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Bibliographic review

The African oil palm (*Elaeis guineensis* Jacq) is a solution for oil production

La palma aceitera africana (*Elaeis guineensis* Jacq) una solución para la producción de aceite

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ABSTRACT: Vegetable oil known as palm oil, the most widely used in the world, is produced from the pulp of the fruit, and from the seed or kernel, the so-called palm kernel oil is obtained. It has multiple uses in the food industry, pharmaceuticals, cosmetics, organic fertilizers, animal feed, as well as a renewable energy source. Its cultivation has a commercial productive life of over 25 years, and it yields five times more oil than soybean cultivation. Although contribute to reforestation and ecological balance in production areas by providing oxygen to the environment and capturing CO_2. This work addresses the taxonomic classification and morphology of the oil palm, its soil and climate requirements, production technology, aspects of the agro-industrial process, the products extracted, its economic importance, as well as the management of the specie within an integrated polyculture system, results of its use in different countries, and its introduction in Cuba, where it already exists naturally.

Key words: palm oil, palm heart, germination, nurseries, polycultures.

RESUMEN: El aceite vegetal conocido como aceite de palma, el más utilizado del mundo, se produce a partir de la pulpa del fruto y de la semilla o nuez se obtiene el llamado aceite de palmiste. Posee múltiples usos en la industria alimenticia, farmacéutica, cosméticos, abonos orgánicos, piensos, así como fuente renovable de energía. Su cultivo posee una vida productiva comercial superior a 25 años y de él se obtiene cinco veces más aceite que con el cultivo de soya. Además contribuye en la reforestación y equilibrio ecológico en las zonas de producción con aportes de oxígeno al medio y captación de CO_2. En el presente trabajo se aborda la clasificación taxonómica y morfología de la palma aceitera, sus requerimientos edafoclimáticos, tecnología de producción, aspectos del proceso agroindustrial, los productos que se extraen, su importancia económica, así como el manejo de la especie dentro de un sistema integrado de policultivos, resultados de su empleo en diferentes países y su introducción en Cuba, donde ya habita de forma natural.

Palabras clave: aceite de palma, palmito, germinación, viveros, policultivos.

INTRODUCTION

Oil palm is a perennial tropical plant adapted to warm climates, typically growing in areas below 500 meters above sea level. It is commercially cultivated for oil extraction and comprises three ancestral varieties: dura, pisifera, and tenera (1). Originating from the Gulf of Guinea in West Africa, it was introduced to other regions of Africa, Southeast Asia, and Latin America, hence its common designation as African oil palm. Its introduction into tropical America is attributed to Portuguese colonizers and slave traders, as it formed part of the dietary staples of enslaved populations in Brazil (2). Today, it is extensively cultivated in Indonesia and Malaysia leading global producers of palm oil as well as in other regions including Central and South America, Thailand, and West Africa (1, 3, 4).

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The vegetable oil extracted from this crop, known as palm oil, is the most widely used worldwide. It is obtained primarily from the pulp of the fruit, while the seed or kernel yields palm kernel oil (3, 5). When cultivated for commercial purposes, oil palm has an average lifespan of 24 to 28 years. Fruit bunch production begins approximately 24 months after planting and continues throughout its productive life, yielding around 10 tons of fruit per hectare annually. Between 24 and 36 months of age, yields may reach up to 28 tons, and by the sixth year in the field, production stabilizes at levels ranging from 26 to 32 tons of fruit bunches annually, sustained for 20 -23 years (6).

Palm oil has multiple applications, including cooking oil and as an ingredient in bakery, confectionery, ice cream, instant soups, sauces, and a wide range of frozen and dehydrated foods, as well as non-dairy creamers for coffee (2). Its solid fat content provides a semi-solid consistency without the need for hydrogenation, making it suitable for products such as margarine and chocolate spreads (3, 6). It also serves as a raw material in the manufacture of soaps, detergents, lubricating greases, and metallic dryers used in paints, varnishes, and inks. By-products include organic fertilizers, animal feed, and potential sources of renewable energy and liquid biofuels.

Several key aspects highlight its importance: oil palm is a profitable crop with a commercial productive life exceeding 25 years; it yields five times more oil than soybean cultivation; it contributes to reforestation and ecological balance in production areas by releasing oxygen and capturing CO_2 (7, 8); and its oil production reduces imports while generating thousands of jobs.

