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Evaluation of two harvesting procedures for oil palm (*Elaeis guineensis* Jacq.) fruits. A case study

Evaluación de dos procedimientos de cosecha de fruto de palma de aceite *Elaeis guineensis* Jacq. Un estudio de caso

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ABSTRACT

This study was performed in Las Brisas Oilseed property located in the Municipality of Puerto Wilches, province of Santander, Colombia. It was evaluated a harvesting procedure that modifies the traditional procedure adding an implement called "pepero" placed on the plate of the palm below the cluster for let the fruit to fall in it after the cutting process. With this procedure, it was not necessary to clean thoroughly the plates, as the fruits were few to collect. Using these method at least two herbicide applications over the plate can decrease annually and for the same reason leaf residues dropped from the pruning would reach their decomposition process, promoting the palm root system growth, thereby, increasing the absorption of nutrients from the fertilizer. During the evaluation, the proposed method reduced 63% of the harvest efficiency, however it was noted that adjusting harvest cycles to avoid clusters of mature young palms and working performance could be improved. We presented very promising application with the hybrid GOX which is replacing current materials as palm, this has small growth and has the tendency to attach the fruits, even than overriped.

Key words: procedure, herbicides, cluster, fruit.

RESUMEN

Este trabajo se realizó en predios de Oleaginosas las Brisas ubicada en el Municipio de Puerto Wilches, Departamento de Santander. En este ensayo se evaluó un procedimiento de cosecha que modifica al procedimiento tradicional adicionándole un implemento denominado "pepero" el cual se coloca en el plato de la palma debajo del racimo para que cuando sea cortado caiga dentro de él junto con los frutos que se suelten con el impacto al suelo. Con este procedimiento no es necesario tener los platos muy limpios ya que van a ser pocos los frutos por recoger, lo que redunde en el hecho de que se pueden disminuir dos aplicaciones de herbicidas al plato anualmente y que por el mismo motivo se puede colocar la hoja picada proveniente de la poda sobre él promoviendo en su descomposición el sistema radical de la palma aumentando con ello la absorción de nutrientes en la fertilización. Durante la evaluación el método propuesto disminuyó en un 63% la eficiencia de la cosecha, sin embargo se notó que ajustando los ciclos de cosecha para evitar racimos sobre maduros y trabajando en palmas jóvenes el rendimiento puede mejorar. Se presenta muy promisoria su aplicación con el hibrido OXG que está reemplazando a los materiales de palma actuales pues este presenta escaso crecimiento y tiene la tendencia a no desprender frutos fácilmente así este sobremaduro.

Palabras clave: procedimiento, herbicidas, racimo, fruto.

Introduction

The harvesting operation for oil palm has a great importance for the production chain of palm oil. This is the final stage of the crop production process, and the quality and percentage of oil extraction obtained from the clusters will highly depend on all the practiced criteria (Mosquera and Fontanilla, 2008).

In the chain of oil palm production, the harvesting and transportation of fruits are the most important operations, because the quality of the oil obtained depends on them and these represent a very important item for the cost of a ton of fruit: 21% according to Lans and Mill Corporation (2008).

In the traditional harvest of palm, when the cluster falls down, a significant amount of fruits are scattered on the ground depending on their maturity. This situation creates the need of an operator to pick them up, and, for that reason, the cost for the harvesting operation increases, with the aggravating circumstance that some of these will not be recovered and the oil content in those fruits will be lost.

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This situation has promoted the evaluation of different implements; some of these are similar to baskets, which are placed under the cluster, and when it is cut, the basket picks it up with most of the fruits scattered. However, although these have presented some efficiency, at the same time, they generate security problems for labor staff.

