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REVIEW ARTICLE

Prospects of American Oil Palm (*Elaeis oleifera,* HBK) Germplasm and Interspecific Hybrids in India

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ABSTRACT

Unlike African oil palm (*Elaeis guineensis*, Jacq.), American oil palm (*Elaeis oleifera,* HBK) has unique traits such as reduced height increment, palm oil with significantly high oleic acid, carotene and tocotrienols. However, a pure stand of *oleifera* is not cultivated and has inherent abnormalities in reproductive structures, which lead to poor fruit set. To overcome these, *oleifera* is backcrossed to *guineensis* (O×G) through interspecific hybridization (IS). Genetic diversity studies indicated that there are four geographically distinct populations of a pure stand of *oleifera* distributed in Brazil, Peru, Central America/North Colombia, and Surinam/French Guiana. *Oleifera* germplasm has been collected from above natural palm grooves and conserved in the field gene banks of oil palm growing countries. Advanced O×G hybrids were developed with a major breeding objective of improving palm oil quality and high-density planting. Some advanced O × G hybrids are reported to produce high oil yields close to that of *tenera* of African oil palm. The interspecific hybrids namely, BRS Manicore, PS4, AA Hybrida IS, #S (& #D), Amazon, Taisha, Sinu-Coari × Coari from EMBRAPA (Brazil), Malaysian Palm Oil Board (Malaysia), Applied Agricultural Resources (Malaysia), Palmelite (Formerly CIRAD, France), Agricultural Services and Development (Costa Rica), Instituto Nacional de Investigaciones Agropecuarias (INIAP), Ecuador and Peru, respectively are important examples for O×G hybrids. There are four *oleifera* accessions, namely, DOPR22, DOPR23, DOPR24, and DOPR25 available in India. Four genetic stocks *viz.*, Palm no.45 of Surinam of DOPR22, Palm No.6 of DOPR23, Palm No 48 of DOPR23, and Palm No.6 of DOPR25 were developed for improvement and introgression into Indian breeding programme. *Oleifera* genetic resources and O×G hybrids have good prospects for achieving high oil quality, disease tolerance/resistance, and suitable for high-density planting. India has a very narrow genetic base, and there is an urgent need to collect new materials from centers of origin by exploration and exchange through unilateral and multilateral collaborative research programmes.

Keywords: *Elaeis oleifera*, germplasm, interspecific hybrids, palm oil quality, India

INTRODUCTION

Oil palm is a strategically important crop to the world, and it is essential for India in view of ever-increasing demand for edible vegetable oil and their industrial utilities (Rethinam *et al.,* 2012, Chadha, 2006, Renjini and Jha, 2019). The cultivated type, *Elaeis guineenis* originated from West and Central Africa whereas, its wild relative *Elaeis oleifera* (HBK) originated from South America (Rey *et al.*, 2004) distributed between 11°N and 15°S (Andrade, 1983 and Corley and Tinker, 2003) and it can be differentiated from African oil palm (*Elaeis guineensis*, Jacq) by dwarf and slant trunk (Corley and Tinker, 2003). *E. oleifera* has important traits such as reduced height increment (Barcelos *et al.* 2000) (10-15 cm per year), tolerance to pest and disease, high quantity of unsaturated fatty acid, carotene (Choo *et al.*, 1997 and Choo *et al.,* 1996) and vitamin E (Corley and Tinker 2003) and Rocha, *et al.* (2006). It is to be noted that canola oil has the number one rank in terms of concentration of unsaturated monounsaturated fatty acids (61%) whereas soybean, sunflower, and African oil palm has 22%, 29.8% and 52.1% of unsaturated and

