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COMPARISON OF 2023 PRODUCTION COSTS BETWEEN HYBRID OxG AND *Elaeis guineensis* CROPS IN COLOMBIA

MAURICIO MOSQUERA-MONTOYA[1]*; ELIZABETH RUIZ-ALVAREZ[1] and DANIEL EDUARDO MUNÉVAR-MARTÍNEZ[1]

ABSTRACT

The area planted with Elaeis oleifera *x* Elaeis guineensis *hybrids (OxG hybrids) crops in Colombia is on the rise and nowadays more than 90,000 ha (10% of the cultivated area in Colombia) are currently planted with them. Today, after 15 years of commercial operations of OxG hybrids, there is a set of management practices that includes artificial pollination, harvesting of fresh fruit bunches (FFB) by implementing appropriate ripeness criteria for each type of OxG cultivar, adjustments to OxG nutrition programs and adjustments to the oil extraction process from OxG FFB. This set of OxG crop management practices is the result of years of research by CENIPALMA and, technological adoption by Colombian companies that have pioneered the planting of OxG hybrid cultivars. The adoption of OxG crop management practices has led to the production of an average of 30 t FFB/ha in mature crops, which is higher than FFB production obtained in* E. guineensis *crops. The results of this analysis allow us to conclude that the OxG hybrid business is currently viable with a unit cost of production of USD102.22/t of FFB [and USD507.90/t of crude palm oil (CPO)], very close to that obtained in* E. guineensis *cultivars of USD107.65/t of FFB (and USD510.03/t of CPO). Our analyses also yield that cropping OxG hybrid oil palms is a better economic alternative than cropping* E. guineensis *oil palms. Presenting results on the estimation of unit costs for OxG crops is relevant because the palm oil agri-business from OxG hybrids is a relatively recent development.*

Keywords: artificial pollination, cost estimation, optimal harvest time.

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INTRODUCTION

In 2022, more than 24 million hectares of oil palm were cultivated worldwide, resulting in a production of 79.157 million tonnes of oil. In 2022, Colombia contributed 2.2% of the oil produced in the world (1,932,000 t grown on 576,799 ha) (FEDEPALMA, 2023). Oil palm (*Elaeis guineensis*) stands out for its high productivity. In 2022, yields/ha ranged from 3.25-4.19 t of crude palm oil (CPO). These results exceed most other oilseeds in the world. It is estimated that to meet the global oil demand, 78 million hectares would be needed under palm cultivation, while other oilseeds would require between 75% and 90% more land (Ritchie & Roser, 2021).

In Colombia, palm oil production has been restricted by the presence of the disease known as bud rot (BR), caused by the pathogen *Phytophthora palmivora* and which has particularly affected the cultivars of *E. guineensis* (Martínez *et al.*, 2014). The spread of this disease has been observed mainly in regions with high rainfall and relative humidity for prolonged periods (Torres *et al.*, 2016).

Over time, there have been BR outbreaks in all oil palm planting regions from Colombia. The first of them destroyed 2,400 ha in the North Zone

[1] Research Results Validation Unit,
Colombian Oil Palm Research Centre (CENIPALMA),
Colombia.

* *Corresponding author e-mail: mmosquera@cenipalma.org*

(Urabá Region). Subsequently, between 2006 and 2012, BR affected more than 75,000 ha in the Central Zone (Puerto Wilches, Santander) and Southwestern Zone (Tumaco, Nariño) palm areas (Mosquera-Montoya *et al.,* 2023). By 2022, BR had forced the elimination of more than 14,000 ha cultivated in the Northern Zone (Magdalena) (Mosquera-Montoya *et al.,* 2023b; Romero, 2022).

One of the strategies that oil palm producers in Colombia have adopted to confront BR has been the establishment of OxG hybrid cultivars. The decision to plant OxG cultivars was due to the partial resistance to BR shown by some OxG crosses (Avila-Diazgranados *et al*., 2016; Ayala-Díaz *et al*., 2023). Since 2007, the planting of OxG cultivars has experienced a sustained increase in Colombia, going from having less than 1% of the cultivated area in 2006 to approximately 14% of the cultivated area in Colombia in 2022 (90,000 ha out of a total of 590,000 ha) (FEDEPALMA, 2023).

There are differences between OxG hybrid cultivars and *E. guineensis* cultivars. In OxG hybrids there is great genetic variability which conditions their physiology, productive behaviour, oil quality (fatty acid content), resistance to BR, and ripening period of the fresh fruit bunches (FFB), among others (Romero *et al*., 2021). The most frequently planted crosses in Colombia are Coari x La Mé, Brasil x Djongo, Ceretè x Deli, Manaos x Compacta (Ayala-Díaz *et al*., 2023).

Hybrids are characterised by having a low rate of stipe growth, which could prolong their economic life. Given the robustness of these cultivars, the commercial planting densities of these crops vary between 116 and 128 palms/ha. In addition, they exhibit high yields, with productions varying between 30 and 45 t FFB/ha/yr depending on the geographical region (Romero *et al*., 2021). The oil of OxG hybrids contains more than 55% oleic acid and 33% saturated acids (Romero *et al*., 2021).

