Andhra Pradesh (Prasad and Raju 2004).

CONCLUSION

The findings revealed that wider skill gaps exist in cultivation of oil palm by oil palm growers. These gaps in most of the practices need to be reduced, by adopting correct techniques for getting high yields. Thus, it emphasizes the need of transferring the skill oriented technology to the oil palm growers in the trainings, where they are lacking the proficiency in practicing various operations in oil palm cultivation.

REFERENCES

Prasad MV, Rayapa Raju DGS. (2004) Critical analysis of trainers training programme on oil palm in relation to perception, knowledge gain, adoption and dissemination by trainees. Journal of Plantation Crops. 32: 502-504.

Table 2: Practice wise skill gap and ranking

Practice	Max obtainable score	Avg. obtained. score	Skill Gap	Skill Gap%	Rank
Ablation	5	1.52	3.48	69.60	I
Plant protection measures	15	4.84	10.16	67.73	II
Planting of Seedling	10	3.32	6.68	66.80	III
Weed management	10	3.4	6.60	66.00	IV
Utilization of oil palm wastes	5	1.75	3.25	65.00	V
Pruning of leaves	5	1.86	3.14	62.80	VI
Pit making	5	2.0	3.0	60.00	VII
Selection of seedling for Planting	10	4.16	5.84	58.40	VIII
Mulching	5	2.09	2.91	58.20	IX
Fertilizer management	25	12.74	12.26	49.04	X
Basin Management	5	2.84	2.16	43.20	XI
Irrigation Management	25	14.45	10.55	42.24	XII
Land Preparation and management.	15	9.92	5.08	33.86	XIII
Selection of Suitable inter crops	5	3.87	1.13	22.60	XIV
Harvesting of oil palm Fresh Fruit Bunches	20	17.15	2.85	14.25	XV

RESEARCH ARTICLE

Effect of inorganic fertilizers on growth and yield of Red ginger grown as intercrop in Oil Palm gardens

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Received: 05 March, 2018, Accepted: 15 June, 2018

ABSTRACT

Oil palm cultivation assumes significance for augmenting the indigenous availability of edible oil as it is the highest oil yielding crop. Oil palm is perennial nature planted at a spacing of 9 m x 9 m and there is wide space available for growing intercrops in oil palm which can more than double the income. Ornamental red ginger *Alpinia purputa* (Vieillard) K. Schumann, is a shade loving crop, comes up well even in dense shade of (70-80%) in oil palm gardens. Nutrients N, P and K play key role in plant growth, flowering and yield of the crop. The field experiment was conducted to study the effect of primary nutrients (NPK applied in inorganic form) on growth and productivity of red ginger grown in mature oil palm at Horticultural Research station, Vijayarai during 2011- 2013. The experiment was laid in randomized block design with nine treatments and three replications. The results revealed that fertilizer treatment had significant effect on plant height, number of leaves, leaf length, number of spikes per clump and spike length and no effect on shoot girth and leaf breadth. Maximum plant height (124.14 cm) and maximum number of leaves per plant (39.33) were produced by the treatment T_4 (10:20:20 NPK/ clump) whereas maximum leaf length (38.38) was produced by the treatment T_5 (20:10:10 NPK/ clump). The highest spike length (20.29 cm) and maximum number of spikes per clump (18.29) were produced by treatment T_7 (20:10:20 NPK / clump) whereas the highest number of bracts per spike (16.95) were produced in T_4 (10:20:20 NPK/ clump). The fertilization dose 20:10:20 NPK/ clump *i.e.,* 88.8 - 44.4 - 88.8 kg NPK ha-1 was the best to favor red ginger yield.

Key Words: Chemicals and fertilizers, intercropping system, oil palm, red ginger, yield,

INTRODUCTION

Oil palm cultivation assumes significance for augmenting the indigenous availability of edible oil as it is the highest oil yielding crop. Oil palm is perennial in nature planted at a spacing of 9m x 9m. There is wide space of growing intercrops in oil palm which more than double the income. Ornamental red ginger *Alpinia purputa* (Vieillard) K. Schumann, is a shade loving crop, comes up well even in dense shade of 70-80% in oil palm gardens. Red ginger (*Alpinia purpurata)* is a tall, upright, herbaceous, evergreen plant from the South Pacific, with bright red floral bracts and inconspicuous white flowers. It is quite popular as an ornamental and cut flower, both for the domestic and for commercial use (Kepler, A.K. 1989). It is one of the most important and universal flower crop which is gaining importance in the floral decoration. Under congenial climatic conditions, flowering of red ginger occurs throughout the year (Kobayashi et al., 2007). Therefore, fertilization is essential for successful cultivation of red ginger as the crop exhaust nutrients from the soil, thereby causes decrease in yields. There are no specific rules for fertilizing tropical ornamentals since soil and climate conditions are different in each region. In Andhra Pradesh, red ginger is cultivated as intercrop in the inter spaces of oil palm garden. Hence, there is every need to standardize optimum growing condition and agro techniques with particular reference to fertilizer to obtain maximum number of spikes per unit area. The main objective of conducting this experiment is to study the effect of NPK fertilizers on growth and yield of red ginger grown as an intercrop in oil palm.

MATERIALS AND METHODS

The experiment was conducted in a randomized block design with three replications at Horticultural Research Station, Vijayarai during 2011- 2012. The spacing adopted for red ginger was 1.5 m × 1.5 m and the plot size was 8 m × 8 m. The experimental soil was red sandy loam in texture, with pH 6.9, EC 0.080 mhos cm-^{1}, $CaCO_3$, 7.2, N 179, available P 12.4 and available K 134 kg ha^{-1}. Treatments imposed to the experiment are organic fertilizers *i.e.,* farm yard manure @ 2.5 kg/ m^2 and inorganic fertilizers - N_1: 10 g, P_1: 10 g, K_1: 10 g, N_2: 20 g, P_2: 20 g, K_2:20 g. A total of eight treatments along with control were imposed and the details are given below (Table 1).

The fertilizers used as the sources of NPK were urea (46% N), single super phosphate (16% P2O5) and muriate of potash (50 % $K_2$0). Basal phosphate fertilization was by applying single super phosphate and mixed in the soil at the time of planting the clumps. Nitrogen and K fertilizers were in the form of urea and Muriate of potash respectively. N and K doses were divided into three equal splits and applied at 3, 6 and 9 months after the establishment of seedlings. The fertilizers were placed around the clump at a distance of 10 cm and 5 cm of depth. The data on plant height, number of leaves, pseudo shoot girth, leaf length, leaf breadth, spike length, number of spikes/ clump, number of bracts/ spike were recorded.

RESULTS AND DISCUSSION

According to the results of the analysis of variance (Table 2), there was significant difference among the treatments with respect to vegetative parameters *viz.,* plant height, number of leaves per plant, leaf length and yield parameters *viz.,* number of spikes/ clump, spike length and number of bracts per spike. The treatment application of 10:20:20 g NPK/ clump (T_4) recorded highest plant height (144.14 cm) closely followed by 10:10:10 g NPK / clump (T1) as against 81.89 cm in the control treatment (T_9 only FYM). Maximum leaves per plant (39.33) was recorded in treatment 10:20:20 g NPK/ plant (T4) closely followed by the treatment (39.20) and the lowest was recorded in control treatment (17.53). The leaf length of the red ginger was recorded highest (38.38 cm) in application of 20:10:20 g NPK/ plant and the lowest (22.62 cm) was recorded in control without fertilization. The shoot girth and leaf breadth were not affected with the application of different doses of fertilizers in red ginger grown as inter crop in oil palm. Although many plant characters are attributed to genetics, application of medium concentration of N, higher concentration P &K promoted the plant height, number of leaves whereas higher concentration of P & K promoted the leaf length in red ginger. The results are in conformity with the findings of Ana María *et al*. (2019) which could be attributed to the fact that N in *Zingiberaceae* plants, such as red ginger, N is the most important macro nutrient for growth and flowering. The lowest values of growth parameters in control suggest that the macro nutrient quantities available in FYM applied were not

Table 1: The number and dosage of treatments under the study

Treatments	Dosage (g/ clump)			Dosage (kg/ ha)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
T_1- N_1 P_1 K_1	10	10	10	44.4	44.4	44.4
T_{2-} N_1 P_2 K_1	10	20	10	44.4	88.8	44.4
T_{3-} N_1 P_1 K_2	10	10	20	44.4	44.4	88.8
T_{4-} N_1 P_2 K_2	10	20	20	44.4	88.8	88.8
T_{5-} N_2 P_1 K_1	20	10	10	88.8	44.4	44.4
T_{6-} N_2P_2 K_1	20	20	10	88.8	88.8	44.4
T_{7-} N_2 P_1 K_2	20	10	20	88.8	44.4	88.8
T_{8-} N_2 P_2 K_2	20	20	20	88.8	88.8	88.8
T_{9-} Control	only farm yard manure			only farm yard manure		

sufficient for good growth, may be attributed to the absence of NPK macronutrients in the control since these elements are essential in the synthesis of molecules for growth (Morais et al. 2010). Castro et al. (2007) reported that N is the most important nutrient in growth and flowering of *Zingiberaceae* plants, and the N content in plants was 67% lower in plants without a complete fertilization. In *Tagetes* spp., higher N and P applications increase plant growth, flower yield and leaf nutrient content.

With regard to yield parameters, there was significant difference among the treatments (Table 3). The number of spikes per clump varied from 8.77 to 18.29. Maximum number of spikes per clump (18.29) and maximum spike length (20.29 cm) were observed in the treatment with 20:10:20g NPK/ clump (T7) whereas the highest number of bracts per spike (16.95) were recorded in 10:20:20 g NPK/ clump (T4) as against 8.77 spikes per clump, 10.91 cm spike length and 7.27 bracts per spike in control treatment. The results of the experiment are in agreement with the findings of the Attoe *et al.* (2013), who stated that the effect of nitrogen was more distinct than K. The combined effect of N and K had significantly increased the yield and other yield contributing characters of zinger. Asafa and Akanb (2018) reported that the rhizome yields of fertilizer applied plants were significantly higher than the control plants. Rhizome yields ranged from 1.67 t/ha in 80 kg N/ha to 3.71 t/ha in 140 kg N/ha.

CONCLUSION

The fertilizer dose 20:10:20 NPK/ clump *i.e.,*88.8 - 44.4 - 88.8 kg NPK ha-1 was the best to get higher yield in red ginger grown as an intercrop in oil palm gardens.

Table 2: Effect of NPK fertilizers on vegetative parameters of red ginger grown under oil palm

Treatment	Plant height (cm)	No. of leaves per clump	Shoot girth (cm)	Leaf length (cm)	Leaf breadth (cm)
T_1-10-10-10	123.00	39.00	2.79	33.47	10.92
T_2- 10-20-10	117.66	39.20	2.71	31.15	10.83
T_3- 10-10-20	116.85	37.40	2.71	31.00	10.18
T_4- 10-20-20	124.14	39.33	2.94	31.49	10.26
T_5- 20-10-10	119.80	38.60	2.64	38.38	10.09
T_6- 20-20-10	114.96	37.27	2.77	32.27	10.71
T_7- 20-10-20	116.69	38.07	2.64	34.41	12.05
T_8- 20-20-20	114.21	38.67	2.68	31.51	12.91
T_9- Control	81.89	17.53	2.75	22.62	8.38
CD P=0.05	8.21	1.66	NS	4.56	NS
SEM	6.05	0.72	0.25	1.93	0.51

Table 3: Effect of NPK fertilizers on yield parameters of red ginger grown under oil palm

Treatment	Spike length(cm)	Number of spikes/clump	Number of bracts/spike
T_1-10-10-10	17.04	17.13	14.55
T_2- 10-20-10	15.41	16.27	14.56
T_3- 10-10-20	16.34	16.77	16.37
T_4- 10-20-20	19.87	10.25	16.95
T_5- 20-10-10	13.99	17.99	16.13
T_6- 20-20-10	12.95	12.86	13.95
T_7- 20-10-20	20.29	18.29	15.91
T_8- 20-20-20	15.56	10.18	14.69
T_9- Control	10.91	8.77	9.27
CD P=0.05	1.32	0.63	0.56
SEM	0.44	0.21	0.18

REFERENCES

María PG, Julián PF, Nydia RB, Los Santos AO. (2019). Effect of Fertilization on Yield and NPK Contents in Red Ginger. *Journal of Experimental Agriculture International* 30(6): 1-8.

Asafa RF, Akanb WB (2018). Growth and Rhizome Yield of Ginger (*Zingiber officinale* L.) as Influenced by Propagule Size and Nitrogen Levels in Ogbomoso, Southwestern Nigeria.*International Letters of Natural Sciences*. 67: 35-45.

Castro ACR , Loges V, Santos CA, Arruda CMFA, Souza de AFA, Gomes WL (2007). Flower stems post harvest characteristics of heliconia under macronutrients deficiency.*Pesqui Agropecu Bras*. 42(9):1299-1306.

Attoe EE, Undie UL, Osodeke VE (2013). Effects of N, P and K fertilizer levels on plant characters and yield of ginger (*Zingiber officinale* roscoe) in two locations in Cross River State of Nigeria. *Journal of Agriculture and Verternary sciences*. 5:15-18.

Kobayashi DK, McEwen J, Kaufman JA (2007). Ornamental ginger, red and pink. Univ Hawai'i - *Coll Trop Agr Hum Res*. 37:1-8.