TAXONOMIC CLASSIFICATION AND MORPHOLOGY OF THE OIL PALM

The oil palm (*Elaeis guineensis*) belongs to the Kingdom Plantae, Division Magnoliophyta, Class Liliopsidae, Subclass Commelinidae, Order Arecales, Family Arecaceae, Subfamily Coryphoideae, Genus *Elaeis*, with two species: *Elaeis guineensis* Jacq. (African oil palm) and *Elaeis oleifera* (Kunt) Cortes (American oil palm) (9).

Among these species, *E. guineensis* is the most widely used commercially worldwide and the most extensively studied (10), whereas the American oil palm *E. oleifera* is native to Central and South America and typically grows in poorly drained, clayey soils or lowland plains (11).

Morphologically, the plant exhibits a single stem or trunk (stipe) without branching, with a single growth point or apical meristem located centrally. The trunk is cylindrical and covered with the bases of previous leaves. Its diameter usually ranges from 45 to 68 cm, with a circumference of about 355 cm, and a thicker basal section. The dry leaf sheaths remain attached to the trunk for long periods, giving the impression of a larger diameter (12).

Inter-specific crosses between *E. guineensis* and *E. oleifera* have produced cultivars with very slow annual stem growth, which has attracted the interest of plant breeders, as this facilitates harvesting (12).

By approximately three years of age, the stem elongates as leaves emerge. These leaves are green, numbering 20-30 per year, and the plant can sustain between 40 and 56 leaves, each measuring 6-8 m in length, arranged spirally in a clockwise direction from top to bottom. Typically, three leaves are produced for each fruit bunch, with an average of two to three new leaves per month. The leaf axis is divided into a basal, broader section with thick, sharp, flat spines along the margins, and a rachis bearing numerous leaflets (10, 12). The proximal part of the rachis, the petiole, broadens and attaches to the trunk, while stomata are located on the abaxial surface of the leaf (10, 12).

At the lower part of the trunk, a conical structure known as the bulb gives rise to primary roots, which in turn produce secondary, tertiary, and quaternary roots. This forms a fasciculated, adventitious, fibrous root system, predominantly horizontal and distributed within the top 60 cm of soil. Although primary roots descend deeper, with some reaching up to 4.5 m, their number varies greatly and continues to be produced throughout the palm's lifespan (10).

The oil palm is a monoecious species, with flowers borne on clustered spikes within a large spadix that develops in the leaf axil. Inflorescences may be interfoliar and spiny, either male finger-like with a pointed tip or female, compactly grouped, with alternating male-female flowering cycles. Each inflorescence produces 25-30 grams of pollen, released 2-3 days after flowering is completed. Pollination occurs through wind and insect activity (13, 14).

The fruits are ovoid drupes, reddish-black in color due to their high β-carotene content. They measure approximately 4 cm in length and consist of an exocarp (skin), mesocarp (pulp), from which palm oil is extracted, and an endocarp enclosing the kernel. The kernel, together with the endocarp, forms the seed, from which palm kernel oil is obtained. Fruits are borne in generally ovoid bunches (10, 15).

EDAPHIC AND CLIMATIC REQUIREMENTS

Oil palm requires well-drained soils to prevent flooding, with profiles between 60 and 100 cm in depth, sandy clay loam textures, flat or slightly undulating topography with slopes below 15 %. Suitable sites are located up to 500 m above sea level, free of gravel within the first 1.2 m of the soil profile, with good aeration and sufficient moisture availability throughout the year. However, the crop does not tolerate permanently high water tables in impermeable soils. Clay soils should be avoided due to drainage problems, as well as sandy soils, which generally present poor water retention and low nutrient balance (10, 15-17).

The appropriate soil pH ranges between 4.5 and 7.0, with organic matter content between 2.0 and 4.0 %. Potassium is the nutrient most absorbed by the crop, contributing to the development of meristematic tissues, playing a fundamental role in water regulation, evapotranspiration processes, and oil production. In balance with nitrogen, potassium helps mitigate pest incidence, while in combination with calcium and magnesium it prevents leaf yellowing (18).

In Cuba, soil classification comprises 15 groupings, 39 genetic types, and 197 subtypes (19), each with specific characteristics that make them suitable for different crops, including oil palm.