A feature of OxG hybrids is their limited natural pollination, which is the result of the sexual incompatibility between the two crossed species. This is reflected in the low viability and germinability of pollen. In addition, female inflorescences have peduncular bracts that prevent access by anemophilous insects (Romero *et al*., 2021). This implies that in OxG hybrid crops, it is necessary to pollinate female inflorescences to induce fruit formation. One of the alternatives is assisted pollination, which consists of applying *E. guineensis* pollen to female inflorescences during anthesis (Ruiz-Alvarez *et al*., 2021a). Another alternative is artificial pollination, which consists of three applications of naphthaleneacetic acid (NAA) to female inflorescences to encourage the growth of parthenocarpic fruits. Commonly, the first application takes place at anthesis, the second seven days after anthesis and the third 14 days after anthesis (Daza *et al*., 2021a; Mosquera-Montoya *et al*., 2023).

The set of practices required for the proper management of OxG cultivars includes the cutting of bunches in an optimal state of ripeness, that is, at the optimal time of harvest (OTH). The difficulty is that the FFBs of each OxG hybrid crossing have different ripeness characteristics (Mosquera-Montoya *et al*., 2023).

The results of the research carried out for the management of nutrition in OxG hybrid cultivars suggest that they are very efficient in the intake of nutrients such as nitrogen (N) and phosphorus (P). Foliar analyses of nutritional content for hybrid OxG cultivars usually yield foliar levels of nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg) and boron (B), lower than those yielded by foliar analyses of *E. guineensis* cultivars (Arias *et al*., 2023).

The fruit from FFB of OxG hybrid cultivars contain less palm kernel than *E. guineensis* cultivars, and even if artificial pollination is implemented there may not be palm kernel at all. This difference has forced the Colombian palm oil agroindustry to rethink the oil extraction process for OxG FFBs, mainly in the pressing process, which in turn affects the demand for energy (electrical and thermal) and water for the process (García-Nuñez, 2023).

The above paragraphs showed the potential investor in OxG hybrid crops that it is a different business from *E. guineensis*. Consequently, this article presents the unit production costs of companies that grow OxG hybrids in the four palm areas of Colombia. It should be noted that the unit cost is an indicator that allows one to evaluate the economic efficiency of a productive activity by considering the expenditure on resources needed to obtain a unit of the product. These resources range from those required to operate (such as labour, agricultural inputs and fuel, among others), investment in infrastructure and machinery, and costs associated with running a business. Presenting results on the estimation of unit costs for OxG crops is relevant because the business of obtaining palm oil from OxG hybrids is a relatively recent development for the global oil palm agroindustry.

MATERIALS AND METHODS

Selection of Participants

Production costs were estimated under an economic engineering approach, ranging from establishment, cropping and palm oil extraction. The production processes were evaluated for hybrid cultivars OxG and *E. guineensis* in the mature stage (more than seven years) in plantations with high levels of technology adoption Mosquera-Montoya *et al.* (2022a). Plantations located in the four palm areas of Colombia were analysed: Eastern, Northern, Central and Southwestern Zones (*Figure 1*). For OxG hybrids, we gathered data from 11 plantations representing 9,258 ha cultivated (approximately 10% of the total area with hybrids in the country). In the case of *E. guineensis* cultivars, costs were estimated in 22 plantations covering 26,049 ha (corresponding to 5% of the cultivated area in Colombia).

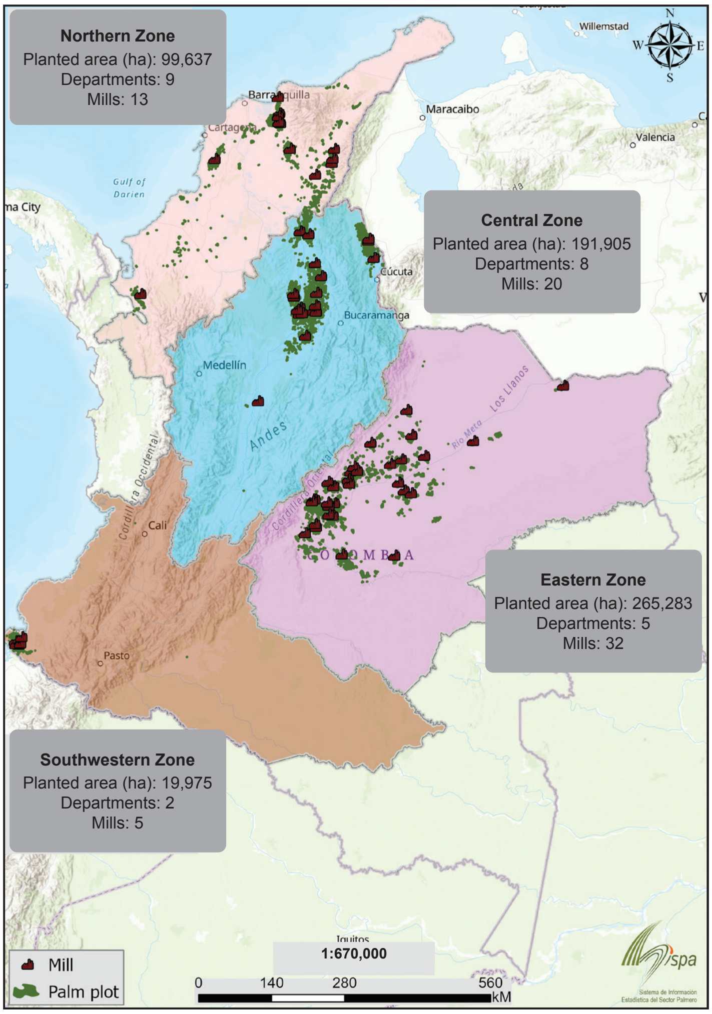
Regarding oil extraction, data were gathered from 59 oil palm mills from four Colombian oil palm growing zones, which corresponds to 89% of the total installed capacity at the national level. A total of 52% of the FFB processed corresponds to *E. guineensis* cultivars, 42% of the FFB processed corresponds to mixtures of *E. guineensis* and OxG hybrids and, 6% of the FFB processed is OxG hybrids.