Kepler AK (1989). Exotic tropicals of Hawaii. *Mutual Publishing Co., Honolulu.*

Morais FJE, Guedes de CJ, de Pinho J, Portela ON, Toledo CVA, de Melo SC (2010). Nutritional deficiency in torch ginger (*Etlingeraelatior* (Jack) R.M.Smith. Effect on dry matter production and biometrical index. *Cienc Agrotech Lavras*. 34(2): 294-299.

RESEARCH ARTICLE

Molecular characterization of oil palm (*Elaeis guineensis*) germplasm using microsatellite markers

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Received: 22 July 2018   Accepted: 07 August, 2018

ABSTRACT

The oil palm *(Elaeis guineensis)* belongs to the family Arecaceae which is commonly known as African oil palm. In the present study we aimed at molecular characterization of selected dura and pisifera oil palm genotypes using microsatellite markers. DNA is extracted from 44 oil palm germplasm of selected dura and pisifera plants by using CTAB Extraction Method. Twenty SSR oil palm markers are selected for assessment of polymorphism and genetic diversity analysis among 44 Oil palm genotypes. The 20 oil palm SSR markers yielded 35 scorable alleles, five loci are found to be monomorphic and 11 SSRs were polymorphic. The number of alleles ranged from 1 to 4 at an average of 2.1 alleles per locus. The SSR locus SMG00016 is found to have maximum number of allele (4) followed by loci SPC00065, SMG00217, and SPSC00163 (3 allele each). High amount of similarity existed between D71 and D108 genotypes followed by similarity between D7 and D30, D7 and D37 genotypes. High amount of dissimilarity existed between D4 and D30 genotypes with 44% dissimilarity followed by D5 and D14, D5 and D7 genotypes. The dendrogram generated through UPGMA analysis grouped all the 44 oil palm genotypes into 2 major groups A and B. The clustering of the Oil Palm genotypes is largely based on their dissimilarities. Highly dissimilar dura (D78) and pisifera (P77) (42%) genotypes can be used in high yielding breeding programmes.

Key words: oil palm, SSR markers, genetic diversity, power marker

INTRODUCTION

The oil palm genotypes are divided in to dura, pisifera and tenera forms based on the shell thickness which is a monogenic and co-dominantly inherited trait. With the discovery of the shell gene (Sh gene) by the oil palm researchers in the congo during 1940's led to more focus on increasing the oil palm production. The dura (D) genotypes consists of thick shell (Sh/Sh, dominant homozygote) whereas pisifera (P) genotype has a shell less with recessive homozygous sh/sh allele. The tenera (T) genotype has a shell less which has 30% more mesocarp and oil production than dura and pisifera, which is generally produced as hybrid from the cross between dura and pisifera. The tenera hybrid yields more oil and also is the basis for commercial palm oil production in all the oil palm growing parts of the world. Genetic diversity analysis is carried out by the help of morphological and biochemical markers which may be affected by environmental factors and do not have the resolving power for differentiating between closely related genotypes by the growing environment. Molecular markers are identifiable DNA sequence, found at specific locations of the genome and associated with the inheritance of a trait or linked gene. Initially, several genetic diversity works were based on using RAPD, RFLP and AFLP molecular markers. However, due to certain drawbacks these markers were replaced by SSR and SNP markers. Use of RAPD for genetic diversity study of oil palm was reported for the first time by Shah (1994). Oil palm germplasm accessions collected from Africa (Cameroon, Tanzania, Nigeria and Zaire) were studied using 20 primes and recorded high levels of genetic variation among the accessions. Rivall et al. (1998) studied the suitability of RAPD markers for detection of soma clonal variants in oil palm. The results from the 387 arbitrary primers showed no intra clonal variability and no difference between mother and regenerated palms. The authors opined that RAPD approach is not suitable for the detection of the mantled variant phenotype. Later Mayes et al. (2000) used RFLP markers (40 probes covering 60% oil palm genome) to assess genetic diversity within 54 palms of a specific oil palm breeding program. Arias et al. (2015) studied genetic and phenotypic diversity of natural American oil palm germplasm. The results from SSR markers and agro-morphological traits showed that analyses of variance for yield and bunch components demonstrated statistically significant differences among countries and geographical regions for several of the traits evaluated. SSR marker analyses revealed high genetic diversity. Recently, few reports on genetic relationship between elite oil palms (Prasanna et al. 2017; Sowmya et al. 2017; Babu et al. 2017). The SSRs are widely used in plants because of their abundance, hyper-variability, and suitability for high throughput analysis. They are randomly tandem repeats of short nucleotide motifs (2-6 bp/nucleotides long). Di-, tri- and tetra-nucleotide repeats, e.g. (GT)n, (AAT)n and (GATA)n, are widely distributed throughout the genomes of plants and animals. The objectives of the present study are 1) Molecular characterization of selected Dura & Pisifera germplasm using microsatellite markers and 2) genetic diversity analysis among dura and pisifera germplasm using SSR markers.

MATERIALS AND METHODS

Fresh tender spear leaf samples from each of 44 selected dura, pisifera oil palm genotypes are collected for extraction of DNA. Mid rib of each leaflet is removed and middle portion of the leaflet, which has fewer veins, without pigment is taken for DNA extraction. The list of the genotypes used in the study is given in table 1.

Table 1: The list of the oil palm genotypes used in the study

SI. No	Cross id	Fruit form	Palm number
1	240D X 281D	Dura	3
2	240D X 281D	Dura	4
3	240D X 281D	Dura	5
4	240D X 281D	Dura	7
5	240D X 281D	Dura	9
6	240D X 281D	Dura	13
7	240D X 281D	Dura	14
8	240D X 281D	Dura	17
9	240D X 281D	Dura	19
10	240D X 281D	Dura	30
11	240D X 281D	Dura	32
12	240D X 281D	Dura	33
13	240D X 281D	Dura	34
14	240D X 281D	Dura	37
15	240D X 281D	Dura	38
16	240D X 281D	Dura	39
17	240D X 281D	Dura	40
18	240D X 281D	Dura	40
19	240D X 281D	Dura	4.
20	240D X 281D	Dura	45
21	240D X 281D	Dura	54
22	240D X 281D	Dura	56
23	240D X 281D	Dura	59
24	240D X 281D	Dura	622
25	240D X 281D	Dura	63
26	240D X 281D	Dura	68
27	240D X 281D	Dura	71
28	240D X 281D	Dura	73
29	240D X 281D	Dura	78
30	240D X 281D	Dura	81
31	240D X 281D	Dura	82
32	240D X 281D	Dura	84
33	240D X 281D	Dura	85
34	240D X 281D	Dura	89
35	240D X 281D	Dura	92
36	240D X 281D	Dura	93
37	240D X 281D	Dura	97
38	240D X 281D	Dura	99
39	240D X 281D	Dura	108
40	-	Pisifera	75
41	-	Pisifera	76
42	-	Pisifera	77
43	-	Pisifera	78
44	-	Pisifera	110

SSR AMPLIFICATION USING PCR AND DATA ANALYSIS

Thermal reaction were carried out in a reaction mixture (20 ìl) consisting of 10 X buffer (Himedia), 2 ìl having 15 mm MgCl2, 0.2 mM of each forward and reverse primer, 2 ìl of 2 mMdNTPs, 0.2 ìl of 1 U of Taq DNA polymerase (Invitrogen, USA) and about 25-50 ng of template DNA. The PCR amplifications were performed in a Thermocycler (Biorad, USA) programmed for an initial denaturation of 3 min at 950Cfollowed by 35 cycles of 30s at 950C, 30s of 500C annealing temperature, extension of 1 min at 720C, with a final extension of 10 min at 720C, and hold at 40C. The PCR products were fractioned on 3 % Agarose gel. The statistical analysis of polymorphism and UPGMA analysis for generating dendrogram was done by using power marker v 3.0 (Liu and Muse, 2005).

RESULTS AND DISCUSSION

SSR polymorphic analysis

In the present study 20 SSR markers are used. In this, 11 markers showed polymorphism (figure 4.15-4.18), 5 markers showed monomorphism and 3 markers did not amplify. Among all the 20 markers primer SPSC00185, SMG00056, SPSC00193, SEG00166 have the major allele frequency with 1.000 and all the primers have mean allele frequency of 0.7738. The banding pattern of SSR primer SEG00156 is given in fig. 1. The major allele number shown by the primer is 4 by SMG00016 and the mean allele number shown by the primers is 2.1. Gene diversity is shown major by primer SMG00016 is 0.67 and the mean gene diversity shown by the primers is 0.29 (Table 2). Heterozygosity is shown maximum by the primer SMG00223 is 1.00 and the mean heterozygosity shown by the primers is 0.37. The PIC (polymorphism information content) is shown maximum by the primer SMG00016 is 0.61 and the mean average shown by the primers is 0.24.

Identification of diversity between dura and pisifera palms

The high amount of diversity observed among dura samples is between dura4 and dura30 (44%) (Table 3), among the dura and pisifera samples high diversity is between dura78 and pisifera 77(42%). (Table 4).

Fig. 1: The banding pattern of the SSR primer SMG00156 across 44 oil palm germplasm.

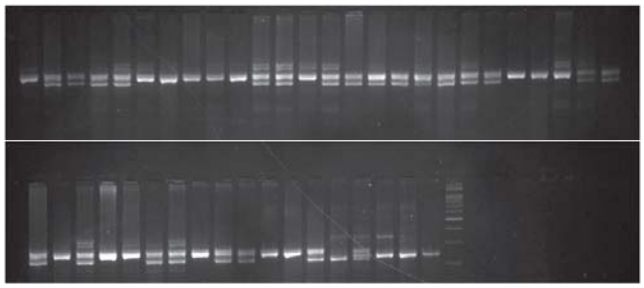

Table 2: The Summary statistics of primers along with allele frequency, number, gene diversity, heterozygosity, PIC.

Marker	Major Allele Frequency	Allele Number	Gene Diversity	Heterozygosity	PIC
SMG00217	0.7558	3.0000	0.3794	0.4419	0.3230
SEG00108	0.8947	2.0000	0.1884	0.0526	0.1706
SPSC00065	0.7436	3.0000	0.3932	0.4615	0.3335
SMG00210	0.5417	2.0000	0.4965	0.9167	0.3733
SPSC00185	1.0000	1.0000	0.0000	0.0000	0.0000
SMG00156	0.7273	2.0000	0.3967	0.5455	0.3180
SEG00094	0.7907	2.0000	0.3310	0.4186	0.2762
SPSC00163	0.6905	3.0000	0.4410	0.5714	0.3626
SPSC00093	1.0000	1.0000	0.0000	0.0000	0.0000
SMG00155	0.9286	2.0000	0.1327	0.0476	0.1239
SMG00227	0.6047	2.0000	0.4781	0.5116	0.3638
SMG00016	0.4186	4.0000	0.6758	0.7209	0.6165
SPSC00063	0.6163	2.0000	0.4730	0.7674	0.3611
SMG00056-	1.0000	1.0000	0.0000	0.0000	0.0000
SPSC00193	1.0000	1.0000	0.0000	0.0000	0.0000
SEG00166	1.0000	1.0000	0.0000	0.0000	0.0000
SMG00223	0.4419	4.0000	0.6028	1.0000	0.5212
Mean	0.7738	2.1176	0.2934	0.3798	0.2437
min	0.4186	1.0000	0.1327	0.0476	0.1239
max	1.0000	4.0000	0.6758	1.0000	0.6165

Table 3: Diversity of dissimilarity among dura oil palm genotypes.

S.NO	Genotype name	Genotype name	% of Dissimilarity
1.	DURA4	DURA30	44%
2.	DURA5	DURA14	43%
3.	DURA5	DURA7	43%
4.	DURA5	DURA82	43%
5.	DURA5	DURA99	43%

Table 4: Diversity of dissimilarity between dura and pisifera oil palm genotypes.

S.NO	Genotype name	Genotype name	% of Dissimilarity
1.	DURA78	PISIFERA77	42%
2.	DURA4	PISIFERA77	42%
3.	DURA30	PISIFERA78	40%

Genetic diversity

The dendrogram generated through UPGMA analysis grouped all the 44 Oil palm genotypes into 2 major groups A and B. The following dendogram contains two clusters A&B with different genotypes. Cluster A contains two clusters (Fig. 2). The sub clusters A1 and A2 consists of 11 genotypes viz., D5, P78, P75, P76, D13, D30, D33, D34, D14, D17, D19 oil palm genotypes. Dura 5 genotype did not cluster with any other genotype. However, cluster B contains two sub clusters. The B cluster consists of 33 genotypes viz., D78, D97, D73, D89, D54, D4, D43, D93, D45, D63, D39, D41, D38, D9, D85, D92, D108, D71, D40, D68, D37, D32, D7, D84, D62, D82, P77, D99, D3, D59, P110, D56 and D81 oil palm genotypes. Highly dissimilar dura (D78) and pisifera (P77) (42%) genotypes can be used in high yielding breeding programmes.

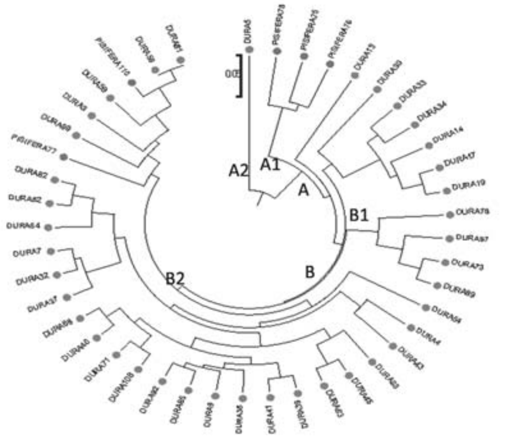

Fig. 2: The dendrogram obtained from 11 polymorphic SSR markers using UPGMA method of power marker software

REFERENCES

Arias D, Gonzalez M, Prada F, Ayala Diaz L, Montoya C, Daza E, Romero HM. (2015). Genetic and phenotypic diversity of natural American oil palm (*Elaeis oleifera* (H.B.K.) Cortes) accessions. Tree genet Gen. 11**:** 122.