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monounsaturated fatty acids, respectively. Liquid or fluidity is more, if palm oil possesses high oleic acid (unsaturated) (Omorefe Asemota and Farida Habib Shah, 2004). The palm oil of *E. guineensis* contains approximately 50 % of saturated fatty acids, with 44 % of palmitic acid (C16:0), 5 % of stearic acid (C18:0), and trace amounts of myristic acid (C14:0). The unsaturated fatty acids are about 40 % of oleic acid (C18:1) and 10 % of poly-unsaturated linoleic acid (C18:2) and linolenic acid (C18:3) (Sambanthamurthi *et al.,* 2000). Whereas *Elaeis oleifera* has an average of 50.10% mono-unsaturated fatty acids, which is two percent lower than African oil palm. *Elaeis oleifera* also has lower saturated fatty acid (33.5+0.5), while normal oil palm has slightly more (47.3+0.1). The fatty acid, palmitic acid, (C16:0) is predominantly present in *guineensis,* whereas, in *E. oleifera*, oleic acid, (C18:1) is a predominant fatty acid. *Elaeis oleifera* produces oil with high carotene content of about 4000 ppm compared to 500-700 ppm in *Elaeis guineensis*. The mesocarp oil and fatty acids extracted from African and American oil palms are used in the cosmetic and biofuel industries (Corley, 1982). African oil palm is reported to grow vigorously about 60 cm/year, whereas *oleifera* shows an average height increment of 10-15 cm/year. Despite several desired features, pure *oleifera* stand has some bottlenecks *viz*., protracted anthesis duration, poor fruit set differences in ripening, and higher percentage of parthenocarpy fruits. These undesirable traits were reported by Rao and Chang (1982). Wiart and Gascon (1975) and Noiret and Wuidart (1976) confirmed that the main source of high levels of unsaturated fatty acids (60 to 75%) is *E. oleifera*. Modern oil palm breeding aims to increase the unsaturated fatty acid content of palm (Arasu *et al.,* 1987). Though, Indian oil palm industry is still in the infant stage it is expected that advanced indigenous technological interventions will bring positive changes. High cost towards harvesting and disease incidence too affects oil palm cultivation (Prasad, 2018). Identification of superior parents and progenies will give raise to superior quality and favors growth of agro industry (Kanimozhi *et al.,* 2018). A total of 1.93 million ha in 18 states has been identified as a potential area suitable for oil palm. About 2, 31,000 hectares are already under oil palm cultivation, of which Andhra Pradesh alone possesses 1, 27,000 ha (2012-13) (https://nmoop.gov.in). The states where there is maximum potential for oil palm cultivation are Andhra Pradesh, Karnataka, Tamil Nadu, Maharashtra, and Odisha. There is also bright scope to expand oil palm cultivation in the North-Eastern regions of the country (https://nmoop.gov.in). Considering the requirement of new varieties and limited availability of germplasm, all-out efforts must be undertaken for the collection of new germplasm, conservation, and effective utilization for the development of new varieties suitable for different agro-climatic conditions. In the present article prospects of *oleifera* germplasm and interspecific hybrids are reviewed with major emphasis to India