Climatic requirements for oil palm cultivation include an annual rainfall of 2000-2500 mm, evenly distributed throughout the year, with monthly precipitation above 100 mm. Optimal growth occurs under maximum mean temperatures of 29-33 °C and minimum mean temperatures of 22-24 °C, with accumulated solar radiation exceeding 1500 hours and at least five continuous hours of sunshine per day. Relative moisture should range between 75 and 85 % (17).

Plants are not static organisms; they constantly change as part of their normal growth and development processes, progressing from seed to seedling. Growth cycles include a vegetative phase followed by a reproductive phase, encompassing flowering, fruiting, and seed formation, which initiates a new cycle. In perennial species such as oil palm, it is possible to identify the precise developmental stage of an inflorescence or fruit bunch, or to monitor the development of a leaf from its emergence to senescence. The duration of each phenological stage is strongly influenced by climate, which determines the basic cycles of plant development (9).

OIL PALM PRODUCTION TECHNOLOGY

The seeds of *E. guineensis* have been classified as intermediate between recalcitrant and orthodox, since storage at temperatures between 0 and -20 °C reduces viability, although they can be preserved with low moisture content (20). After maturing inside the fruit, seeds generally enter dormancy, which is broken when exposed to prolonged periods of heat, moisture, oxygen, and scarification, among other factors (21). In West Africa, oil palm seeds germinate sporadically under natural conditions over several years; however, under continuous treatment at temperatures between 38 and 40 °C, germination occurs within a few months (22).

Seed heating is commonly used to weaken the operculum and initiate germination (20). Two techniques are employed commercially: dry heat and moist heat, with the former being most widely used. Under dry heat, seeds undergo two imbibitions and heating at 37-39 °C for 50 days. This method has the advantage that moisture content is less critical compared to moist heat, and with relative humidity between 14-21 %, germination rates above 85 % can be achieved (23).

Once germination occurs, a haustorium develops rapidly at the expense of the endosperm, eventually filling the kernel. At this stage, seedlings are transferred to the pre-nursery for 3-4 months. During this period, young seedlings pass through the following stages: germinated seed transplanted with plumule and radicle; emergence of the first two leaves and adventitious roots during the first month; and by the second month, the first lanceolate leaf and primary root appear (24).

At four months, seedlings are ready to be transplanted into nursery bags under sunlight, having developed 3-4 lanceolate leaves and a well-formed root system with primary, secondary, and tertiary roots. Shade is progressively removed (24). Between 12 and 14 months, seedlings reach the optimal stage to withstand field transplanting shock (1). Only vigorous seedlings are selected to ensure successful plantation establishment, early fruiting, and desirable yields, while abnormal seedlings (poorly developed, stunted, erect, fused lamina, rolled or narrow leaves) are discarded (25, 26).

Different experiences indicate that the minimum nursery period for identifying phenotypic traits and discarding abnormal palms is 10 months (1, 27, 28). In single-phase nurseries, the minimum transplanting age is 11 months, whereas in two-phase nurseries it is 12 months (29, 30). The maximum transplanting age depends on nursery purpose; for new or renewal plantings, the recommended maximum nursery period is 14 months.

Industrial programs usually establish nurseries near the definitive planting site and water sources. Soils must be well-drained, with slight slopes to facilitate runoff, and free of weeds. Nursery beds are typically 1.5 m wide and 20 m long, containing about 5000 bags separated by 0.8 m paths, with shading to promote establishment and reduce seedling dehydration (24). Shade may be provided with fresh palm leaves arranged on crossbars (3-4 per linear meter) or artificial polyethylene shade nets. Surrounding the pre-nursery with a drainage trench 25-30 cm deep is also recommended (24).

Polyethylene bags (8.5 cm wide, 20 cm high) perforated with 20 holes of 5 mm diameter at the base are filled with humiferous topsoil (10 cm), enriched or not with organic matter, and disinfected 15 days before transplanting. A 2-3 cm deep hole is made in the center of each bag, where the seed is placed with the radicle downward, covered with a maximum of 1 cm of soil. After transplanting, light irrigation is applied, and weeds are controlled manually in beds and chemically in paths (24).

Substrates must allow good seedling establishment. Weekly supplements may be applied from the end of the first month, consisting of 25 g of urea dissolved in 10 L of water for 1000 seedlings, followed by light irrigation to prevent burns (24).