Babu BK, Mathur RK, Kumar PN, Ramajayam D, Ravichandran G, Venu MVB. (2017) Development, identification and validation of CAPS marker for SHELL trait which governs dura, pisifera and tenera fruit forms in oil palm (*Elaeis guineensis* Jacq.). PLoS ONE 12(2): e0171933. doi:10.1371/journal.pone.0171933.

Liu K, Muse M (2005) Power Marker: an integrated analysis environment for genetic marker analysis. Bioinformatics 21: 2128–2129.

Mayes S, Jack PL, Corley RHV. (2000) The application of molecular markers in a specific breeding programme for oil palm. Heredity. 85: 288-293.

Prasanna Kumar G, Venu MVB, Kalyana babu B, Ravichandran G, Mathur RK (2017). Identification of oil palm fruit forms using SNP based CAPS marker among the Tenera/ Tenera (T X T) crossed progeny. International Journal of Oil Palm Vol. 9 (1&2), 21-24

Rivall A, Bertrandt, Beul M, Combeps C, Trousloantd P, Lashermes (1998) Suitability of RAPD analysis

Shah FH, Rasid O Simon, AJ, Dunsdon A (1994) The utility of RAPD markers for the determination of genetic variation in oil palm (*Elaeis guineensis*). Theory and Appl. Gene., 89: 713-718.

Sowmya Ch, Venu MVB, Kalyana babu B (2017). Identification of polymorphic microsatellite markers for(Elaeis guineensis Jacq.). International Journal of Oil Palm Vol. 9 (1&2), 17-20

REVIEW ARTICLE

Global perspective of germplasm and breeding for seed production in oil palm

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ABSTRACT

Palm oil derived from oil palm plays a vital role in the edible oil sector apart from innumerable industrial uses and downstream products. Oil palm is grown in about 43 countries. The production of palm oil has been estimated to increase by 2.63 % to 75.51 million tons during 2019-20 from the total cultivated area of 21.33 million hectares. Globally, the oil palm industry is developing at a faster rate. The increase in area under oil palm and the replanting programme had also increased the demand for quality planting materials. Elite germplasm base with inherent economic traits are essential for breeding for seed production. Globally, Indonesia and Malaysia are major players in oil palm research and development. Breeding stocks and superior planting materials of Indonesian Oil Palm Research Institute (IOPRI) are widely adopted by oil palm industry. Asian Agri (AA) group and Golden Agri Resources (GAR) are of the major seed producers from private side in Indonesia. The public sector Malaysian Palm Oil Board (MPOB) has released 14 PS (Planting Series) to the industry. The seed production and supply to large and smallholders in Malaysia are undertaken through agencies approved by Malaysian Palm Oil Board. Agricultural Services and Development (ASD) is a private organisation in Costa Rica involved in oil palm R&D and distributing oil palm seeds and clones in all the regions of tropical America, Asia and Africa. Palmelite, France has been supplying CIRAD® planting materials worldwide. CIRAD commercial seeds are produced by its long-standing partners in Benin (CRA-PP), Ivory Coast (CNRA), Cameroon (CEREPAH), Indonesia, Colombia, Ecuador and Thailand. In case of Africa, out of twenty countries, only six countries namely Nigeria, Cameroon, Cote de Ivory, Ghana, Congo and Benin are having capability to produce large scale quality planting materials. The 'Thodupuzha-dura' and 'NIFOR -pisiferas' are the base breeding material extensively utilized for Indian oil palm industry and semi wild and elite germplasm from Cameroon, Tanzania, Zambia and Guinea Bissau, Senegal, Sierra Leone and other resources are being utilized to develop genetic stocks and hybrids. India has potential area of 1,933,250 hectares in 18 states. India imports bulk of its demand of planting materials from abroad. There are three options of commercial planting materials (advanced D×P seeds, clonal/semi clonal and O×G hybrids) are available for the oil palm growers. Few of the important sources of planting materials which are commercially available worldwide are 1. ASD Costa Rica 2. Palmeite-CIRAD®, 3. Sime Darby Plantation, 4. AAR, Malaysia, 5. FGV-Felda, 6. Sawit Kinabalu Seeds, 7. IOI, Malaysia, 8. Asian Agri, Indonesia 9. PT Dami Mas Sejahtera, Indonesia. In Malaysia, Oil palm D×P seed production reached 131 million in 2013. ASD Costa Rica has marketed 30 million seeds of compact hybrids. It is reported that out of 200 million seeds of worldwide market of oil palm seeds, around 30 to 50 million seeds are supplied per year from Palm elite. It is suggested to study the hybrid/clone performance in the local conditions before taking decision on order for planting materials.

Key words: oil palm, seed production, germplasm, breeding

INTRODUCTION

Oil seeds and vegetable oil emanate direct impact on world economy as their uses are extensively diversified for food and non-food industries. Oil palm, *Elaeis guineensis* J. entered into the global vegetable oil pool with its two types of oils *viz.* palm oil and palm kernel oil in a small way in sixties had emerged as the second largest vegetable oil source during nineties next to soya bean and occupied the first place after 2000. Oil palm is grown in about 43 countries (http:// theoilpalm.org/ about/), but the biggest plantations are in Indonesia and Malaysia. The developing countries and emerging countries such as Brazil, Peru and Central and Western Africa are promoting oil palm cultivation as a major contributor to poverty alleviation in view of increasing demand and shrinking arable cultivable land available. Globally, the oil palm industry is developing at a faster rate. Several West Africa countries have formulated national programs to encourage both national and foreign investments in establishing new oil palm plantations. There are 26 countries figured in the list of World Palm Oil Producers published by USDA (USDA, 2019) and their latest area, Fresh Fruit Bunch (FFB) production and average productivity and palm oil production (FAOSTAT, 2019) has been estimated. Out of 203.83 million tons of vegetable oil production, 73.53 million tons is palm oil in 2018-19. The production of palm oil has been estimated to increase by 2.63 % to 75.51 million tons during 2019-20 from the actual cultivated area of 21.33 million ha. Indonesia produces 43 million tons followed by Malaysia which account for 21 million tons of palm oil. Malaysia and Indonesia hold 85% of the total production (57 % from Indonesia and 43% from Malaysia). India has large area (about 0.33 million ha) of oil palm under irrigated conditions. India's share in production, consumption and world edible oil import during previous year (2017-18) were 7, 12 and 20 % respectively (USDA, 2018). The demand for edible oil in India has been increasing year by year which is about 6% per year, whereas countries edible oil production is increasing at the rate of 2 percent per year only. Around 60 % of India's domestic demand is met through import from abroad and three fourth of the import is palm oil. This increase in area under Oil Palm and the replanting programme had also increased the demand for quality planting materials (Renjini and Girish Jha, 2019). Many West African countries and countries in other parts of Africa are planning to have area expansion for oil palm industry. The oil palm industry is developing at a faster rate in Indonesia and few other countries like Philippines, Thailand and India are also making considerable progress. The developing countries and emerging countries such as Brazil, Peru and Central and Western Africa are promoting oil palm cultivation as a major contributor in view of increasing demand and shrinking arable cultivable land available (USDA-FAS, 2011). The production of oil palm clonal and bi-clonal seeds provides additional avenue as source of planting material. Costa Rica and CIRAD network of African countries are other important seed producers. This implies that highly productive planting materials of varieties adapted to these diverse growing conditions are to be supplied worldwide to the growers. In order to develop the best planting materials in the medium and long term, the main strength in any breeding program is to have the greatest genetic diversity possible. This is especially important in a long cycle crop like oil palm. The choice of planting material is also important to ensure the production of high yield with good oil quality for economic sustainability to oil palm industry. In this article, global perspectives of oil palm planting material are discussed to assess the status and prospects of oil palm industry with respect to new varieties and planting material production.

BACKGROUND OF BREEDING FOR SEED PRODUCTION

The discovery of shell gene (*dura*;Dominant homozygote (Sh+ Sh+) forms thick-shell *dura* (D), *tenera*:Heterozygote (Sh+ Sh-) forms thin-shelled *tenera* (T) and *pisifera*homozygote (Sh- Sh-) forms shell-less *pisifera* (P)) in the oil palm fruits by Beirnaert and Vanderweyen (1941) has led to commercial production of *Dura* ×*Pisifera* (D×P) planting materialwhich revolutionized the oil palm cultivation in the world. The universal oil palm improvement scheme is reciprocal recurrent selection scheme (RRS). This is being followed by majority of the oil palm seed producers. In case of RRS, the *dura* and *pisifera*populations are maintained in the seed garden in separate block. After evaluation and selection of parental palms and progeny testing, the crossing programme is undertaken to produce *tenera*. The performance of inter-origin crosses is attributed to the additive effect of favorable genes combination from the parents. According to Rajanaidu et al. (2000), the RRS is preferred because of about 18% palm oil hike per cycle in the hybrids over their base population. World over oil palm breeding and seed production is moving towards second (or)third cycle materials of *dura* and *tenera*s and some of the centres are establishing new seed gardens. *Elaeis oleifera* (HBK) is a promising genetic resource for some of the desirable traits related to biotic and abiotic stress tolerances. In spite of desirable qualities, the cultivation of pure stand of *E. oleifera* is not viable economically, due to its low yields (< 1.0 tonne oil/ha/yr) as compared to the *E. guineensis* (4-5 tonnes oil/ha/yr.). However, since the two species hybridize easily, interspecific hybrids could be obtained with yields around 90% of the *E. guineensis*. To introgress the traits of oil quality and low height increment (dwarfness) from *E. oleifera* into *E. guineensis*, two species were hybridized to produce *Oleifera* × *Guineensis* (O×G) hybrids. Subsequently, O× G hybrid was backcrossed to its *E. guineensis* parent to improve the yield (Moretzsohn et al. 2002). Recent development and extensive replanting programme with commercial planting of EG×EO hybrids attributed to outbreak of disease problems in some oil palm growing regions of South America (De Franqueville 2003). BRS Manicoré is a first O×G hybrid developed by Embrapa (Cunha and Lopes 2010). Hybrid seed production is done by controlled pollination between selected *Dura* and *Pisifera* palms. In recent years, the tissue culture technique clonal propagation has been promoted for developing elite oil palm materials (Sakhanokho and Kelley 2009). Apart from traditional method of seed production, clonal propagation through tissue culture and semi clonal production of selected parental palms are also popularized by the industry owing to problem of segregation un-uniformity in seed derived palms. There is a potential application of tissue culture technique to multiply parental palms (which have been progeny-tested) to produce semi- and bi- clonal seeds. A number of companies such as AAR, UP and FELDA Agricultural Services Sdn. Bhd. (FASSB) have since been marketing semi-clonal seeds. The major players possessing good wealth of germplasm and sound seed production programme (Murugesan and Shareef 2015) are 1. Malaysian Palm Oil Board, 2. Indonesian Oil Palm Research Institute, 3. Nigerian Oil Palm Research Institute, 4. Palmelite (Commercial arm of CIRAD, France, 5. Agricultural Service and Development (ASD, Costa Rica), 6. Sime Darby, Malaysia, 7. Asian Agri group, Indonesia and 8. AAR, Malaysia. 9.Socfindo, Indonesia), Corporation Centre for Oil Palm, (CENIPALMA), Indu Palma, Hacienda La Cabana (all in partnership with Palmelite), Brazilian Agricultural Research Corporation, Palmeras del Ecuador S.A. are some organizations from South America, five organizations (1. The Institute of Agricultural Research for Development (IRAD), Cameroon, 2. Centre National De Recherche Agronomique (CNRA, Ivory Coast), 3. Institut National des Recherches Agricoles du Benin (INRAB, Benin), 4. Cote de Ivoire and 5. The Oil Palm Research Institute (OPRI) of Ghana Formerly, West Africa Institute for Oil Palm Research (WAIFOR) is involved in seed production programme from Africa apart from NIFOR. In the subsequent section, seed production in some of the important global level organizations are reported with a view know progress and current advances in planting material production. Breeding for seed production in major seed producing countries are given below:

BREEDING FOR SEED PRODUCTION IN INDONESIA

The palm oil production derived from 9.3 million ha of oil palm plantation estates. The majority of (50 %) is from private organizations and 38 % growers/ farmers and rest of the area managed by state owned plantations (Gustina Siregar et al. 2018). Planting material production has been elaborately reported by Edy Suprianto et al. (2016). Oil palm planting materials produced through sound base of breeding and plant biotechnology from IOPRI are widely adopted by in Indonesian oil palm industry. It collaborated with CIRAD at the early stages and utilized RRS Breeding Scheme to produce high yielding planting material. The first cycle of improvement covering 1950s and the sixties at La Me Station (Cote d'Ivoire) and the second cycle deployed in West Africa, South America, and South East Asia from 1970s to the end of last millennium were the corner stones in the network. During this period the per hectare yield increase was 42% more or less 1.0 % per year besides reduction in palm height and resistant to Fusarium wilt (De Franqueella and Renard (1990) and Jacquemard et al. (2001). Introduction of new oil palm genetic material from Cameroon and Angola has opened the opportunity for IOPRI to develop oil palm cultivars with novelty traits. Improving oil quality has been implemented by backcross program of O× G hybrids with the best parents from RRS schemes (Edy Suprianto et al. 2016). Asian Agri group is one of the major seed producers from private side in Indonesia. It is reported that parental materials of AA group were progeny tested in 486 hectares and 112 top D× P combinations from 12 *dura* families and Ekona, Nigeria and Ghana of '*pisifera*s' were formed base of hybrid seed production. Currently, 3rd Generation of Planting Materials (GEN-3 Topaz) are utilised in the present cycle of seed gardens. AA is reported to have production capacity of 15 million D× P seeds per year (Mukesh Sharma et al. 2016). Aek Loba Plantation is a largest oil palm plantation of PT Socfin Indonesia; it is located in Asahan, North Sumatera, and Indonesia. They utilise Deli Dabou and Deli Bangun Bandar as well as La Mé, Yangambi and NIFOR for hybrid seed production in Aek Loba Seed Production unit (ALSP). It started to produce oil palm seeds in 2008 and have production potential of 50 million seeds per year and supplied 14 million seeds in the year 2017 (Harold Owen Williams, (2016) and www.socfindo.co.id). Recently, PT-SMART-Research Institute, a subsidiary of Golden-Agri

Resources Ltd (GAR), has announced its breakthrough in cultivating exceptionally high-yielding oil palm planting materials-Eka 1 and Eka 2 – are registered in Indonesia's Catalogue of Seeds and were approved for cultivation on 21 April 2017 by the Directorate General of Plantation, Ministry of Agriculture. The company claims that they carry the potential of increasing the company's crude palm oil yield to more than 10 tonnes of CPO/hactare/year at prime age (10-18 years) from the current capability to achieve around 7.5-8 tonnes/hectare/year under optimal weather and soil conditions (Anonymous, 2017). The total production potential and requirement of seeds for Indonesia is summarised in the section world production potential and requirement etc.