MATERIALS AND METHODS

Elaeis oleifera genetic resources

Elaeis oleifera is considered one of the precious genetic resources to overcome some of the problems being faced by oil palm industry. Dwarf palms facilitate easy to harvest (Diana Arias *et al.*, 2015; Murugesan *et al.,* 2011). The *Elaeis oleifera* is naturally found in South, Central America, from Honduras to Colombia and in the Amazon region (Raja Naidu, 1983). Researchers from various oil palm growing countries have collected *E. oleifera* germplasm and established field gene banks in Malaysia, Ivory Coast, Costa Rica, Brazil, and Colombia etc. The major players involved in oil palm collections in the primary centers of origin are MPOB (Malaysia), CIRAD (France), CENIPALMA (Colombia), EMBRAPA (Brazil), CNRA (Ivory Coast), INRAB (Benin), IRAD (Cameroon), ASD (Costa Rica) and INIAP (Instituto Nacional de Investigaciones Agropecuarias, Ecuador and others. Oil palm is cultivated in Brazil in the state of Pará located in the north. This region holds 80% of the Brazilian oil palm fields. O×G hybrid was mainly introduced here to reduce the incidence of bud rot (Chia *et al.,* 2009). In the Amazon forest, *E. oleifera* populations are usually found near rivers, on fertile and well-drained lands (Moretzsohn *et al.,* 2002). The molecular marker study revealed that there are four geographically distinct populations distributed in Brazil, Peru, Central America/North Colombia, and Surinam/French Guiana. The research findings of Araya *et al.,* (2009) and Barcelos *et al.,* (2002) confirmed the status of four geographically distinct populations of *oleifera* in the South American continent. Digner Ortega Cedillo *et al.,* (2016) studied and confirmed significant variation from accessions of *oleifera* in Ecuadorian Amazon. Extensive *E. oleifera* germplasm collection was also carried out in Latin America by Malaysia (Rajanaidu 1986). The performance of *Elaeis oleifera* from Panama, Costa Rica, Colombia and Honduras planted during 1982 were evaluated in Malaysia and reported significant differences for fatty acids compounds (Mohd Din *et al.,* 2000). Rajanaidu *et al.,* (1989) reported details of fatty acid components of O×G hybrids of South American germplasm collections in Malaysia, which are conserved in the field gene bank. It is reported that the '*oleifera*' found in Surinam is unique with very slow vertical growth and small inflorescence and high saturated fatty acid profile under Malaysian condition (Rao *et al*,1989). Surinam source of germplasm is not only diverse but also unique which deserves immediate attention for gene pool conservation (Corley and Tinker, 2003). Hardon (1969) demonstrated that there are significant differences between the species *Elaeis oleifera* and *Elaeis guineensis* regarding the content and type of fatty acids present in their oils. Wei Xia *et al.,* (2019) assessed fatty acid compounds in 200 genotypes and recorded 31.3 to 48.8-of palmitic acid, 31.3 to 50.1%, of oleic acid, 7.1 to 18.5% linoleic acid with total oil content of 29.8 to 70.3%. A total of 175 accessions of *E. oleifera* collected from the Amazon River basin were assessed for genetic diversity, and most of the variations were observed within-population, which confirms allogamous nature of perennial species (Moretzsohn *et al.*, 2002). *Oleifera in situ* characterization from Amazonian Trapezoid collected by Cenipalma revealed high variation in vegetative characteristics and bunch components. The values in ranges for unsaturated fatty acid, Iodine Value, carotene content and Vitamin E are 68-73.5%, 76.4 to 84.5, 1880-6527ppm, 519 to 1140ppm, respectively (Rey *et al.,* 2004). Barcelos *et al*., (2005) highlighted the presence of traits responsible for the drought, waterlogging, and nutrient deficiency management in *oleifera* germplasm. Hence, the collection and conservation of germplasm should be further intensified to prevent the extinction of diverse and wild relatives.