Main Characteristics of Cropping Systems in Colombia

The companies in which the costs were estimated are characterised by the adoption of good agronomic practices in the different production processes and are mentioned in detail in *Table 1*.

Production Cost Estimation

The methodology proposed by Mosquera-Montoya *et al*. (2022a) was implemented. Consequently, production costs according to crop age were estimated for three different moments of palm development (unproductive oil palms, immature oil palms and adult oil palms). The method consisted of three stages. The first stage consisted of average yield estimation. To this end, surveys were carried out inquiring about the average productivity of each participating company for each year after planting. The values were then weighted according to the company´s area.



Source: FEDEPALMA (2023).

Figure 1. Palm areas of Colombia.

The second stage consisted of asking for prices and amounts required of labour, inputs, tools and machinery for each oil palm productive process. To this end, surveys and interviews were conducted with the agronomic directors of the participating plantations, in which they inquired about doses and prices of inputs, frequencies of execution of tasks, labour yields, wage rates, costs associated with machinery and equipment, land rent values, payments for supervision, management and technical assistance of the crop.

The third stage was the estimation of unit cost/ha and cost/t of FFB and cost/t of CPO. The cost/ha for each company was estimated as the sum of the costs of each task carried out in that unit of area along the whole economic lifecycle of the crop. The total costs were estimated for labour, supplies, tools and machinery, fuel and utilities. The unit cost/t was obtained from the ratio between the sum of the cost/ha over the sum of yields over 25 years. To obtain the national values, a weighting of the costs of the companies was made according to the area.

Cultivation costs. Oil palm is a long-term crop, so the time window of analysis is wide given that costs and yields are not the same at different times of plant growth. In the context of this study, the unproductive stage goes from the first to the third year; the developmental stage goes from the fourth to the sixth year and the adult stage covers from the seventh year onwards when production stabilises (*Table 2*).

TABLE 1. CHARACTERISTICS OF CROPPING SYSTEMS IN COLOMBIA

Task	Most used method
Fertilisation	It is carried out manually together with wheeled containers pulled by working animals. Machinery is used to bring fertilisers to the border of the lots. Fertilisation rates vary in accordance with fertilisation prescription but, on average, OxG hybrid cultivars received 11.69 kg/palm/yr, while *E. guineensis* cultivars received 8.99 kg/palm/yr (Mosquera-Montoya *et al*., 2023).
Harvest	FFB cutting is performed manually with the help of sickles at FFB phenological stages 807 and 809 (Romero, 2022). For picking up FFBs one may use either labour/grabber and FFBs are placed in wheeled containers pulled by working animals/tractors.
Weed control	It is carried out manually with the support of scythes/machete. Manual control alternates with the application of herbicides. Less frequently, it is observed the use of tractors with weed cutters.
Pruning	It is done manually with the help of a sickle.
Phytosanitary control	Phytosanitary control consists of two processes: 1) Monitoring: The work is manual and is carried out by trained personnel. 2) Control and disposal: The work is manual with the help of a scythe for the removal of oil palm trees and pesticide sprayers. Since OxG cultivars are partially resistant to diseases such as lethal wilt and bud rot less frequent monitoring with respect to *E. guineensis* crops is required (CENIPALMA, 2023).
Pollination	This task is performed only on OxG hybrid crops. It is carried out manually with the assistance of tools for the removal of bracts and for the spraying of pollen or NAA. Each inflorescence is applied three times, first at anthesis, the second application seven days after anthesis and the third application fourteen days after anthesis (Camperos *et al*., 2021; Ruiz-Alvarez *et al*., 2021b).
Irrigation	Irrigation is not very common in oil palm in Colombia but in some areas highly exposed to water deficit (more than four months a year). Surface irrigation is the most used irrigation system.