BREEDING FOR SEED PRODUCTION IN MALAYSIA

Malaysian Palm Oil Board (MPOB) carries out numerous explorations in Africa and South America since 1973 with cooperation of host countries and collects materials and shares equally between the host countries and MPOB. Collections in Nigeria provided an important source of dwarf palms for breeding for dwarf palm population (Rajanaidu et al. 1998). These collections were planted in MPOB, Kluang Research Station and Kertong as field gene banks and they are used for evaluation and utilization. It is the largest germplasm collection in the world. Several trials laid out using materials from Tanzania, Senegal, Guinea Conakry and Ghana was evaluated for Harvest Index (Malike et al. 2011). Tanzanian germplasm showed the highest mean of Harvest Index (HI) with significant values. From the two expeditions undertaken to Angola; the first 1991 collection has been planted and evaluated in Kluang Johar showed high potential for yield and long stalk. The second expedition was undertaken during 2010 and 125 accessions from 10 provinces of 25 sites (5 bunches per site) jointly by MPOB, Director General of Estate Crops, Indonesia and Nacional Do Café Angola (INCA) were collected which had several promising traitsviz., compactness, high mesocarp and long stalk (Marhalil and Rajanaidu 2011). Population collected from Cameroon, Nigeria and Sierra Leone showed high genetic diversity. Cameroon and the DRC (Ex-Zaire) showed high tolerance to Ganoderma. Similarly, materials collected all over the world were characterized and their evaluation is still going on (Hayiti et al. 2004). Indonesia and Malaysia are the largest consumers of oil palm planting materials in the world. About 500,000 ha planted in Indonesia and 100,000 ha in Malaysia. The field gene bank of oil palm is located at the MPOB Research Station at Kluang, Johor, Malaysia (Rajanaidu, 1986).Nigerian population is the main collections and apart from that prospection was made from other countries in Africa such as Angola, Cameroon, Zaire, Ghana, Guinea, Gambia, Madagascar, Sierra Leone, Senegal and Tanzania (Rajanaidu et al. 2013). Malaysian Palm Oil Board has released 14 PS (Planting Series) to the industry (Table 2). The new varieties/planting materials with novel were developed from population of Nigeria, Angola, etc. and transferred to oil palm industry and companies. The details of those planting materials are given in Table 1. Currently, there are 14 PS series with PS1 being designated as slow height increment of the Nigerian population 12. PS2 is the high iodine value of the Nigerian palms from trial 0.151. PS3 is the high kernel palms in response to the lauric oils demand. PS4 is the high carotene in the *E. oleifera*. Thin-shell *tenera*s are the attributes of the PS5. PS6 is the large fruit *dura*s while PS7 focuses on the high bunch index. PS8 features high vitamin E of the *E. guineensis* while the peach palm (*Bactris gasipaes*) for palm heart production makes PS9. For ease of harvesting, the long stalk palms from the Angola population give rise to PS10. PS11 also contributes to high carotene from *E. guineensis* instead of *E. oleifera*. There are PS12 and PS13 which are known for then high oleic and low lipase respectively. Recent PS series of PS 14 has special biochemical trait of high crude protein (Zulkifli et al. 2017)

New generation of oil palm planting materials are mainly derived from Dami, Chemara, MARDI, Sofino, Socfin, Dabou, Banting Deli *dura* s and sources of *pisifera*s are Nifor (Calabar), Ekona, Yangambi, La Me and AVROS (Rajanaidu et al. 2007). The seed production and supply to large and smallholders in Malaysia are undertaken through agencies approved by Malaysian Palm Oil Board (MPOB). Certification is issued from Standards and Industrial Research Institute of Malaysia (SIRIM 2005).The leading seed producers of oil palm in Malaysia are 1. Applied Agricultural Resources Sdn. and Felda Global Ventures (FGV). AAR is an associated company of Boustead Holdings and Kuala Lumpur Kepong Berhad known for varieties with dumpy characteristic. Between 1986 and 2003, AAR produced AA D×P planting materials from selected Deli *Dura*× Dumpy AVROS *Pisifera*. Through the years, further breeding, selections and improvements made on AAR's breeding programme resulted in the creation of the AA Hybrida IS. Hybrid seeds are produced through bi-clonal seed production. FGV is one of the largest oil palm seed producers in Malaysia.FGV is reported to produce 25 million oil palm seed per year

Table 1: Details of varieties/planting materials of oil palm developed from research institutes of Malaysian Palm Oil Board

Sl. No	Name of the germplasm/population	Name of the * Planting material	Traits/variety characters	Reference
1	Nigerian germplasm	PS1	Dwarf palm	Rajanaidu et al. (2000)
2	Nigerian germplasm	PS2	High iodine value	
3	Nigerian germplasm	PS 3	Large kernel	
4	Nigerian germplasm	PS6	large fruit *dura*	Kushairi et al. (2003a)
4	Nigerian germplasm	PS12	High Oleic acid	Isa et al. (2006)
5	Angola germplasm	PS10	Long female bunch stalk	Noh et al. (2005)
6	Angola germplasm	D×P	High variability in Fatty Acid Components	Noh et al. (2002)
7	Madagascar germplasm	Selected individual palms	Iodine value (IV) (>60) (Normal 50)	Kushairi et al. 2003b
8	Tanzania germplasm	PS5	Extremely thin-shelled *tenera*	Kushairi et al. (2003c)
9	Tanzania germplasm	PS7	High Bunch Index	Junaidah et al. 2004
10	Tanzania, Cameroon, Nigeria and Angola germplasms	-	High Bunch Index	Fadila et al. (2016)
11	Angola, Cameroon, Nigeria, Tanzania and Zaire germplasm	Selected individual palms (PS8)	High Vitamin E	Kushairi et al. (2004)
12	*Elaeis oleifera* germplasm from Hon*dura*s, Brazil, Panama, Colombia, Costa Rica, Suriname, Ecuador and Peru	PS4	High carotene value	Mohd Din et al. (2002)
13	Tanzanian germplasm	PS 11	High carotene content	Mohd Din et al. (2006)
14	Cameroon, Guinea and Tanzania germplasm	PS13	Low lipase	Maizura et al. (2008)
15	Ghana, Cameroon, Gambia, Senegal, Tanzania and Zaire	PS14	High crude protein	Noh et al. (2014)
16	Nigerian germplasm	Ideal palm	Balanced bunch number and bunch weight (15Kg × 15Kg ×15g) including fruit weight	Rajanaidu et al. (2011)

* PS9 is the planting material developed from peach palm

for local and overseas market. (Abdul Rahim et al. 2017). FGV have the second largest oil palm germplasm collection after MPOB. FGV had released Felda Yangambi planting material in 2002 and an improvised version Felda Yangambi ML161 in the subsequent years and followed by Felda 3-way D×P was released in the early 2010. FGV through its subsidiary company, Felda Agricultural Services Sdn Bhd (FASSB) has emerged as one of the top seed producer in Malaysia, producing 23 - 26 million per annum and commanding more than 43% of the Malaysian seed market in 2015. To date FASSB has sold over 330 million seeds of Felda Yangambi and 4.9 million seeds of Felda 3-way. Sime Darby, Guthrie, H&C (Golden Hope) breeding programmes were consolidated into a single entity under Sime Darby which has operations in Malaysia, Indonesia, Liberia, Papua New Guinea and Solomon Islands and Sime Darby plantation division takes up seed production. Hybrid seed variety called 'Calix 600' is produced which has ability to produce 10t of oil /ha after 24 to 36 months of field planting. It is reported that genome select high - yielding planting material developed from Sime Darby is under advance stage of field validation trial (Teh et al. (2016) and Kwong et al. 2017). It is reported that the Sime Darby has mission to achieve 100% replacement of traditional hybrids with genomic selection by 2023 (https://biosearch-cdn.azureedge.net/assetsv6/customer-case-study-sime-darby.pdf)

BREEDING FOR SEED PRODUCTION FROM ASD COSTA RICA

Information about ASD Costa Rica has been reported by Alvarado and Escobar (2016). Agricultural Services and Development (ASD) is a private organisation in Costa Rica involves in oil palm R&D and distributing oil palm seeds and clones in all the regions of tropical America, Asia and Africa since 1986. According to Alvarado et al. (2009), ASD can supply wide range varieties namely, Deli, African Bamenda, African Tanzania, Compacts with classical *pisifera*s (AVROS, Yangambi, Ekona and La Me), Ghana, Nigeria and Evolution (compact pollen source populations). African oil palm was introduced in the year 1926 at Lancetilla Botanical garden of Hon*dura*s by United Fruit Company; erstwhile company of Agricultural Services and Development. They were responsible to start small plantations in Guatemala, Honduras, Nicaragua, Costa Rica, Colombia and Ecuador. Today, the Agro Industry 'Numar group' possesses 21,000 hectares of own oil palm captive plantations and 19,500 hectares with partners. Development and distribution of oil palm varieties and clones is one of the main activities for ASD apart from crude palm oil production, processing, refining, bi-product diversification and marketing. ASD started seed production at Coto, Costa Rica in 1975 using Deli *dura* introduced from Malaysia. In the year 1977 itself seeds exported to Honduras and Colombia. A dedicated wing of seed production i.e. ASD de Costa Rica was established in the year 1986 at Costa Rica SA. Initially ASD started to supply traditional varieties such as Deli ×AVROS, Deli ×Ekona and Deli × Yangambi. Subsequently new varieties with desired traits have been added to the list (Table 2). It is estimated that 295 million seeds have been supplied by ASD which might had covered 1.7 million hectares world-wide. Oil palm seeds are certified by National Seed Bureau of Government of Costa Rica. ASD has 450 hectares for field experiments in Coto and owns one of the most diverse oil palm germplasm collections in the world. They had introduced several BPRO from Malaysian Research Stations and intensively use MAR 559 for seed production due to high additive genetic effect in relation to several economic traits. Angola *dura* is commonly used as female parents which were selected from Ivory Coast and Kade Research Station in Ghana. Apart from above, ASD use Bamenda (Cameroon) and Kigoma (Tanzania) (Barbosa and Chinchilla 2003). It is reported that Deli *dura* types had better oil and kernel yields than African types (Richardson 1995). Calabar materials have a shorter leaf length and higher leaf area than other traditional materials. Ekona materials have greater oil to bunch ratio. ASD Costa Rica breeding programme has been producing commercial oil palm planting materials since 1974. The seed production programme is oriented towards the exploitation of the genetic potential present within Deli and AVROS BPROs. They recently included new sources of germplasm viz., Djongo, La Me, Nigeria and Ekona. During the period between 1986 to 2015, ASD has been reported to supplied seeds to cover >1.8 million hectares plantations in tropical America, Asia and Africa (Alvarado and Escobar 2017)

OIL PALM BREEDING AND SEED PRODUCTION IN PALMELIT

Palmelite is a commercial wing of CIRAD-IRHO France. It is a joint venture owned by CIRAD and Sofiproteol. Since its inception in 2009, Palmelite have been supplying CIRAD planting materials worldwide. Palm elite company was established in the year 2009 with seven partners and five experimental stations in Latin America, Africa and Asia, three disease resistance screening units for Ganoderma basal stem rot and Fusarium wilt and two tissue culture laboratories in close association with CIRAD, France which is now PalmElit's majority shareholder. For several years from now, CIRAD has been supplying base variety of 'Deli x La Mé' materials and of late started supplying different variants suited to different locations of agro-climatic conditions with qualitative traits in addition to high FFB, CPO, compactness and unsaturated fatty acids. This mean there is a provision for varieties with slow height increment, resistances against diseases, and low lipase material etc. (Turnbull et al. 2016). The other promising materials are Deli × Yangambi and interspecific *E. oleifera*×*E.guineensis* hybrid. La Me is a spectacular outcome of French Agricultural Services during the initial period of 1920 in Cote de Ivoire then French Colony in West Africa. During the period between 1925 to 1935, Deli seeds from North Sumatra was planted in Dabou (Cote de Ivoire) and subsequent selection from the population resulted in Deli Dabou' (another