RESULTS AND DISCUSSION

Interspecific hybrids

American oil palm is the main source of genetic variability for oil palm breeding. Despite desirable qualities, cultivation of pure stand of *E. oleifera* is not viable economically, due to its low yields (< 1.0 tonne oil/ ha/year) compared to *E. guineensis* (4-5 tonnes oil/ ha/year). Since two species hybridize easily, interspecific hybrids could be obtained with yields around 90% of the *E. guineensis* (Amblard *et al.*, 1995). To introgress traits of oil quality and low height increment from *E. oleifera* into *E. guineensis*, two species are hybridised (Hardon and Tan, 1969) to produce *oleifera* × *guineensis* (O×G) hybrids. Subsequently, O× G hybrid is backcrossed to its selected *E. guineensis* parent to improve the yield. The hybrid between above two O × G hybrid is nowadays suggested for specific situations like bud rot infested area (Torres *et al.,* 2010) and high-density planting etc. Replanting of O× G hybrids is also undertaken by some oil palm countries in view of catastrophic bud rot disease spread in South African countries (De Franqueville 2003). The palm with a high content of unsaturated fatty acids attracts a new market for growers (Montoya *et al.* 2013). BRS Manicoré is the first national O×G hybrid developed by EMBRAPA (Cunha and Lopes, 2010). First reported F1 hybrids were from Oil Palm Genetics Laboratory, Johor, Malaysia, during 1969. Malaysian Palm Oil Board has developed a hybrid, namely PS 4 enriched with palm oil with high carotene content utilized from *Elaeis oleifera* germplasm (Mohini *et al.,* 2002). Malaysia has developed an oil palm hybrid with high oleic acid (approximately 52%) (Rajanaidu *et al.,* 2017). A company, namely, Applied Agricultural Resources Sdn. AAR, Malaysia has an exclusive breeding programme of *E. oleifera* that resulted in the creation of the AA Hybrida IS. Interspecific hybrids are commercially produced for local and overseas markets (Abdul Rahim *et al.,* 2017) under a favorable growing environment, a maximum of 35 tonnes of fresh fruit bunch and 8-9 t of crude palm oil per hectare is reported in Hybrida1 during 7-10 years after planting. Hybrid seeds of O× G are produced through bi-clonal seed production system. Another France based company called Palmelite (formerly known as CIRAD) developed interspecific hybrids with premium oil quality (low lipase and acidity) and high-density planting (Legen *et al.,* 1991). Some improved interspecific hybrids found to exhibit slow fruit detachment even after full ripe maturity (Ochoa *et al*., 2013). 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 (IER) of CPO and 160 palms population hectare^{-1} can be accommodated for '#D'. One O ×G hybrid 'Amazon' (with high oil quality) developed by ASD Costa Rica (South America) can accommodate 135 palms in a hectare of land (Alvarado and Escobar, 2016). Amazon was developed from the *oleifera* germplasm collected from Manaos region of Brazil (Murugesan and Sunil Kumar, 2014). It is reported that O × G hybrids developed from Taisha (Ecuador) had the potential to produce high oil yields close to that of *dura* × *pisifera* (*tenera*) seeds of *E. guineensis*. There are indications that interspecific hybrid (*E. guineensis* × *E. oleifera*) presents tolerance to drought, waterlogged soils and nutrient deficiency (Barcelos *et al.