Permanent phytosanitary monitoring enables early detection of pests. The main pre-nursery disease is anthracnose (*Colletotrichum gloeosporioides*), associated with excessive humidity, which can be prevented with good aeration and preventive fungicides. Insects such as defoliators, ants (*Formicidae*), termites (*Isoptera*), mole crickets (*Gryllotalpa gryllotalpa*), slugs (*Stylommatophora*), snails (*Stylommatophora*), and rodents (*Rodentia*) may also cause damage (24).

In the field, common diseases include bud rot (*Phytophthora palmivora*), foliar cryptogamic diseases caused by *Curvularia*, *Bipolaris* (*Helminthosporium*), *Cercospora*, and anthracnose (*C. gloeosporioides*) in the Americas (24).

Recommended planting density is 143 palms per hectare, with spacing of 9 m between stakes and 7.8-8 m between rows (27, 29). Nutrition at this stage should include basal fertilization with organic matter, as well as maintenance with nitrogen, which enhances leaf greenness, stem girth, and plant height (28, 29). Gibberellic acid is also recommended, as it stimulates segment elongation and is associated with floral initiation processes, being vital for male and female fertility (1).

Water deficit in oil palm cultivation reduces leaf production and delays leaf opening, thereby lowering transpiration. This results in delayed leaf emission, awaiting favorable conditions for expansion. Inflorescences associated with these leaves are similarly delayed, affecting production 15-24 months later. Water stress may also reduce fruit weight and oil content (31, 32).

AGRO-INDUSTRIAL PROCESS AND PRODUCTS EXTRACTED FROM OIL PALM

The industrial process of African oil palm (*Elaeis guineensis*) extraction comprises the reception and storage of fruit bunches, sterilization, fruit stripping, digestion and pressing, clarification, kernel recovery, steam generation, oil refining, and effluent treatment. Harvesting of fruit bunches in plantations must follow optimal criteria to ensure both yield and oil quality. Immature fruits contain lower oil percentages, while overripe fruits produce oil with high acidity; therefore, yield and final product quality are largely determined in the field (33).

Once bunches enter the processing facility, the industrial process begins with sterilization. Sterilizers are horizontal boilers using saturated steam at 42 psi and 105 °C. The purpose of this step is to neutralize acidity, loosen fruits from the bunch, soften the pericarp pulp, condition kernels through dehydration, and break down mucilaginous materials to prevent colloid formation, thereby facilitating crude palm oil clarification. Subsequently, sterilized fruits are separated from the bunch and macerated under direct steam for 20-25 minutes to loosen the pericarp and rupture oil-bearing cells in the pulp, releasing oil. This operation separates liquids (water, oil, fibers) from solids (fiber, broken kernels, nuts). Clarification then mechanically separates oil and water into two distinct layers (33).

In kernel recovery, pneumatic equipment is used to separate heavier particles from lighter ones. Press cake is separated from nut fiber, which is used as boiler fuel. Nuts are cracked in mills, and kernels are separated from shells pneumatically, stored in drying silos, and processed to obtain palm kernel oil and palm kernel cake. Waste products (fiber and shells) serve as excellent boiler fuels, creating a circular process that sustains fruit cooking, process temperatures, and electricity generation. Oil refining involves heating crude oil to 100-110 °C, followed by filtration. The oil is then deodorized (removal of free fatty acids), cooled, and stored (33).

Effluent treatment in the industry involves lagoons constructed in soil, where wastewater is retained and subjected to physicochemical processes mediated by microorganisms. This effluent removal system is designed to capture methane gas, which is used as boiler fuel and to generate electricity via biogas (33).

Processing of oil palm bunches, particularly the clarification stage, largely determines not only process efficiency but also the quality of crude palm oil in terms of moisture, impurities, and free fatty acid content (34). Oil extracted from kernels represents 20-25 % of bunch weight, while palm oil production reaches 4-5 tons per hectare annually. Each bunch also yields fiber equivalent to 13 % of its weight and rachis (empty stalks) equivalent to 22 % (33).

Palm oil is refined without chemical solvents, reducing the risk of contamination by residues. It contains balanced proportions of unsaturated and saturated fatty acids: approximately 40 % oleic acid (monounsaturated), 10 % linoleic acid (polyunsaturated), 44 % palmitic acid (saturated), and 5 % stearic acid (saturated). It is a natural source of vitamin E (tocopherols and tocotrienols) and, in its unrefined form, also of vitamin A (6, 35).