Table 2. Special features and suitability of environments of ASD de Costa Rica varieties and clones (Alvarado y and Escobar 2017)

Sl. No	Name of the variety	Special features	Suitability
1	Deli× Nigeria	Produce two types bunch colours viz, virescens and nigrescens 50 % each	Facilitate easy identification bunch ripening at the time of harvest
2	Evolution	>30 % oil content with large bunch size >22kg and fruit weight of 11g	It is recommended for favourable environment
3	Deli×La Me	Produce small bunch < 18Kg with moderate oil content	Suitable for Costa Rica Nicaraqua where drought occurs. Low incidence of spear rot
4	Tanzania ×Ekona	Slow vertical growth 40-50cm/year, large kernel and thin shell	Tolerant to drought and low temperature
5	Bemenda ×Ekona	Slow vertical growth medium bunch size 18-22Kg and small fruits (<9g)	Good performance even in areas with low solar radiation and high altitude
6	Deli ×Ghana	Short leaves 7-7.3 meter and accommodate 160 palms/ha	Good performance reported even in areas with low solar radiation and high altitude up to 1000 MSL
7	Compact × Ghana	The short rachis (6.5m) and it can accommodate 170palms/hectare	Good performance is reported even in high altitude. Advance generation is called as Challenger
8	Deli×Compact	The leaves are <7m and it can accommodate 170palms/ha. Oil content reported was >30%	Suitable for favourable environments without any stress. Adavance variety is named as 'Supreme'
9	Amazon	*E. oleifera* × *E.guineensis* hybrid. Mother palm is from Manaus Brazil and crossed with compact *pisifera*. High unsaturated oil content around 22%. Fruits are medium size	High tolerance to spear rot and pollen is self-compatible. Compact palms
10	Titan, Tornado and Sunrise	Ortets of best compact palms of ASD company used as explants for cloning. Short rachis and slow vertical growth. It is reported to accommodate 170-200 palms per hectare	It is reported to be tested in commercial plantations of Costa Rica, Ecuador, Nicaragua, Guatemala, Colombia and Thailand

Breeding Population of Restricted Origin) (Cochard 2008). After establishment of IRHO (1942) and CIRAD (1984) (Corley and Tinker 2003), modified Reciprocal Recurrent Selection (RRS) breeding scheme was followed utilising Deli *dura* and African *tenera*s. The second cycle of RRS population was planted in Indonesia, Cote de Ivoire, Cameroon and South America (Nouy et al. 1991) and FFB along with oil yield to the tune of 15-18% obtained. In Africa, Fusarium wilt resistant materials were developed at Dabou (Renrad et al. 1980). Subsequently new varieties which are resistant to dreaded fusarium wilt were released to the growers. It is to be noted that casual organism for bud rot in South America is not known till date as there were report of 100 % mortality in commercial plantations with commercial varieties. In some cases, 30-40% death of palms as per reports by Amblard et al. (2009) and Louise et al. (2014). CIRAD has taken up collaborative breeding programme with PHV Colombia, SEPALM and Murrin Ecuador to manage bud rot complex in South America and released #PC2.0 a high resistant and #PC1.0 partially resistant varieties. During that period (1980s), progress in tissue culture was also achieved step by step (Pannetier 1981). According to *Dura*nd-Gasselin et al. (2010), liquid media embryo suspension culture has been employed for successful protocol but 5% somoclonal variation was reported in the plantations and recent efforts in Indonesian unit of Palm elite expected breakthrough for breeding and tissue culture planting materials. Another novel approach developed by Palmelite is 'Super machos palms' which help to overcome non-pollination problem in commercial planation with poor fruit set and FFB yield in view of non-availability of pollen due to high female sex ratio. Palm elite are also supplying seeds of 'super machos' of *E.guineensis* material with very high male sex ratio (www.palmelite.com). In the past years, Palme Elit has developed different categories of planting materials adapted to different agro-climatic conditions. CIRAD commercial seeds are produced by its long-standing partners in Benin (CRA-PP), Ivory Coast (CNRA), Cameroon (CEREPAH) and Indonesia. They also started seed gardens in Colombia, Ecuador and Thailand. In order to assist Palm Elite some companies were identified in different regions. The companies identified are 1. Hacienda La Cabana (Colombia, Mexico, Venezuela and central America), 2. Palmeras de los Andes (Ecauder and Brazil), 3. Mr. Lambert Pie Pau (Peru), 4. IRAD/CEREPAH (Cameroon), 5. CNRA (Ivory coast) and 6. INRAB/CRA-PP (Benin). Presently the planting materials produced from CIRAD conglomerations are commercialised under the brand CIRAD® are made available through the seed gardens established worldwide in close collaboration with subsidiaries (www.palmelite.com).

OIL PALM BREEDING AND SEED PRODUCTION IN AFRICA

Oil palm breeding for seed production has following objectives. 1. To maximize the productivity of palm oil and palm kernel oil 2. Breeding for dwarf palms to accelerate high density planting 3. To develop resistant and tolerant varieties to Fusarium wilt and drought and production of palms for premium oil quality (Unsaturated fatty acids). Like Deli in South East Asia, some of the important Breeding Population of Restricted Origin (BPRO) is originated from African Oil Palm Breeding Centres. Mass selection and breeding work was started as early in 1920 in Democratic Republic of Congo (DRC) and resulted in the development of famous 'Djongo' (BPRO) which is one of the pedigree parent of SP540 *pisifera*. It is to be noted that SP540 is the main male parent of Deli *Dura* in most of the seed production programme in South East Asian countries. Democratic Republic of Congo (DRC) is also famous for single gene inheritance of shell thickness as per the the work of Beirnaert and Vanderweyen (1941). One more world famous BPRO is 'La Me' from West African country namely Cote de Ivoire; selection and breeding work in wild palm grooves at LaMe and Bingerville Botanic Gardens resulted in spectacular 'La Me -BPRO' with high bunch numbers. La Me is also one of the world-famous breeding materials known to all the oil palm seed producers. At La Mé (Côte-d'Ivoire), the genetic resources namely 'Man' with low fluidity oil and slow growing Akpadanou population (Benin origin) were characterized for conservation, utilization and future breeding (Ricardo, 2013). These base materials have been utilized to develop planting materials with high oil quality. Another notable breeding work performed by Institut de Recherche pour les Huiles et Oleagineux (IRHO-French Research Organisation) is exchange breeding materials among five oil palm stations viz, La Me (Cote deIvoire), Pobe(Benin), Sibiti(Congo), Yangambi (DRC) and SOCFIN (Malaysia) Crossing programme was established with inter and intra population to find out best combiners (Gascon and de Berchoux 1964). Accordingly, best combiners of intra populations were adjusted as best which led the development of cross combinations utilizing Deli South East Asian countries × African *pisifera*s from African locations. From plethora of reports, it is inferred that the oil palm research centres namely La Dibamba (Cameroon), La Me (Cote de Ivoire), Pobe (Benin) and NIFOR, Benin City (Nigeria) and Pamol (Cameroon) had been pursuing either Reciprocal Recurrent Selection or Modified Reciprocal Recurrent Selection. Notable breeding programme and seed production Africa is known worldwide through Nigerian Institute for Oil Palm Research which was established in 1939 as Oil Palm Research Station (OPRS). A most important significant contribution from NIFOR is bunch analysis procedure reported by Blaak et al. (1963). This is a vital protocol used extensively in all the seed production centres for palm selection. According to Okwuagwu, (1986), oil palm field gene bank was established during 1912 with genetic resources from Calabar, Aba, Nkwele from South Eastern Nigeria and later promising parental palms were selected for improvement and breeding. The NIFOR base materials consist of five Deli *dura*, nine African *dura*, and 13 *tenera* material which were subjected to improvement by RRS with new introductions in the second cycle of breeding programmes. Exchange of genetic material also contributed to widen NIFOR genetic base (Okwuagwu 1986). It is reported that the original collections/introduced materials are maintained in field gene bank maintained in different locations of Nigeria *viz.*, Aba, Ufuma and old Nsukka province (Okwuagwu et al. 1993 and Omoti 2003). The existing collections of Nigerian Research Institute for Oil Palm includes 1954 Ufuma and Aba collections, 1973 NIFOR/MARDI collections from 45 Nigerian locations from the marginal zone of the old Nsukka province. Apart from this, various African, deli origins have been made and exploited for breeding and selection. Very detailed evaluation of these collections has been carried out both in Nigeria and elsewhere (Rajanaidu et al. 2001). NIFOR had extensive collections from the main oil palm belt, Eastern part of Nigeria (High lands 200-400 m above sea level) was covered during recent expedition where greatest diversity exists. The area included was Afikpo, Abakaliki, Okigwe and Umuahia which were unexploited (Okwuagwu et al. 2011). They recommended the use of molecular markers to get information on germplasm diversity. Ataga (1994) reported high kernel variation in Nigerian germplasm collections at Benin City, Nigeria. Though African oil palm is originated in Africa; its yield and production are low when compared to South East Asian countries as it has been grown traditionally as subsistence crop in small-scale farming systems for thousands of years. In view of domestic marketing and supply-side constraints, subsidies for other edible oils competing crops availability of palm oil is always problem. Improved breeding schemes undertaken in French colonies resulted in significant yield improvements in some estates with best *tenera* progenies. However, there is a growing concerned about significant genetic erosion in natural oil palm groves. There is the new initiative called 'Africa Palm Oil Initiative (APOI)' by Tropical Forest Alliance (2020) have sustainable developmental plans in Africa for oil palm industry. It is reported that several multinational planation companies are evincing interest to develop oil palm based agro-industry projects in Africa (www.tfa2020.org).

OIL PALM BREEDING FOR SEED PRODUCTION IN INDIA

The systematic plantation of oil palm was established in India during 1961 at Thodupuzha (Kalayanthani, Vettimattom, Idukki district), Kerala with dura and tenera materials introduced from Malaysia and Nigeria (Nampoothiri 1994, Pillai and Nampoothiri 1981 and Murugesan et al. 2011).The Dura × Dura population consisting of over 700 palms available at Thodupuzha formed the base breeding material for Indian Oil Palm industry. Tenera (D×P) hybrids were produced, crossing 11 promising dura palms of Thodupuzha with pisifera (30.103) imported from Nigerian Institute for Oil Palm Research (NIFOR), Nigeria. These hybrids were planted during 1976 in the progeny trial at Palode, Thiruvanathapuram district of Kerala. After field evaluation, two hybrids (65D × 30.103P and 120D × 30.103P) were selected as most promising ones with a potential of yielding >4.6 tons of palm oil per hectare under rainfed condition (Nampoothiri et al. 1993). Selfed and inter se matted 65D and 120 D dura progenies were established as separate seed garden during 1982 for hybrid seed production at Palode oil palm station (Murugesan et al. 2006). In order to have wider choice of suitable *pisiferas* (as pisifera pollens were imported from Nigeria and non-availability of selected pisifera), seven high yielding teneras with the progenitors 65D × 30.103Pand 120D × 30.103P were selfed and progenies were planted at Palode (Kerala) during 1991 (Murugesan et al. (2008) and Murugesan et al. 2011). Intense selection on the Thodupuzha descendants by selfing/ inter se crossing gave rise to present advanced dura and T×T populations planted in 1989 at M/S NavaBharat Agro Products, Lakshmipuram, West Godavari district of Andhra Pradesh to produce indigenous planting material and based on the yield (150 kg /palm /year) performance 45 dura palms out of 380 dura palms and six pisifera palm out of 519 T×T. The field performance of these hybrids are planted around Jangareddygudem (Andhra Pradesh) was performing well (Rethinam and Murugesan, 1998). Subsequently four seed gardens namely Rajahmundry (Department of Horticulture, Government of Andhra Pradesh), Taraka (Department of Horticulture, Government of Kamataka), Thodupuzha (Oil Palm India Limited, Joint venture of Government of Kerala and India) and Palode (Regional Station of Indian Institute of Oil Palm Research, Kerala) (Rethinam et al. 2000); Murugesan et al. 2006). Studies on Interspecific hybridization of *Elaeis guineensis* ×*Elaeis oleifera* planted in 1995 at Palode Centre showed superior over conventional tenera which has to be exploited for seed production (Rethinam and Vinod Kumar 1998).Two advanced breeding materials fromASD Costa Rica imported under the UNDP subprogramme "Breeding for Seed Production" along with advanced dura crosses from Palode were planted as sixth seed garden at National Research Centre for Oil Palm, Pedavegi during 2000 (Rethinam et al. 2001). Under FAO assistance, during 1995-96, India collected wild and semi wild oil palm germplasm from Cameroon, Tanzania, Zambia and Guinea Bissau (Pillai et al. (2000) and multidisciplinary team has been evaluating for breeding, improvement and seed production (Rethinam et al. (1999-2000); Mathur et al. 2001, Suresh et al. 2004, Murugesan and Mandal 2010 and Murugesan et al. 2015) and six genetic stocks with unique traits (early fruit maturity, dura palm with dark orange fruit colour, long bunch stalk, sterile pisifera with viresence fruit colour, dwarf palm with high fruit set and compact tenera palm) are registered with ICAR-National Bureau of Plant Genetic Resources (Anjali Kak and Veena Gupta 2017). All the germplasm accessions were conserved as field gene bank maintained at Pedavegi, Andhra Pradesh and Palode, Kerala. As oil palm parental materials planted in the seed gardens of Palode, Thodupuzha, Taraka and Navabharath have grown tall and to augment the continuous availability of quality planting material, Government of India, in collaboration with ICAR Indian Institute of Oil Palm Research is now focusing on establishment of new seed gardens with new parental materials developed from exotic germplasm. Four more new seed gardens namely, Morumpudi, Dept. of Horticulture, Rajahmundry (AP), Gopannapalem, Dept. of Horticulture, Rajahmundry (AP), Taraka (Taraka-II), Department of Horticulture, Taraka, Karnataka, Kabini, Department of Horticulture, Taraka, Karnataka were established during 2012, 2014, 2012 and 2012, respectively (https://nmoop.gov.in). The tables 3 and 4 clearly infer that though there is potential to produce 4.9 million seeds annually from existing seed gardens only 50% could be produced and the new seed gardens established will be in a position to produce seeds in another six to ten years.