*, 2005). Moreover, some selected interspecific hybrids (Deli × Yangambi NIFOR) were found to have slow fruit detachment (Ochoa *et al.,* 2013); lower lipase activity and slow development of free fatty acids in oil (Cadena, 2013). Promising four back crossed families (sourced from South American countries) were developed from United Plantation Berhad, Malaysia, capable of fresh fruit bunch yield up to 35 tonnes/ha/year in the second year of harvest with oil/ bunch ratio of 32 percent and oil yield potential of 10 tonnes/ha/year. Selection of ortets from these back crossed progenies are under progress with an objective to develop compact clones and seed progenies with 6.25 per cent *E. oleifera* traits. Such hybrids are amenable to high-density planting of 200 palms/ha compared to conventional 136-160 palms/ha. An interspecific hybrid from Peru namely, Sinu-Coari ×Coari ×La me had a higher capacity of Co_2 fixation coupled with desirable agronomic performance (Rivera *et al.*, 2013). Ibarra-Ruales and Reyes-Cueta (2015) reported that O × G (F1) hybrid showed vigorous growth and accumulated more biomass (when compared to normal *tenera* hybrid) in the plant parts maintained in the nursery in Colombia. The popular interspecific hybrids of CENIPALMA of Colombia, namely Coari× Lame (O×G) hybrids, had mean lipase enzyme activity ranged between 28.5 to 38.6 Free Fatty Acid, whereas *E. quieensis* and *E. oleifera* recorded lipase value of 52.7 % and 0.6%, respectively (Cadena *et al,* 2013). Preciado *et al.,* (2011) predicted the ripeness period of O×G hybrid and obtained high oil extraction between 170 and 180 days after artificial pollination. Similarly, Rincon *et al.,* (2013) obtained optimal harvest stage coinciding with high oil content at stage 807 in hybrid Coari ×Lame and estimated to take 204 days to complete fruit ripening up to senescence. Phenology of O×G hybrid has been studied by Hormaza *et al.,* (2012) and Sandra Milena Rincóna, (2013). Macfarlane *et al.*, (1975) had analyzed mesocarp and kernel oils from the *oleifera* and their progenies. World over about 2.5 million interspecific hybrid seeds are produced every year from Ecuador (CIRAD Partners – 1 million), Colombia (La cabana – 0.3 million, Indupalma – 0.2 million) and Brazil (Embrapa – 1 million) for commercial cultivation (Murugesan and Rethinam, 2018). Interspecific hybrid of Brazil namely 'BRS Manicoré' when tested for seed germination showed only 30-35 % germination owing to its wild character (Wanderlei Antônio Alves Lima *et al.,* 2014). The above organizations could establish multi-location trials using the collected materials both in donors and their research stations. A selection cycle that includes evaluation and phenotypic selection and hybridization to produce new progenies requires around 20 years (Corley and Tinker, 2003). Genomic *in Situ* Hybridization (GISH) developed at Malaysian Palm Oil Board (MPOB) could be utilized to ascertain the amount of introgressed parental genomes into O × G hybrids (Madon *et al,* 1999). This technique can show a clear differentiation between the *E. oleifera* and *E. guineensis* genome. Singh *et al.,* (2004) sequenced the genome of *E. guineensis* and found to be about 1.8 GB and detected no significant differences between two species. Interspecific hybrids have thin shell but lack fiber ring unlike that of normal hybrids (*tenera*) developed by crossing *dura* (thick shell) and *pisifera* (shell-less) in *E. guineensis*. Fruit detachment and build-up of free fatty acids are slow in *E. oleifera* compared to *tenera*. The yield of the hybrids in terms of total fruit weight was promising, but the oil content of the mesocarp is intermediate between the parental species and lower than in *E. guineensis*. E. *oleifera* has a marked tendency towards the production of parthenocarpy fruits and this character was fully dominant in the hybrids. Because of this, the percentage fruits per bunch in the hybrids tend to become greater than in *E. guineensis,* and this partly helped to compensate for the lower percentage of oil in the mesocarp. 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). We need to evaluate the genetic variability of the progenies of *oleifera* and interspecific hybrids to select best-combining parents (Rui Alberto Gomes *et al.*, 2014).