TABLE 2. COST INDICATOR

Indicator	Descriptions
Establishment (USD/ha) (Year 0)	It corresponds to the summation of costs related to investments that must be made before planting oil palm in the field (plantation design, soil correction, land preparation, nursery and sowing, among others).
Unproductive stage (USD/ha) (Year 1-3)	It is defined as the sum of costs incurred along the period between planting and its third year when palms have low to no yield.
Immature stage (USD/ha) (Year 4-6)	It is the sum of the costs incurred for the maintenance of the plantation, the harvest, and FFB transportation to the oil palm mill, which occur from the moment in which the palms begin to produce bunches but have not yet reached productive maturity.
Adult stage (USD/ha) (Year 7 onwards)	It corresponds to the annual costs incurred to manage an oil palm plantation, once it has reached productive maturity. For this study, it is considered that this moment arrives from year 7.

The unit cost in terms of USD/t FFB is obtained from the ratio between the sum of costs/ha for each year at all stages of the crop with respect to the sum of production/ha over the entire life cycle of the crop, as expressed in the following Equation (1).

Cost/t of CPO. The estimate of the cost/t of CPO results from three components: 1) Costs of processing 1 t of FFB, 2) the cost of raw material and 3) palm kernel credit which results from selling the kernel to PKO producers. These values depend on the installed capacity of the plant (determines the fixed costs), the OER (determines the amount of raw material required to obtain 1 t of oil), the kernel content/t FFB (establishes the amount of kernel obtained after processing the bunches), the prices/t of palm kernel and prices/t of FFB.

The cost of processing includes plant depreciation and variable costs (maintenance, labour, and industrial services). Labour costs include operational, administrative, support, and maintenance personnel. Maintenance costs refer to the costs of spare parts and outsourced equipment maintenance services. Industrial service costs refer to energy and water. Finally, the cost of the raw material, this is for the purchase of FFB, was obtained considering the estimated costs for the cultivation stage by zones and at the national level. The cost of production of 1 t of oil (USD/t of CPO) is expressed as Equation (2).

The production cost of palm oil was calculated by estimating the amount of tonne of FFB required to obtain a tonne of CPO, plus fixed and variable costs of processing FFB at the oil palm mill (Guerrero-Sanchez *et al.*, 2020). The cost of raw material (*i.e.*, FFB) was defined as the cost of production/t at cropping. In addition, the cost of raw material (FFB) was estimated based on the price/t of FFB and the amount of FFB needed to extract 1 t of palm oil. Note that the oil extraction rate (OER) is the key parameter. This study considered data from oil palm mills that process in separate lines for each type of cultivar (either *E. guineensis* or OxG hybrids). Fixed costs include investment in palm oil mill equipment and palm oil mill infrastructure. Variable costs include labour (direct and indirect), maintenance (spare parts, supplies for repairs and outsourcing of maintenance services) and industrial services (energy and water). In the case of *E. guineensis* cultivars, at the palm oil mill, one separates the palm kernel and sells it to companies producing palm kernel oil (PKO) and palm kernel cake. The selling price of palm kernel is calculated as 35% of PKO price due to PKO´s extraction rate. This study used the 2023 PKO average price of USD976.77/t.

Economic Indicators to Comparing OxG Hybrid Crops with Respect to *E. guineensis* Crops

Financial indicators that allow one to compare an economic standpoint the two different types of cultivars were estimated. We estimated the net present value, yearly expected income/ha, payback period and internal rate of return. To estimate these indicators, it was considered the cash flow for each type of cultivar (*i.e., E. guineensis* and OxG hybrids) regarding a 25 year crop life cycle. For estimating these indicators, it was used the 2023 average price/t of FFB (USD151.45). As a discount rate, we used an annual value of 8.75% corresponding to credit lines for investing in oil palm cropping, offered by the Colombian Agriculture Ministry through Banco Agrario. This interest rate reflects the opportunity costs of the money borrowed for investing in oil palm crops. In Colombia, these indicators are relevant because most oil palm growers are FFB suppliers. This is a company owning a palm oil mill that does not necessarily own most of the crops where the FFB is produced for its business.

RESULTS AND DISCUSSION

2023 Crop Yield

OxG hybrid cultivars and *E. guineensis* cultivars start producing FFB from the second year of planting and show an upward behaviour of crop yield until maturity is reached. In 2023, for the adult stage, the yield of OxG hybrid cultivars reached an average of 30.4 t of FBB/ha/yr, while *E. guineensis* cultivars reached 26.3 t of FFB/ha/yr (*Figure 2*). These results indicate the higher productive potential of OxG hybrid cultivars. This has been true after the previously referenced set of management practices for the OxG hybrid cultivars were implemented (Ayala-Díaz *et al.*, 2023). Specifically, reference is made to nutrition, sanitary management, artificial pollination and optimal harvest moment (Ayala-Díaz *et al.*, 2023; Daza *et al.*, 2021; Mosquera-Montoya *et al.*, 2023; Ruiz-Alvarez *et al.*, 2021b).