OIL PALM WITHIN AN INTEGRATED POLYCULTURE SYSTEM

Sustainable production implies the efficient use of resources, thereby reducing pressure on the environment, soil, and natural resources (36, 37). This is achieved through the adoption of good agricultural practices, application of circular economy principles, substitution of high-impact inputs, replacement of obsolete technologies, and innovation in processes (38). For its implementation, the oil palm sector must focus on renewable energy use, optimization of land utilization, biodiversity protection, adoption of sustainable agro-industrial practices with low carbon emissions, utilization of biomass generated during oil extraction to produce energy and products that drive the circular economy, and proper effluent treatment to minimize pollution and greenhouse gas emissions. Furthermore, effluents rich in nutrients should be recovered and reintegrated into plantation soils to reduce dependence on chemical fertilizers (39).

Environmental groups, research institutions, and ecologists have expressed concern regarding the expansion of oil palm cultivation and its effects on native habitats, plant and animal diversity (40). The main issue remains ecological sustainability, which requires environmentally friendly management practices that achieve high yields while mitigating ecological impacts, particularly on soil biota (41).

To mitigate ecological problems and improve crop management, proposals have been identified to reduce biodiversity impacts and address ecological obstacles caused by the expansion of oil palm cultivation, including aspects related to ecosystem services and agroecological practices (42-44). Some studies argue that oil palm cannot be intercropped with food crops due to its canopy coverage, which limits light availability at the soil surface (45). However, subsequent results demonstrate that oil palm can be combined with other agricultural and forestry crops (46), increasing household income, restoring degraded areas, and reducing greenhouse gas emissions (47).

During the first three years in the field, oil palm can be intercropped with short-cycle crops. After this stage, alternate rows may be used for crops such as coffee, which require lower light intensity, or for small livestock grazing.

The increasing frequency of extreme events such as droughts, floods, temperature variation, and pest pressure will progressively exert more negative effects on global food production, growth, and yield (48). Climate change alone is expected to increase food prices, leading to more frequent social disruptions (49).

Therefore, oil palm cultivation must adapt to climate change through agroecological measures that include diversification of agroecosystems in the form of polycultures, agroforestry systems, and integrated crop-livestock systems (50). These should be accompanied by organic soil management, water conservation and harvesting, and a general increase in agrobiodiversity. Transformation is needed to promote plant diversity, landscape heterogeneity, and strategies that enhance productivity, sustainability, and resilience of agricultural production, while reducing socio-economic and environmental impacts of climate change (51, 52).

In Cuba, researchers conducted a survey of oil palm and found specimens in Pinar del Río province (Los Palacios municipality), 82 in Artemisa (Los Pinos locality), three in Havana (National Botanical Garden), and 18 in Matanzas (Hotel Gran Memory Resort gardens). According to local surveys, palms in Artemisa were introduced into the country by Ernesto Che Guevara in 1960, planted over an area of 4.5 ha. Palms found in Matanzas appear to possess some resistance to salinity, although no references were found in the literature. Researchers concluded that exploitation of African oil palm is possible, as specimens in different localities produce bunches without recommended agronomic management, and its presence in other unexplored areas cannot be ruled out (53).

Oil palm production in Cuba can be linked to climate change adaptation through agroecological techniques such as diversification with other species, organic soil management with biofertilizers (54, 55), efficient water harvesting systems to increase resilience to drought and extreme climatic events, and carbon sequestration (7, 8), which helps mitigate climate change. International experiences show that oil palm production can be combined with land restoration (56). Integration with native flora may also serve as a model to prevent deforestation and promote biodiversity (56).

Thus, it is necessary to train producers in agroecological techniques specific to oil palm, foster community participation, and ensure public policies that support sustainable production and climate change adaptation, thereby guaranteeing food and nutritional security in each territory (53). In Cuba, oil palm can be intercropped with species that enhance biodiversity, such as nitrogen-fixing legumes that improve soil fertility, fruit trees and climate-adapted forest species, favoring diversified agroforestry systems, and plant species that host beneficial insects (56).

CONCLUSIONS

From the African oil palm (*Elaeis guineensis* Jacq), the most widely used vegetable oil in the world is obtained, serving both food and industrial purposes, including biodiesel production. In Cuba, specimens exist in different localities which, despite not being subjected to the recommended agronomic management practices, are capable of producing fruit bunches. These palms can be utilized to develop a production technology that meets the demand for oil intended for food, industrial applications, and as a renewable energy source in the form of biofuel.

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