Elaeis oleifera in India

There are four *oleifera* accessions namely, DOPR22 (Suriname), DOPR23 (Malaysia), DOPR24 (Costa Rica), and DOPR25 (Oil Palm India Limited-Chithera) available in India (Murugesan, and Sunil Kumar, 2014). They were introduced to India along with commercial planting materials (Murugesan and Sunil Kumar, 2014). Out of four sources, three accessions are available at Palode, Kerala, and another source (two palms) was located at Chithara Estate of Oil Palm India Limited (OPIL), Kerala (Murugesan, 2010). Three accessions planted at Palode have been designated as DOPR G 22, 23, and 24 and evaluated for selection of promising individual palms for further improvement (Murugesan and Shareef, 2014). Interspecific hybridization programme has been undertaken in India with an objective to obtain cultivars with high fruit and oil production per unit of area, low annual height increment, and oil with high content of unsaturated fatty acids and carotenes (Murugesan and Sunil Kumar, 2014). Interspecific hybrids (O×G) of seven combinations were developed in India utilizing *oleifera* of DOPR 23 and Palode *dura* and the progenies were planted during 1998. Three promising dwarf interspecific palms, namely 47 (361Eg × 11Eo), 48 (16Eo × 18Eg) and 6 (12Eo × 82Eg) were identified from this field trial (Sunil Kumar *et al* .,2015). Notably, palm No 48 (genetic stock from one of the above combinations) namely, 16O × 18G showed unique characteristics *viz*., high fruit set, and unique fruit color (deep red skin and yellow mesocarp) apart from compact slow height increment (Murugesan *et al.*, 2019). The evaluation indicated that DOPR G23 and DOPR G24, grow vigorously and with a height increment of 24 and 34cm, respectively. They also had a rachis length of 6.66 m in DOPR G23 and 6.24 m in DOPR G24. DOPR 23 had a height increment of 15 cm with 6.4 m rachis length. Leaf area is also considered for screening of germplasm as it contribute to photosynthesis (Kalarani *et al.*, 2018). One interspecific palm No. 6 of DOPR 23 with high yield and other desirable characters was alone taken forward to F1 backcrossing programme after evaluation at Palode, Kerala (Murugesan and Shareef., 2014) which recorded highest FFB yield and possessed compact characteristics was ultimately selected for producing interspecific hybrids and further breeding for dwarf palms. *E. oleifera* from OPIL exhibits all the desirable characters, especially for fruit weight (15.41g), Fruit to Bunch (61.46%), and height increment (15cm). Notably, it has a distinct trait of the large kernel with an average nut weight of 6.95g per fruit. Selfed and *inter se* mated progenies of DOPR 25 were planted during 2010 as an observation trial at Palode and progenies showed precocity for bunch production, with very low height increment and normal fruit set and high sex ratio (Murugesan and Sunil Kumar (2014a) and Murugesan and Sunil Kumar, 2014b). A germplasm accession of *Elaeis oleifera* of Surinam source showed early fruit ripening and harvestable maturity (4.5 months) under the tropical climate of south India (Murugesan *et al*., 2011). These Suriname materials were believed to be sourced from Nigeria and the identified palms were located inside the Oil Palm India Limited estate located at Chihara, Kollam district of Kerala (Murugesan, 2010). To get uniform germination and seedlings and to facilitate the precise evaluation of progenies of interspecific hybrids, the mechanical scarification techniques were developed (Murugesan *et al*., 2015). Notably, four genetic stocks *viz*., Palm no.45 of Surinam of DOPR 22, Palm No.6 of DOPR G 23, Palm No 48 of DOPR 23 and Palm No.6 of DOPR 25 were developed for improvement and introgression into current Indian breeding programme. *Oleifera* genetic resources and O×G hybrids have good prospects for achieving high oil quality, disease tolerance/ resistance, high-density planting, and commercial cultivation. But, India has a very narrow genetic base (Rethinam and Vinod Kumar, 1998) and there is an urgent need to collect new materials from centers of origin by exploration and exchange through unilateral and multilateral collaborative programmes for broadening the genetic base (Murugesan *et al.,* (2016) and Rethinam, 2018).

CONCLUSION

Oleifera germplasm has been collected from the natural palm grooves of South America and conserved in the field gene banks of Malaysia, Ivory Coast, Costa Rica, Brazil, Colombia, and other oil palm growing countries. Though *oleifera* is not in cultivation but extensively used in advanced crop improvement programmes as they have desirable traits, *viz*., slow vertical growth, superior oil quality, and disease tolerance. Interspecific hybrids (O×G) are produced through the conventional breeding programme for introgression of desirable traits. Several advanced O×G hybrids were developed from different research organizations with a major breeding objective of improving palm oil quality and high-density planting. Replanting O× G hybrids is also undertaken by some oil palm producing countries in view of catastrophic disease spread in the plantation planted with *tenera* hybrids, especially in South America. Some advanced O×G hybrids are reported to produce high oil yields close to that of *tenera* of *Elaeis guineensis*. Interspecific hybridization programme has been initiated in India with an aim to achieve superior palm oil quality with palms suitable for high-density planting. The preliminary evaluation indicated that some individual palms of indigenously developed genetic stocks showed precocity for bunch production and recorded very low annual height increment with normal fruit set and high sex ratio. Four such *oleifera* genetic stocks and breeding lines are available for further evaluation and improvement. There is an urgent need to introduce targeted germplasm from centres of origin by exploration and exchange through unilateral and multilateral collaborative programmes for broadening the genetic base for the development of new varieties suitable to different agro-climatic conditions of India.

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