$$\frac{USD}{t\ FFB} = \frac{Establishment\ (USD/ha)_0 + \sum_{i=1}^{3} Unproductive\ (USD/ha)_i + \sum_{i=4}^{6} Immature\ (USD/ha)_i + \sum_{i=7}^{25} Adult\ (USD/ha)_i}{\sum_{i=1}^{30} Annual\ yield\ (t\ FFB/ha)_i} \quad (1)$$

$$\frac{USD}{t\ CPO} = Processing\left(\frac{USD}{t\ CPO}\right) + Raw\ material\left(\frac{USD}{t\ CPO}\right) - Palm\ kernel\ credit\left(\frac{USD}{t\ CPO}\right) \quad (2)$$

Establishment Costs

In 2023, the cost of establishing 1 ha of OxG hybrid cultivars was 20% lower than establishing 1 ha of *E. guineensis* cultivars (*Figure 3*). The difference is explained by the planting density, given that in a ha of OxG, oil palm is planted between 116-128 palms/ha, while for *E. guineensis*, oil palm is planted 143 palms/ha.

Costs per Cropping Stage

In both types of cultivars as the palms reach productive maturity, the cropping costs/ha increase. This is because the demand for nutrients increases, as well as there is a greater demand for labour to pollinate female inflorescences and FFB harvesting (*Figure 4*).

The unproductive stage covers the first three years after planting. It is characterised by the low participation of harvesting and pollination (in the case of the OxG hybrid) in the total costs, due to the low production of bunches (*Figure 5*). Fertilisation and weed control are the direct costs that dominate the cost structure at this stage.

The developing stage runs from the fourth to the sixth year after planting. As palms come into production, items such as harvesting, transportation, and pollination begin to weigh more heavily on the cost structure. The cost of the hybrid is 21.9% higher compared to *E. guineensis* not only because of the pollination requirement but also because the yields achieved are higher and this increases the cost of harvesting and transport (*Figure 5*).

The adult stage runs from the seventh year onwards and at this stage, FFB yields tend to

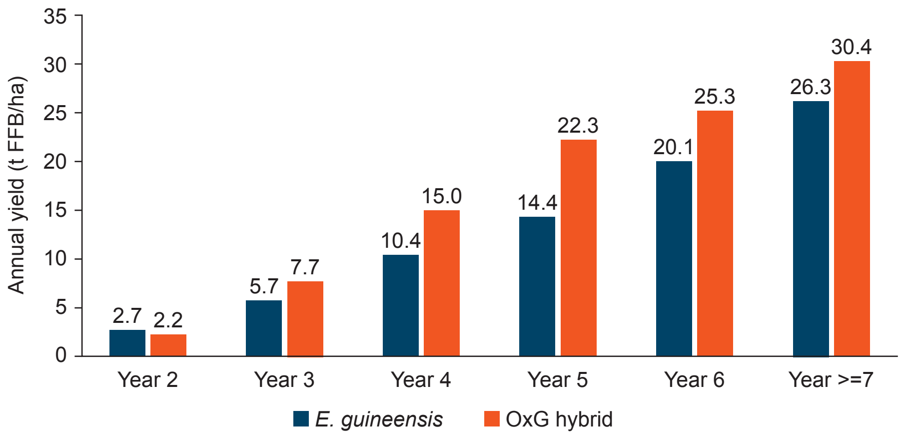


Figure 2. Yield according to age and cultivar.

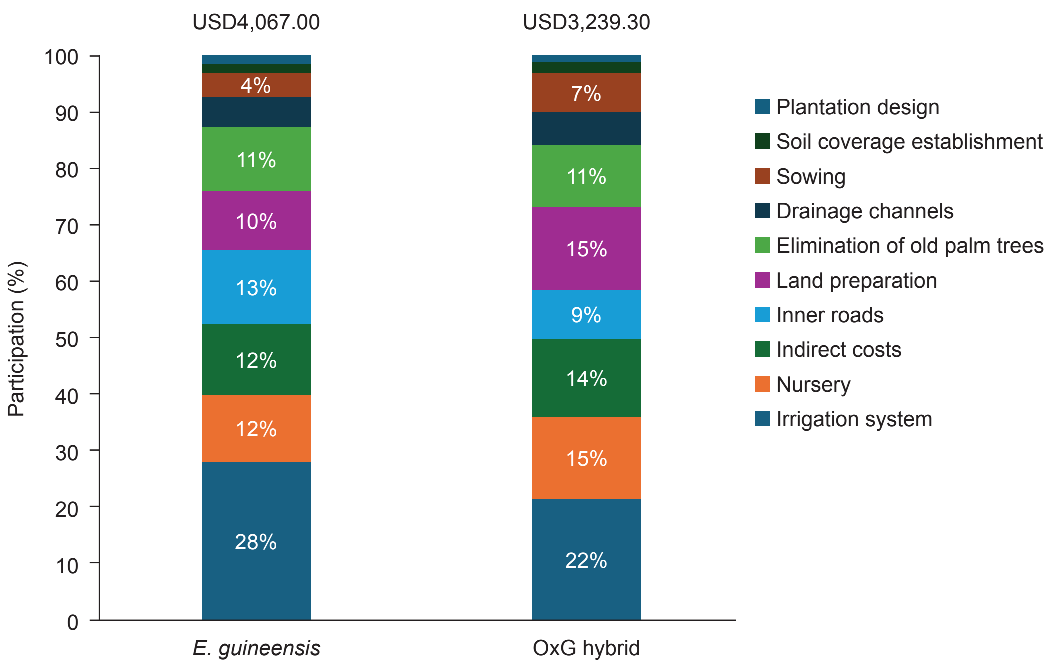


Figure 3. Crop establishment costs structure according to the type of cultivar.

stabilise. The increase in yield implies a greater requirement for nutrients so fertilisation costs increase, compared to the developing stage for both cultivars. FFB harvesting, FFB transportation and pollination (in OxG hybrids) also increase compared to the developing stage.