Table 3: Oil palm seed gardens (Old and new) in India- Potential and supply status (Source: (https://nmoop.gov.in).

Sl.No	Name of location	Year of planting	Potential (Lakhs)	Supply (Lakhs) (2013-14)	Balance (Lakhs)
1	ICAR-IIOPR, Pedavegi, Andhra Pradesh	2000	6.0	3.1	2.9
2	ICAR-IIOPR, Research-Research Centre, Palode, (Kerala)	1982	8.0	3.1	4.9
3	M/s. Navabharath Private Ltd., Lakshmipuram (A.P.)	1990	6.0	3.8	2.2
4	Department of Horticulture, Rajahmundry (A.P.)	1992	10.0	4.7	5.3
5	Oil Palm India Limited, Thodupuzha (Kerala)	1994	11.0	6.0	5.0
6	Department of Horticulture, Taraka, (Karnataka)	1994	8.0	3.7	4.3
	Total	-	49.0	24.4	24.6
7	Morumpudi, Department of Horticulture, Rajahmundry (A.P.)	2012	5.0*	New	-
8	Gopannapalem, Department of Horticulture, Rajahmundry (A.P.)	2014	5.0**	New	-
9	Taraka (Taraka-II), Department of Horticulture, Taraka, Karnataka	2012	5.0*	New	-
10	Kabini, Department of Horticulture, Taraka, Karnataka	2012	8.0*	New	-
	Total	-	23.0		

* Expected year of initiation of seed production-2020
** Expected year of initiation of seed production-2020

Table 4: Availability of exotic and indigenous planting material and area expansion in India (Source: https://nmoop.gov.in)

Exotic/indigenous/Area coverage	Year wise supply (Lakhs) and area coverage (hectares)				
	2010-11	2011-12	2012-13	2013-14	Total
Exotic	26.00 26	34.00	70.50	40.20	170.70
Indigenous	8.46	16.22	20.32	24.40	57.24
Area coverage (Ha)	17,925	28,388	26,300	22,948	95,561

According to Rethinam et al. (2012), India has potential area of 1,933,250 hectares in 18 states -Andhra Pradesh, Karnataka, Tamil Nadu, Goa, Gujarat, Maharashtra, Chhattisgarh, Kerala, Odisha, Bihar, West Bengal, and North Eastern states like Mizoram, Assam, Arunachal Pradesh, Tripura, Meghalaya, Nagaland and Andaman Nicobar Islands. Rethinam (2018) has also elaborated the planting material production programme for next 20 years in a policy paper for which large quantity of planting materials of 400 million are estimated which necessitate import of bulk quantity of exotic seed materials from other seed producing countries. The starting of production of indigenously developed hybrids from ICAR- Indian Institute of Oil Palm Research in collaboration with All India Co-ordinated Research Project on Palms (AICRP on Palms) may take 10 years from now.

As on to day, India imports bulk of its demand of planting materials through import from foreign countries as supply from indigenous source is only half of the demand as per the estimate in the National Mission on Oil Seeds and Oil Palm. The report of NMOOP had clearly indicated the above fact (Table 4). Government is advocating augmenting indigenous seed production in India. According to Murugesan et al. (2004) the performance of indigenous seed materials is on par with exotic materials. Top official level Indian delegation led by Joint Secretary (Oilseeds) visited Malaysia during 22-25 August, 2016 and recommended for high density oil palm planting materials and encouraged, new varieties such as Calix and Guthrie from Malaysia and exchange of germplasm for research and improvement of new varieties (https://nmoop.gov.in). Accordingly, two sources of germplasm namely, Sierra Leone and Senegal of 20 different accessions were introduced to India from MPOB after field evaluation (Murugesan and Sunil Kumar (2015) and Murugesan et al. (2016) and both resources have lower Free Fatty Acid content apart from drought tolerance.

GLOBAL HYBRID SEED PRODUCTION POTENTIAL AND ESTIMATES

D×P seeds

In 2009, global seed production was estimated at 490 million (Kushairi et al. 2011) and Malaysia and Indonesia require about 120 million seeds per year for new commercial planting and replanting demands which will be fulfilled through D×P seeds as the production of clonal seeds and tissue culture plantlets are limited.In Malaysia, Oil palm D×P seed production capacity has more than doubled from 50 million in 1995 to 109 million in 2000 and currently at 124 million in 2010 and 131 million in 2013 (Rajanaidu et al. 2013). Indonesia (250 million), Malaysia (132 million), Papua New Guinea (30 million) and Costa Rica (30 million) were the main producers and capable of exporting a large quantity. Palm elite joint venture company has 1600 hectares of field trials eight seed gardens in Africa, America and Asia. Palm elite has sound base for planting material production. It is reported that out of 200 million seeds of worldwide market of oil palm seeds, 30 to 50 million seeds are supplied per year from Palm elite. ASD has been supplying oil palm planting materials to meet the global expansion of the crop as commercial basis. To date, ASD has marketed 30 million seeds of compact variety. ASD-Bakrie Indonesia Oil Palm Seed (ASD-Bakrie) develop new high-quality planting materials which are adapted to local microclimate. PT ASD-Bakrie Indonesia Oil Palm Seed has been set forth to expand their production quantity until 20 million seeds per year. Apart from Nigeria, nineteen African countries are growing oil palm for palm oil and kernel oil production. Out of twenty countries only six countries namely Nigeria, Cameroon, Cote de Ivory, Ghana, Congo and Benin are having capability to produce large scale quality planting materials of oil palm. According to Bakoumé (2016), African continent has seed production potential of 50 million seeds per year. Cameroon is reported to produce about 13 million seeds followed by Ghana (4 million seeds). Palm elite (commercial arm of CIRAD) takes care seed production at Pobe Benin and NIFOR is having the seed production potential of 7 million seeds per year but reported to supplied 1.76 million germinated seeds during 2015. The other seed producers in Central/South America are, Gene Palm, Honduras (2 million), Mungas and Lowe in Colombia (2million), La Cabina CIRAD resale (1.5 million) INIAP Equador (2 million) and Embrapa Brazil (1 million).

Clonal/semi clonal seeds

A total of eleven companies (Clonal palm, FELDA, AAR, Sime Darby, IOI, Bornea Samudra and others) are reported to achieve commercial scale clonal palm production in Malaysia (Soh, et al. 2011). Besides conventional D×P seed production about 6 million plantlets are produced through micro propagation (Malaysia 5 million, Indonesia 0.5 million and Coast Rica 0.5 million) at global level. (MPOB 2018)

Interspecific hybrids

Elaeis oleifera (American oil palm) is partially domesticated species of oil palm as it is readily crossable with American oil palm and Inter specific hybrids are mostly produced in South and central American countriesto the tune of 2.5 millionEquador (CIRAD partner): 1. million, Colombia (La Cabana): 0.3 million, Colombia (Indu palm): 0.2 million, Brazil (EMBRAPA): 1.00 million). (Cunha et al. 2012).

POTENTIAL COMMERCIALLY AVAILABLE GLOBAL PLANTING MATERIAL

Over a period of time, oil palm undergone tremendous progress in Fresh Fruit Bunch and palm oil yield and productivity due to the efforts and intensive research and development carried out by public and private research organizations. Before the invention of single gene discovery by Beirnaert and Vanderweyen (1941), dura type of planting materials was utilized for commercial cultivation. Subsequently, the type of material progressed from D×P seeds, tissue cuture plantlets, inter specific hybrids and clonal/ semi clonal seeds/genomic selection. SHELL gene discovery by MPOB and Orion Genomics paved the way for precision breeding in oil palm (Nathan Lakey, *et al* 2016). Therefore, there is wide choice available now to order for planting materials with high yield and quality as well as resistant to biotic and abiotic stresses. Few of the planting materials which are commercially available worldwide are given as bullet points below.

- ASD Costa Rica had developed several commercial hybrids (avalanche, amazon, supreme, challenger, Bamenda, Kigoma, LaMe, Evolution Blue, Spring and Themba) and clones (drake, sabre, sunrise, titan and tornado) which were reported to field tested in different environments/ countries. ASDs 'Tornado' has yield potential of 43.6 ton of FFB/ha with oil to bunch ratio of 36.7%. One O ×G hybrid 'Amazon' can accommodate 135plams in a hectare of land.

- Palmelite is supplying oil palm seeds in the name of 'CIRAD®'. They had developed many hybrids and clones for achieving high yield coupled with special features of disease resistance (Ganoderma and Fusarium wilt), premium oil quality (low lipase and acidity) and high-density planting. The produce namely '#S' and #D denoted for dwarf and high-density hybrids, respectively. The '#S' have 46-50cm of height increment year^{-1} with 26-28% Industrial Extraction Ratio of CPO and 160 palms population hacatare^{-1} can be accommodated for '#D'

- Sime Darby's hybrid 'Calix 600'developed from Deli dura and AVROS Pisifera is reported to produce up to 10 MT/ha/yr. with precocity in FFB production.

- AAR Hybida IS being the commercial hybrid developed by Applied Agricultural Resources Sdn. Bhd (AAR), Malaysia. Under a favorable growing environment, maximum of 35tonnes of FFB and 8-9t of CPO per hectare is reported in Hybrida1 during 7-10 years after planting.

- Felda Global Ventures (FGV)-Agricultural Services Sdn Bhd. had developed 'Yangambi' 3-way crosses with an FFB yield level ranging from13.45 -23.59 ton/ha from 1 to 3 years and 23.59 to 31.47 t/ha from 4 years and above with oil yield of 8.92 t/ha, OER 26.99 % and kernel oil of 0.94 t/ha.

- Sawit Kinabalu Seeds Sdn.Bhd, Sabha, Malaysia had developed D×P planting Materials for achieving high FFB, OER, bunch numbers and precocity. The expected yield levels reported was 13 to 16 ton from the first year harvest itself s and go on increase to 29 to 34 tons FFB/ha.

- IOI Deli × AVROS seed – is produced for commercial sale by IOI Group-Batang Melaka, Malaysia. The IOI Deli x AVROS hybrid seed is reported to gives high yields from the earliest years of production and is widely adaptable to different planting environments.

- Topaz oil palm is a D ×P custom commercial hybrid developed by Asian Agri; Indonesia is reported to have higher yields even in marginal soils and reduced vertical growth. The parent of Topaz has been extensively progeny tested in North Sumatra and Riau.

- PT Dami Mas Sejahtera (Subsidiary of Golden Agri Resources Ltd, Indonesia) is one of the top D×P seed suppliers in Indonesia and markets 'Dami Mas Sejahtera D×P seeds'. It has launched high-yielding new planting materials namely, Eka 1 and Eka 2 during 2017.

It is to be noted that varieties/hybrids have been developed through different breeding programmes in the countries *viz*., Malaysia, Zaire, Nigeria, Ivory Coast, Indonesia and Papua New Guinea and field tested for the environmental conditions of their own areas (Rey et al. 2004). Therefore, it is necessary to study the hybrid performance in the field trial under different environments and local conditions before taking decision on order for planting materials (Romero et al. 2007 and Rodriguez and Romero 2019).

CONCLUSION

Oil palm breeding for seed production has direct influence on growth of oil palm industry at global level. Oil palm industry aims to improve not only productivity of oil but also emphasis for different qualitative traits and develop new seeds/varieties suitable for different agro-climatic conditions from diverse germplasm by adopting conventional breeding and molecular approaches. In view of recent developments of newer countries taking up oil palm cultivation, existing oil palm growing countries expanding the areas, newer varieties developed for resistance to diseases, tolerance to drought, improved architecture, decrease of oil acidification etc. Choice of planting material will differ according to many local factors. It is difficult to assess global level seed requirement, because in majority of oil palm growing countries, the crop is grown by small farmers and in case of Africa, oil palm is grown with different agro- system. It is suggested to study the hybrid performance in the local conditions before taking decision on order for planting materials. India is developing oil palm in an area of about 2.0 million ha over a period of two decades, requires large numbers of planting materials of about 400 million sprouts in 20 years or approximately 20 million seeds. The following two pronged approaches are suggested for planting material requirements in India. 1. Strengthening and augmentation of indigenous seed production and import of promising exotic materials after evaluation in local conditions.