Cultivation costs/ha of OxG hybrid palm are 14% higher compared to cultivars of *E. guineensis.* Since these are different cultivars, input and labour requirements also vary. The main difference is the need for assisted pollination in hybrid OxG cultivars.

In artificial pollination (*Figure 4*), labour represents about 70% of the cost of the task (Ruíz Álvarez *et al.*, 2022). The estimated cost is USD433/ha/yr and labour productivity ranges from 3-5 ha/man/day (Daza *et al.*, 2021; Mosquera-Montoya *et al.*, 2023).

Pollination for the management of OxG cultivars increases the demand for daily wages/ha, which has an impact on the indicator of the area served for each worker. In 2023, OxG hybrid crops value was 6.9 ha/worker/yr (to performing all cropping tasks), while in *E. guineensis* it was 11.6 ha/worker/yr (to performing all cropping tasks) (Ruíz-Álvarez *et al.*, 2022). This indicates that it is needed to continue research on strategies to increase pollination´s labour productivity. On the other hand, in 2023, harvesting costs and FFB transportation costs were 23% higher in hybrid crops compared to *E. guineensis* crops, due to the higher yield of hybrid OxG crops (*Figure 6*).

An important difference between the two types of cultivars studied corresponds to the cost of pests and disease control, which includes phytosanitary control. The reduction in pest controlling costs is 59% in OxG hybrid cultivars compared to that of *E. guineensis* cultivars. This is due to the partial resistance to BR of some OxG hybrid cultivars (Coari x La Me and Coari x Pobe crosses). These cultivars have evidenced a lower degree of severity and a lower number of removed palms/ha, compared to *E. guineensis* cultivars when attacked by BR (Avila-Diazgranados *et al.*, 2016; Ayala-Díaz *et al.*, 2023).

Figure 4. Artificial pollination.

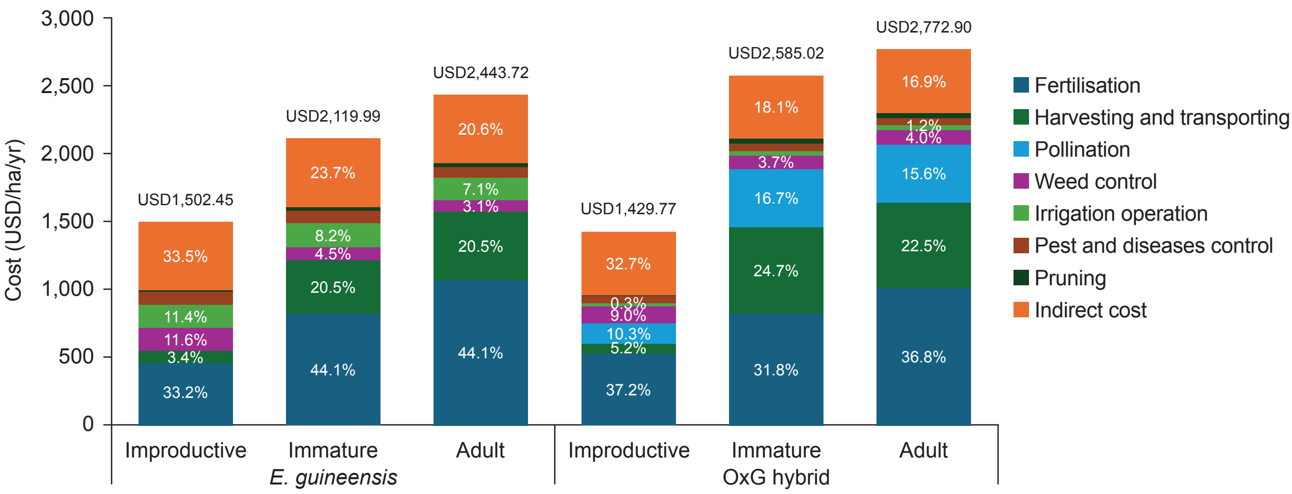


Figure 5. Costs for each hectare by age and cultivar.

Figure 6. Mature bunches of OxG hybrid cultivars.

Cost Structure According to Cultivar

Figure 7 and *8* show the tasks with the highest cost participation along the oil palm crop life cycle for each type of cultivar. Fertilisation and harvesting, in both cases, are the tasks requiring the most resource investment. Note that OxG hybrids, require pollination as well and it participates with about 15% of the hybrid OxG crops' cost structure.

Unit Costs

Cost/t of FFB. The unit cost includes all expenses from the establishment of the crops to maintenance during the 25 years useful life of the productive project. In addition, it includes the yields of FFB (t) that occur in that period on a cultivated ha. The costs/t of FFB are similar in the two cultivars, close to USD100.00 (with a 5% difference in favour of the *E. guineensis* cultivars). If the opportunity cost of land was not considered, the total cost is estimated at USD94.31/t. If only the costs of the adult stage were considered, then hybrid OxG crops had a unit cost of 2% lower than those of *E. guineensis* crops (*Table 3*).

TABLE 3. FFB UNIT COST OF PRODUCTION

Item	Total cost (USD/t FFB)	Cost without land cost (USD/t FFB)	Adult stage cost (USD/t FFB)
E. guineensis	107.65	98.10	93.01
Hybrid OxG	102.22	94.31	91.19

Mainly, the lower planting density and the higher productivity of a hectare of land cultivated with OxG hybrids make it possible to compensate for the cost overruns associated with the inclusion of artificial pollination in these cultivars. It is important to note that the current competitiveness of OxG hybrid cultivars in Colombia is due to the experience and adaptation of appropriate technological alternatives for these crops, and this trend has been consistent over the last five years (Mosquera Montoya *et al*., 2022a).

Cost/t of CPO. Once FFBs are taken to the palm oil mill for oil extraction, the cost of raw material is defined by the oil content. In the case of the OxG hybrid cultivars, a higher OER was found, compared to that of *E. guineensis* cultivars. This result is consistent with the higher accumulated oil content in parthenocarpic fruits resulting from NAA application (Romero *et al*., 2021). However, palm kernel content is higher in *E. guineensis* cultivars (4.22%) compared to OxG hybrid cultivars (0.55%), which is consistent with a greater formation of normal fruits in *E. guineensis* cultivars (Cortés *et al*., 2024; Daza *et al*., 2021). Thus, although the extraction rate is higher in the raw material from OxG hybrids when considering the palm kernel credit, it yields a higher cost of OxG hybrid raw material (*Table 4*).

TABLE 4. CPO UNIT COSTS

Item	*E. guineensis*	Hybrid OxG
OER (%)	21.99%	23.49%
Kernel content per t of FFB (%)	4.22%	0.55%
Price of FFB needed to obtain 1 t of CPO (USD/t CPO)	490	435
Milling costs (USD/t CPO)	87	92
Palm kernel credit (USD/t CPO)	-66	-8
CPO unit costs (USD/t CPO)	510	508

In terms of processing costs for the two types of FFB, processing 1 t of hybrid OxG FFB is 13% more expensive compared to *E. guineensis*. This is due to palm oil mills processing FFB from hybrid OxG crops using the same technology for *E. guineensis* with minor adjustments (García-