REFERENCES

Abdul Rahim MF, Lee Yang Ping, Mohd Nasruddin Mohamad, Mohd Latif Kamarudin, Mohd Mahfuz Roslan, Naderman Samin, Nur Adibah Ishak, Suthashinikisan Krishnan, NoorSusilawati Mandangan, Nurul Fatiha Farhana Hanafi, Leao Ling Jiun and Tan Joon Sheong (2017). FGV Integrated Breeding System (FIBS): Managing Integration of Breeding Data and Operation. Proceedings of the International Seminar on 100 years of technological advancement in Oil Palm Breeding & Seed Production (13 November, 2017). KLCC Kula lampur, Malaysia. Pp 83-99

Addae-Kagyah KW (1988). Effect of seed storage, heat pretreatment and its duration on germination and growth of nursery stock of the idolatrica palm, *Elaeis guineensis var idolatrica* (*Chevalier*). Tropical Agriculture (Trinidad) 56 (1): 77-83.

Alvarado y, Escobar R (2017). Seed production and oil palm breeding in Costa Rica ASD Oil Palm Papers. 47: 19-26.

Alvarado A, Escobar R (2016). Seed Production and Oil Palm Breeding in ASD Costa Rica (Agricultural Services and Development, Costa Rica), In: Proceedings of international seminar on oil palm breeding and seed production, (29-30 September 2016), Kisaran Indonesia. Pp 21-38.

Amblard P, Louise C, Zambrano J (2009). El Programma de Mejoramiento de la Palma Aceitera de PalmElit y de Sus Socios en Ecuador y Colombia. (Challenges in Sustainable Oil Palm Development). XVI palm Oil International conference, (23rd to 25th of September 2009), Cartagena de Indias, Colombi.

Anjali Kak, Veena Gupta, (2017). Inventory of Registered Crop Germplasm (2015-2017). ICAR-National Bureau of Plant Genetic Resources, Pusa Campus, Indian Council of Agricultural Research (ICAR), New Delhi-110 012, 74p.

Annonymous (2017). New high yielding oil palm planting material developed in Indonesia. Far Eastern Agriculture (Magazine).

Ataga CD (1994). Variation in kernel size in Nigerian oil, palm (*Elaeis guineensis* Jacq.) germplasm collection.

Bakoumé C, Ngando Ebongué G, Ajambang WCD, Ataga CD, Okoye MN, Enaberue LO Konan JN, Allou D, Diabate S, Konan E and Etta CE, (2016). Oil palm breeding and seed production in Africa. In proceedings of International seminar on oil palm breeding and seed production and field visits, (29-30 September 2016) Kisaran, Indonesia. P39-62.

Barbosay R, C Chinchilla, (2003). ASD Oil palm germplasm from Nigeria, ASD Oil Palm papers NR" 26, pp 33-44.

Beernaert A, Vanderweyen R (1941). Contribution à l'étude génétique et biométrique des variétés d'*Elaeis guineensis Jacq.* [Contribution to genetic and biometric study of *Elaeis guineensis Jacq.* Varieties] Pub. de l'INEAC. Série Scientifique 27.

Blaak G, Sparnaaj LD, Menendez T 1963. Breeding and inheritance in oil palm (*Elaeis guineensis Jacq.*) Part II. Methods of bunch quality analysis. *Journal of West Africa Institute of Oil Palm Research 4, 145-155.*

Cochard B (2008). Etude de la Diversité Génétique et du Déséquilibre de Liaison au sein de Populations Améliorées de Palmier à Huile (*Elaeis guineensis* Jacq.). Thesis Supagro Montpellier.

Corley RHV, Tinker PB (2003). The Oil Palm, Oxford: John Wiley & Sons.

Cunha RNV, Lopes RBRS, (2010). Manicoré: híbrido interspecific entre o caiaué e o dendezeiro africano recomendado para áreas de incidência de amarelecimento-fatal. Manaus, (2010). 4p. (Embrapa Amazônia Ocidental. Comunicado Técnico, 85). (http://www.snt.embrapa.br/publico/usuarios/ produtos/85-Anexo1.pdf).

Cunha RNV, Lopes R, Rocha RNC, Lima WAA, Teixeira PC, Barcelos E, Rodrigues MRL, Rios SA (2012). Domestication and Breeding of the American Oil Palm. In: Borém A, Lopes MTG, Clement CR (Ed.). Domestication and Breeding: Amazonian species. Viçosa: UFV, p.275-296, (2012).

De Franqueville H (2003). Review paper: oil palm bud rot in Latin America. Experimental Agriculture 39: 225–40.

Edy Suprianto, Yurna Yenni, Nanang Supena, M Arif; Sujadi, Heri A Siregar, Hernawan Y Rahmadi, Sri Wening, Retno D Setiowati, Rokhanah Faizah and Abdul Razak Purba, (2016). Current Status of IOPRI Oil Palm Breeding Program and Seed Production. In: Proceedings of international seminar on oil palm breeding and seed production, (29-30 September 2016), Kisaran, Indonesia. Pp 6.

Fadila, A M; Norziha, A; Mohd Din, A; Rajanaidu, N and Kushairi, A (2016). Evaluation of bunch index in MPOB oil palm (*Elaeis guineensis Jacq.*) germplasm collection. J. Oil Palm Res.Vol. 28: 442- 451.

FAOSTAT, (2019). http://www.fao.org/faostat/en/#data/QC

Gascon JP, de Berchoux C (1964). Caractéristiques de la production d'Elaeis guineensis Jacq. de diverses origines et leurs croisements. Application à la sélection du palmier à huile [Characterisation of *Elaeis guineensis Jacq.* production from diverse origins and crosses. Application to oil palm selection]. Oléagineux 19(2): 75-84.

Gustina Siregar, Mailina Harahap, Desi Novita, (2018). Readiness of oil palm smallholders in facing oil palm replanting in North Sumatra. International Conference on Agribussines, Food and Agro-Technology. IOP Conf. Series: Earth and Environmental Science 205: 1-8.

Harold Owen Williams, (2016). Pt Socfindo Aek Loba. In: Proceedings of international seminar on oil palm breeding and seed production, 29-30 September 2016, Kisaran, Indonesia. Pp 96.

Hayiti, A., R. Wickneswari, I.Maizura and N.Rajanaidu, (2004). Genetic diversity of oil palm (*Elaeis guinenesis, Jacq.)* germplasm collections from Africa: implications for improvement and conservation of genetic resources. *Theo Appl. Genetics 108: 1274-1284*.

http:// the oil palm.org/about/

https://biosearch-cdn.azureedge.net/assetsv6/customer-case-study-sime-darby.pdf

https://nmoop.gov.in

Isa ZA, Mohd Din A, Maizura I, Noh A; Kushairi A and Rajanaidu N (2006). PS12: Breeding population for high oleic acid palm oil. MPOB Information Series No. 313. MPOB, Bangi, Malaysia.

Junaidah J, Kushairi A, Isa ZA, Mohd Din A, Noh A, Rajanaidu N (2004) PS7: high bunch index breeding population. MPOB Information Series No. 221. MPOB, Bangi.

Kushairi A, Mohd Din A, Rajanaidu N. (2011). Oil Palm Breeding and Seed Production. IN: Mohd Basri W, Choo YM, Chan KW (Eds) Further advances in oil palm research (2000–2010) MPOB, Bangi, pp. 47–101.

Kushairi A; Rajanaidu N, Mohd Din A (2003b). Mining the germplasm. Proc. of the ISOPB Seminar on the Progress of Oil Palm Breeding and Selection, Medan, Sumatra, Indonesia.

Kushairi A, Rajanaidu N, Mohd Din A, Isa ZA, Noh A, Junaidah J (2003a). PS6: Breeding populations selected for large fruit *dura*s. MPOB Information Series, No. 184. MPOB, Bangi.

Kushairi A, Rajanaidu N, Mohd Din A, Isa ZA, Noh A, Junaidah J (2003c). PS5: Breeding populations selected for thin shell *tenera*s. MPOB Information Series 183. MPOB, Bangi, Selangor.

Kushairi A, Rajanaidu N, Sundram K, Maizura I (2004). PS8: vitamin E breeding population. MPOB Information Series No. 222. MPOB, Bangi.

Kwong QB, Ong AL, Teh CK, Chew FT, Tammi MT, Mayes S, Kulaveerasingam H, Yeoh SH, Harikrishna JA, Appleton D. (2017) Genomic Selection in Commercial Perennial Crops: Applicability and Improvement in Oil Palm (*Elaeis guineensis* Jacq.) Sci. Rep. 7: 2872.

Louise C (2014). Alternativas Frente al Complejo PC en Ecuador. Ecupalm. Congresso Internacional de Palma Aceitera. Santo Domingo de los Tsáchitas , Ecuador. 8-11 de abril 2014.

Maizura I, Kushairi A, Nohd Din A, Noh A, Marhalil M, Wong YT, Sambanthamurthi R (2008). PS13: Breeding populations selected for low lipase. MPOB Information Series No. 400. MPOB, Bangi.

Maizura I Kushairi A, Nohd Din A, Noh A, Marhalil M, Wong YT, Sambanthamurthi R (2008). PS13: Breeding populations selected for low lipase. MPOB Information Series No. 400. MPOB, Bangy.

Malike FA, N Abdullah, N Ahmad. (2011). Evaluation of Harvest Index in the MPOB germplasm collections. pp 172-175. In: Proceedings of Agriculture, Biotechnology & Sustainability Conference, PIPOC, 2011, 15-17, November, KLCC, Malaysia.

Marhalil M, N Rajanaidu, (2011). Oil Palm germplasm (*Elaeis guineensis*, Jacq): Second prospection. pp 133-140. International seminar on breeding for sustainability in oil palm 18th Nov 2011 KLCC, Kuala Lumpur.

Mathur RK, Suresh K, Nair S, Parimala S, Sivaramakrishna VNP (2001). Evaluation of exotic Dura germplasm for water use efficiency in oil palm *(Elaeisguineensis, Jacq.). Indian J. Plant genetic Resources. 14: 257-259.*

Mohd Din A, Noh A, Mohd Isa ZA, Maizura I, Kushairi A, Rajanaidu N (2006). PS11: High carotene *E. guineensis* breeding population. MPOB Information Series No. 312. MPOB, Bangi.

Mohd Din A, Rajanaidu N, Kushairi A, Mohd Rafii Y, Mohd Isa ZA, Noh A (2002). PS4: High carotene *E. oleifera* planting materials. MPOB Information Series No. 137. MPOB, Bangi.

Moretzsohn MC, Ferreira MA, Amaral ZPS, Coelho PJO, Grattapaglia D, Ferreira ME. (2002). Genetic diversity of Brazilian oil palm (*Elaeis oleifera* H.B.K.) germplasm collected in the Amazon forest. Euphytica 124: 35-45.

MPOB, 2018. Malaysian Oil Palm Statistics, (2017). 37th Ed, MPOB, Bangi 205pp

Mukesh Sharma, Ang Boon Beng, Harkingto, Manjit Sidhu (2016). Performance of Asian agri group's 2nd generation D×P planting materials - moving to the next level of improved D×P. In: Proceedings of international seminar on oil palm breeding and seed production, (29-30 September 2016), Kisaran, Indonesia. Pp 7.

Murugesan P, Sunilkumar K (2015). Depuation report on visit to Malaysia under the collobrative research project on oil palm germplasm exchange for R&D between India and Malaysia (F.No.10-171/2015-ASIA dated 9th October, 2015). ICAR-Indian Institute of Oil Palm Research, Regional Station, Palode, Pacha-695562, Trivandrum, Kerala.p 43

Murugesan PJ, Meenu Merlin, Dipu Joseph, SJ Bindu, RSN Pillai, KUK Nampoothiri, (2011).Yield potential and phenotypic variation of fruit and seed characteristics of oil palm duras at Thodupuzha, *Journal of Plantation Crops*, (2011), 39 (1): 114-118

Murugesan P, KL Mary Rani, DRamajayam, K Sunil Kumar, RK Mathur, G Ravichandran, P Naveen Kumar, V Arunachalam, (2015). Genetic diversity of vegetative and bunch traits of African oil palm

(*Elaeis guineensis*) germplasm in India. *Indian Journal of Agricultural Sciences 85 (7): 892–5*

Murugesan P, K Sunilkumar, RK Mathur (2016). International collaboration: Enriching oil palm genetic resource in India. Indian Horticulture. July-Aug, pp 33-36

Murugesan PS, Gopakumar, H Haseela (2011). Performance of tenera × tenera progenies derived from Thodupuzha (Kerala) oil palm germplasm II. Bunch quality components. *Indian J. Hort. 68(3): 303-306*

Murugesan PS, Gopakumar T, Krishnakumar J, Santhosh Kumar, H Haseela. Performance of *Tenera* × *Tenera* progenies derived from Thodupuzha and Nigerian Oil Palm germplasm under rain fed condition*, Journal of Plantation Crops,* 2008, 36 (3): 161-165

Murugesan P, Mandal G (2010). Identification and characterization of *pisifera* palms from different oil palm genetic resources *International J. Oil Palm 7: 33-37*

Murugesan P, RSN Pillai, RK Mathur, M Ravi Kumar, Shivanand Kapashi, M Kochu Babu (2006). Oil palm selection and hybrid seed production in India. The planter, 82(961): 227-244

Murugesan PC, Balachandran RSN, Pillai, PS Ravindran (2004). Performance of indigenous and Costa Rican planting materials of oil palm (*Elaeis guineensis*, Jacq) in coastal districts of Andhra Pradesh. Journal of Planation Crops, 32(Supl): 16-19.

Muurgesan P, M Shareef (2015). An overview of national and international strategies in seed germplasm conservation in oil palm, in: Advances in Tree Seed Science and Silviculture (Editors C. Buvaneswaran et al), Institute of Forest Genetics and Tree Breeding (Indian Council of Forestry Research and Education), Coimbatore, Tamil Nadu. Pp42-57

Namboothiri KUK (1994). Oil palm Breeding. pp. 255-267. In: Advances in Horticulture (Eds.) Chadha KL and Rethinam P.