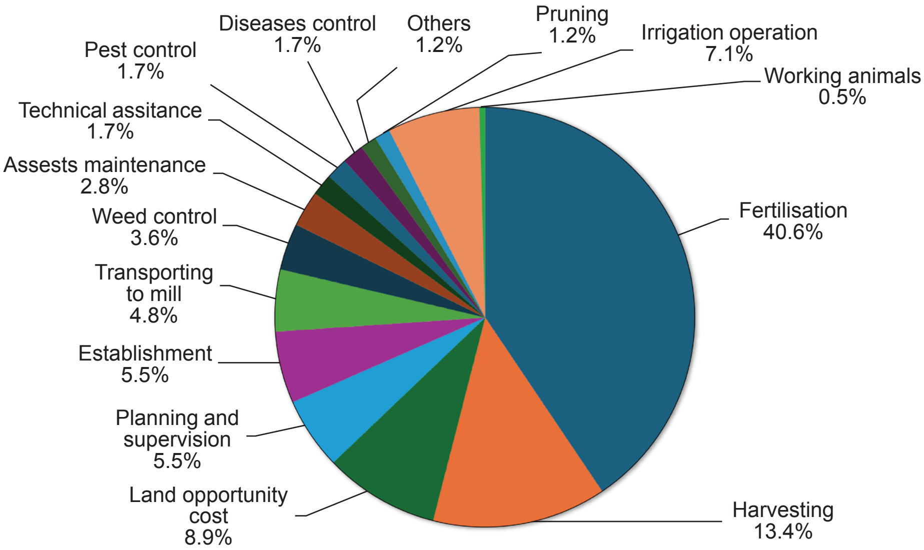


Figure 7. Cost structure for E. guineensis *in 2023.*

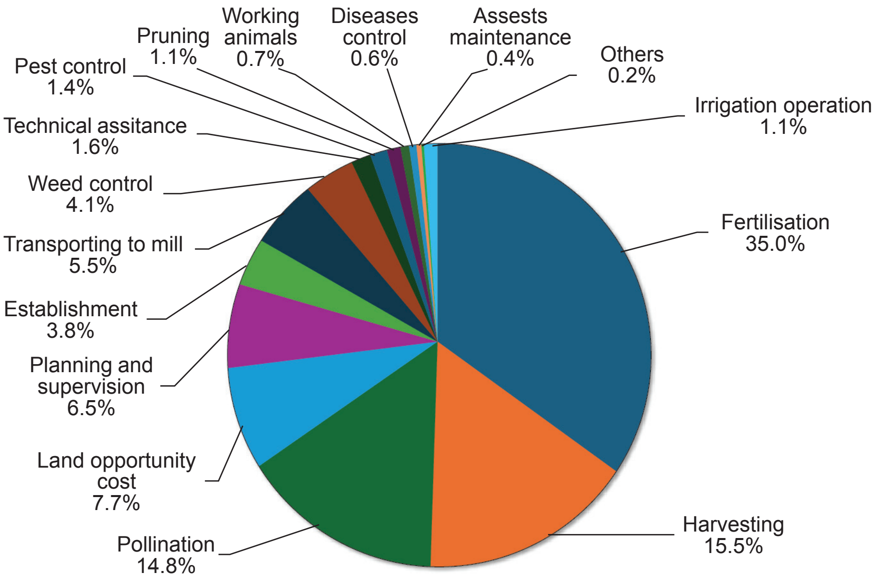


Figure 8. The cost structure for OxG hybrid in 2023.

Nuñez *et al.*, 2023). Given that OxG hybrids FFB have higher fibre content and a lower content of nuts there is a loss in pressing capacity ranging from 15%-20% (Ruiz-Alvarez *et al.*, 2021b; Ruíz *et al.*, 2024).

Taking into account the above considerations production of 1 t of CPO from FFB of OxG hybrids was 0.41% less expensive than using raw material from *E. guineensis* cultivars.

Economic Indicators for OxG Hybrid Crops and *E. guineensis* Crops

Table 4 synthesises the results of economic indicators comparing the two types of crops under consideration. Note for both crops NPV yields positive values (greater than zero) indicating that both crops are to be considered good investment alternatives (*Table 5*), however, the NPV for OxG crops is almost two times greater than the one estimated from *E. guineensis* crops. The internal rate of return (IRR) is five percentual points higher for OxG hybrid crops (with a value of 18%) with respect to the IRR estimated for *E. guineensis* crops with a value of 13% (*Table 5*). Regarding the annual expected income per hectare OxG crops yield a value 36% greater than the one estimated for *E. guineensis* crops. The payback period for *E. guineensis* would be the 17^{th} year, while the payback period for OxG hybrid crops would be the

10th year. All in all, these economic indicators allow one to state that OxG crops are a better alternative to investing financial resources than *E. guineensis* crops

TABLE 5. ECONOMIC INDICATORS FOR *E. guineensis* CROPS AND OxG CROPS

Indicator	*E. guineensis*	OxG hybrids
Net present value (NPV)	3,394	7,071
Annual expected net income per ha	861	1,172
Payback period (yr)	17	10
Internal rate of return (IRR)	13%	18%

Departing from these figures, one could state that in 2023 the Colombian oil palm agroindustry had the potential of generating USD536.00 million of net revenue/yr from cropping oil palms. This is considering that in the year 2023, about 500,000 ha was planted with *E. guineensis* cultivars and 90,000 with OxG hybrid cultivars. If the whole area planted with oil palms in Colombia in 2023, had been planted with OxG cultivars the Colombian oil palm agroindustry would have got a net revenue of USD691 million where the difference between these net revenue scenarios is 29%.

CONCLUSION

The production of palm oil from the planting of OxG hybrid cultivars during the last 15 years in a commercial way, has allowed us to conclude that the business of these cultivars is different from that traditionally implemented with *E. guineensis* cultivars, with a different technological package that involves adjusting the cultivation and oil extraction processes. However, the potential is great, considering that in some plantations across the country yields as high as 45 t/ha or 11 t CPO/ha have been achieved.

OxG hybrid cultivars have become a real alternative for investors in the oil palm industry. Over the past 15 years, technological adjustments have been made including a methodology for parthenocarpy induction, ripeness criteria for bunches of different types of hybrid cultivars, and modifications to the hybrid pressing process. These changes have helped make hybrids an attractive business for those interested in oil production, especially in areas affected by BR outbreaks. In 2023, with the set of OxG cropping and milling practices available, producing 1 t of FFB from hybrid cultivars has been 5% less expensive than from *E. guineensis* cultivars, while producing 1 t of CPO has been 0.42% lower in hybrids compared to *E. guineensis* cultivars.

Although hybrids have been a strategy to deal with BR, it is necessary to continue implementing strategies for monitoring and timely control of this disease. Although it is not evident in this document, there are already records of significant BR incidence in regions with high precipitation regimes in Colombia.

The FFB from OxG hybrids imply important changes in the palm oil extraction process that increase energy consumption (thermal and electrical). However, it is crucial to make progress on processing FFB from hybrids OxG, as this could lead to optimising palm oil extraction costs. Finally, it should be noted that the characteristics of OxG hybrid palm oil are different from those of *E. guineensis* oil, so they have different markets where to be sold.

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