Nampoothiri KUK, Pillai RSN, Ravindran PS (1993). Strategies for self-sufficiency in indigenous oil palm seed production. *J. Plantation Crops* 21: 403-405.

Nathan Lakey, Rajinder Singh, Meilina Ong Abdullah, Eng-Ti Leslie Low, Leslie C-L Ooi, Rajanaidu Nookiah, Steven W Smith, Jared M Ordway, Robert A Martienssen, Ravigadevi Sambanthamurthi (2016). Translating the oil palm genome information into precision agriculture breeding practices. In: Proceedings of international seminar on oil palm breeding and seed production, (29-30 September 2016), Kisaran, Indonesia. Pp86-93.

Noh A, Kushairi A, Mohd Din A, Maizura I, Isa ZA, Rajanaidu N (2005). PS10: Breeding populations selected for long stalk. MPOB Information Series No. 263. MPOB, Bangi.

Noh A, Rajanaidu N, Kushairi A, Mohd Din A, Wan Nooraida WM (2014). PS 14: Oil palm breeding population selected for high protein kernel. MPOB Information Series No. 566. MPOB, Bangi.

Noh A, Rajanaidu N, Kushairi A, Mohd Rafii Y, Mohd Din A, Mohd Isa ZA, Saleh G (2002). Variability in fatty acid composition, iodine value and carotene content in the MPOB oil palm germplasm collection from Angola. J. Oil Palm Res.Vol. 14: 18-23.

Nouy B, Lubis RA, Kusnadi TT, Akiyat, Samritaan G (1991). Oil Palm (*Elaeis guineensis*) Production Potential Results for Deli x La Mé Hybrids in North Sumatra. Oleagineux, 46: 91-99

Okwuagwu CO (1986). The genetic basis of the NIFOR oil palm breeding programme. In: Proc: International Workshop on Oil Palm Germplasm and Utilization. Workshop Proc. Palm Oil Res. Inst., Malaysia. No.10, pp 228-237.

Okwuagwu CO, Ataga CD, Okolo EC 1993. Collecting Oil palm germplasm in Nigeria. FAO/IBPGR Plant Genetic Resources Newsletter 93: 38-39.

Okwuagwu CO, Ataga CD, Okoye MN, EC Okolo (2011). Germplasm collection of highland palms of Afikpo in Eastern Nigeria. *Bayero Journal of pure and applied Sciences*, 4(1): 112114.

Omoti U 2003. Oil Palm Research at NIFOR, Nigeria. BUROTROP Bulletin 19, Special Issue: Oil Palm, 43-46.

Pannetier C, Arthuis P, Liévoux C (1981) Néoformation de jeunes plants de *Elaeis guineensis* à partir de cals primaires obtenus sur fragments foliaires cultivés in vitro. Oléagineux, 36 (3): 119-122

Pillai RSN, Nampoothiri KUK (1981), Preliminary investigations on pisifera with special reference to the genetic improvement of Oil Palm (*Elaeis guineensis, Jacq*) in India. pp. 308- 313.In: PLACROSYM, IV- Genetics, plant breeding and horticulture. (Eds.) Vishveshwara et al; ISPC, Kasargod.

Rajanaidu N (1986). The oil palm (*Elaeis guineensis*) collections in Africa. Proc. of the International Workshop on Oil Palm Germplasm and Utilisation. PORIM, Bangi. p. 59-83.

Rajanaidu NA, Kushairi KW, Chan, A Mohd Din (2007). Current status of oil palm planting material in the world and future challenges. PP 503-520. In: Proceedings of the PIPOC (2007) International Palm Oil Congress (Agriculture, Biotechnology and Sustainability. KLCC, Kuala Lumpur.

Rajanaidu NA, Kushairi MY, Rafii A, Moh'd Din, I Maizura BS, Jalani (2001). Oil palm breeding and genetic resources. pp 171-237. In: (Basiron, Y; Jalani B.S, and Chan, K.W) Mlaysian Palm Oil Board, Kuala Lumpur.

Rajanaidu N, A Kushairi, MY Rafii, A Moh'd Din, I Maizura BS, Jalani. (2001). Oil palm breeding and genetic resources. pp 171-237. In: (Basiron, Y; Jalani B.S, and Chan, K.W) Mlaysian Palm Oil Board, Kuala Lumpur.

Rajanaidu NBS, Jalani, A Kushairi (1998). Oil palm genetic resources, the development of novel planting materials. Pp.208-220. In International Oil Palm conference, Nusa Dua Bali, September 23-25.

Rajanaidu N, Ainul MM, Kushairi A, Mohd Din A (2013). Historical review of oil palm breeding for the past 50 years - Malaysian journey. Proc. of the International Seminar on Oil Palm Breeding - Yesterday, Today and Tomorrow, Kuala Lumpur, Malaysia. p. 11-28.

Rajanaidu N, Ainul MM, Kushairi A, Mohd Din A (2013). Historical review of oil palm breeding for the past 50 years - Malaysian journey. Proc. of the International Seminar on Oil Palm Breeding - Yesterday, Today and Tomorrow, Kuala Lumpur, Malaysia. p. 11-28.

Rajanaidu N, Kushairi A, Mohd Din A, Marhalil M, Fadila AM, Isa ZA (2011). Selection criteria (15-15-15) to develop sustainable oil palm planting materials. Proc. of the International Seminar on Breeding for Sustainability in Oil Palm. Kuala Lumpur, Malaysia. p. 112.

Rajanaidu N, Kushairi A, Rafii M, Mohd Din A, Maizura I, Jalani BS (2000). Oil palm breeding and genetic resources. Advances in Oil Palm Research (Yusof B, Jalani BS and Chan KW Eds.). MPOB, Bangi, Selangor. p. 171-237.

Renard JL, Noiret JM, Meunier J (1980). Sources et Gammes de Résistance à la Fusariose chez le Palmier à Huile *Elaeis guineensis* et *Elaeis oleifera*. Oleagineux 35: 387-393.

Renjini VR, Girish K Jha (2019). Oilseeds sector in India: A trade policy perspective. Indian Journal of Agricultural Sciences 89 (1): 73–8.

Rethinam P, Vind Kumar (1998). Studies on Inter-specific hybridization in Oil Palm. Annual Report 1997-1998, National Research Centre for Oil Palm, Pedavegi-534 450, West Godavari District, Andhra Pradesh, p.18.

Rethinam P, P Murugesan, M Saraswathy, K Parimala (2001). Oil palm seed production-a short review. International Journal of Oil Palm Research, 2(1): 1-6

Rethinam P (2018). Perspective role of oil palm in the vegetable oil economy and farmers prosperity in India, SOPOPRAD Publication, pp.76.

Rethinam P, Arulraj S, Rao BN (2012). Assessment of additional potential areas for oil palm cultivation in India. Report submitted to Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India. Directorate of Oil Palm Research, Pedavegi, Andhra Pradesh, pp. 1-84.

Rethinam P, P Murugesan (1998). Breeding for Seed Production. Annual Report 1997-1998,National Research Centre for Oil Palm,Pedavegi-534 450,West Godavari District, Andhra Pradesh, p.18-19.

Rethinam P, RSN Pillai, K Suresh (2000). Evaluation of drought tolerant Oil Palm Germplasm. In Annual Report 1999-2000, National Research Centre for Oil Palm, Pedavegi-534 450,West Godavari District, Andhra Pradesh, p.25-28.

Rethinam P, RSN Pillai, P Murugesan (2000). Oil Palm Indigenous Hybrid Seed Production In Annual Report 1999-2000, National Research Centre for Oil Palm,Pedavegi-534 450,West Godavari District, Andhra Pradesh, p.13-18.

Rey L, Gmez PL, Ayala IM, Delgado W, Rocha PJ (2004). Colecciones genéticas de palma de aceite *elaeis guineensis (jacq.)* y *elaeis oleifera* (h.B.K.) de cenipalma: Characteristics de importancia para el sector palmicultor. Palmas. 25:39-48.

Richardson DL (1995). La historia del mejoramiento genético de la palma aceitera en la compañía United Fruit en América (The History of Oil Palm Breeding in the United Fruit Company). ASD Oil Palm Papers 11, pp1–22 (Online: http://www.asdcr.com/images/History_UFCo_palm_OPP_11 _1995.pdf).

Rodriguez, C B, HM Romero (2019). Physiological and agronomic behavior of commercial cultivars of oil palm (*Elaeis guineensis*) and OxG hybrids (*Elaeis oleifera x Elaeis guineensis)* at rainy and dry seasons. *Austrailan Journal of Crop Science*, 13(3): 424-432.

Romero HM, Ayala IM, Ruíz R (2007) Ecofisiología de la palma de aceite. Revista Palmas. 28 (especial):176-184

Sakhanokho, H F, Kelley, R Y (2009). Influence of salicylic acid on in vitro propagation and salt tolerance in Hibiscus acetosella and Hibiscus moscheutos (CV Luna Red). *Afr J. Biotechnol*. 8: 14741481.

SIRIM (2005). Department of Standards Malaysia (2005). Oil Palm Seeds for Commercial PlantingSpecification (Third Revision), Malaysian Standard MS 157: (2005). Standards and Industrial Research Institute of Malaysia Berhad, Selangor.

Soh AC, Wong G, Tan CC, Chew PS, Chong SP, Ho YW, Wong CK, Choo CN, Nor Azura H, Kumar K (2011). Commercial -scale propagation and planting of elite oil palm clones: Research and development towards realization. *J. of Oil Palm Research* 23: 935-952.

Suresh K, Nagamani CH, Sivasankar S, Kumar KM, Vinod Kumar P (2004). Variations in the photosynthetic rate and associated parameters in the different Oil Palm germplasm. *J. Plantation Crops. 32: 67-69.*

Teh CK, Ong AL, Kwong QB, Sukganah A, Chew FT, Mayes S, Mohamed M, Appleton D, Kulaveerasingam H. (2016) Genomewide association study identifies three key loci for high mesocarp oil content in perennial crop oil palm. Sci. Rep. 6: 19075

Turnbull N, Cazemajor M, Guerin C, Louise C, Amblard P, Cochard B, Durand-Gasselin T, (2016). Oil Palm Breeding and Seed Production in PalmElit. In: Proceedings of international seminar on oil palm breeding and seed production, (29-30 September 2016), Kisaran, Indonesia. Pp 8-18.

USDA (2011). Production, Supply and Distribution Online. (United States Department of Agriculture-Foreign Agricultural Service, Washington, DC, 2011).

USDA (2019). Production, Supply and Distribution Online. (United States Department of Agriculture-Foreign Agricultural Service, Washington, DC, 2019).

USDA (2018). Oilseeds: world markets and trade. United States Department of Agriculture, Foreign Agricultural Service. https://apps.fas.usda.gov/psdonline/circulars/ oilseeds.pdf

Zulkifli Y, Norziha A, Naquiddin MH, Fadila AM, Nor Azwani AB, Suzana M, Sansul KR, Ong-Abdullah M, Singh R, Parveez,GKA, Kushairi A (2017). Designing the oil palm of the future. J.of Oil Palm Research. 24(4): 1440-455.

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INTERNATIONAL JOURNAL OF OIL PALM

1.	Place of publication	:	Pedavegi - 534 450, Andhra Pradesh, India
2.	Periodicity of its publication	:	Half yearly (June and December)
3.	Printer's name	:	Dr. B. Narsimha Rao
	Nationality	:	Indian
	Address	:	Secretary, Society for Promotion of Oil Palm Research and Development, (SOPOPRAD) ICAR - Indian Institute of Oil Palm Research, Pedavegi - 534 450, West Godavari District, Andhra Pradesh, India Phone: 08812-259532; Fax: 08812-259531 e-mail:sopoprad@gmail.com
4.	Publisher's Name	:	Dr. B. Narsimha Rao
	Nationality	:	Indian
	Address	:	Secretary, Society for Promotion of Oil Palm Research and Development, (SOPOPRAD) ICAR - Indian Institute of Oil Palm Research, Pedavegi - 534 450, West Godavari District, Andhra Pradesh, India Phone: 08812-259532; Fax: 08812-259531 e-mail:sopoprad@gmail.com
5.	Editor's Name	:	Dr. P. Rethinam
	Nationality	:	Indian
	Address	:	ICAR - Indian Institute of Oil Palm Research, Pedavegi - 534 450, West Godavari District, Andhra Pradesh, India Phone: 08812-259409; Fax: 08812-259531 e-mail : dr.rethinam@gmail.com
6.	Ownership	:	Society for Promotion of Oil Palm Research and Development, (SOPOPRAD) ICAR - Indian Institu.te of Oil Palm Research, Pedavegi - 534 450, West Godavari District, Andhra Pradesh, India
7.	Name of the Printing press	:	New Image Graphics, Vijayawada, Andhra Pradesh, India Phone: 0866 - 2435553, Cell: 93475 53274

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December, 2018

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Reg. No: 334/1996

International Journal of Oil Palm

Vol. 10 (1&2) June and December, 2018

CONTENTS

Printed and Published by: **Dr. B. Narsimha Rao**
Secretary on behalf of the Society for Promotion of Oil Palm Research and Development,
ICAR-Indian Institute of Oil Palm Research, Pedavegi-534 450, Andhra Pradesh, India
Printed at New Image Graphics, Vijayawada-2. Phone: 0866-2435553, Mobile : 93475 53274