Having the need to assign an additional staff to collect the fruits scattered on the ground, costs increase for the operation of harvest, even than the production per batch decreases and, eventually, these fruits germinate, originating the so-called spontaneous palms. These become focus of pests and diseases because they are not considered in crop management programs. From the foregoing it can be deducted the need to modify the current operation procedure for harvesting, adding the tool denominated "pepero," which is placed on the palm plate and when it falls, the cluster and the detached fruits drops inside it. From the research the following question was generated: when this implement is used in the process of harvesting whether the tool denominated "pepero" increase the efficiency in fruit recollection or not.

By modifying the harvesting procedure with the implement called "pepero" it is expected to obtain the additional benefit of no need to keep clean the plates to recollect the fruits. It allows economic savings and elimination of at least two applications of herbicides that are performed every year. The leaves from pruning may be placed on the plate enhancing the development of the root system and, thereby, improving the nutrient absorption. It is noteworthy that the construction of the implement, product of this study, is a simple and inexpensive procedure.

Due to sustained increase in the planting area of oil palm in Colombia it has been presented a raise in the demand for labor, in order to enhance productivity in oil palm cultivation industry. The labor cost in this activity represents 25.5% of the cost of a ton of palm oil (Duarte, 2009), so it is necessary to generate strategies to increase the efficiency of human resource.

It is important to add that oil palm plantations are established in areas with the deficit of labor and the harvest is the work, which has the highest requirement of this important resource (Fontanilla *et al*., 2010).

In a study by Corlye (2009), the palm cultivation generated a permanent job for every 10 ha planted and the daily income of a palm oil worker was 10 USD, five times higher than the poverty line estimated in two USD at that year.

Bernal (2009) proposed designs for a palm plantation based on the type of soil, topography, water sources, harvesting system, and location of the extraction plant. For this, it is necessary to have the topographic study and aerial photography. The managers should not plan batches exceeding 25 ha or under 5, since the management tasks can become harder, and also it is necessary to keep in mind that palm cultivation requires the movement of large quantities of inputs, for which the personnel, supplies and harvest have an efficient and timely move depending on the good condition and design of the track.

Oil palm is sensitive to both deficiency and excess of water, so it is important to ensure the appropriate supply of water in the periods of water deficit; for this purpose the lots should be guided with irrigation channels and drainage, and these have to be made in favor of the slope, so there will not be rectangular batches (Franco, 2003).

The cluster harvest is the culminating work of the production process in the cultivation of oil palm. It is important at this time to apply appropriate criteria for cutting the clusters as they should be at the peak of ripeness to harvest and bring these to processing plant as soon as possible to avoid the deterioration of the oil. Although this operation seems to be a simple task, it is a specialized activity that requires great skills, training, and continual supervision (Bernal, 2009). After fertilization, which represents 35% of the costs of crop production, the most expensive item is the harvest with 20%, followed by the transport with 12%. Hence, the reduction of harvesting costs and improving crop competitiveness are important (Fairhurst and Hardter, 2012).

It is important to highlight that palm bunches must be harvested as soon as they mature. For this purpose, the plantation must be examined visiting regularly all the palms, every 7 to 13 d (harvest cycle) cutting the clusters that are separated or ripe (Bernal, 2009). The cutted bunches should be sent to the production plant the same day when harvested, to prevent increase in the content of free fatty acid (FFA) within the fruit in a process called acidification. This is originated as a result of an enzyme called lipase, which acts on triglycerides releasing fatty acids. This enzyme begins its activity as soon as the cluster reaches maturity and accelerates once it is cut off from the palm or due to mechanical damage in the fruits. Toong and Yeang (1993) indicate that adoption of a minimum five fruits naturally dislodged per cluster and harvest cycle every 10 d is satisfactory for production of fresh fruit bunches of good quality.

In order to perform the harvesting operation, it is necessary to organize squads that consist of one to five workers divided between cutters and lifters, with the following tools: an implement called *angarilla*; a cart, on which the loose fruit is placed along with clusters, a mule, buffalo, ox or tractor, pulling or carrying charge harvest and taking it to the collection point, a *palin* for cutting the bunches of young palm or Malay knives for adult palm bunches, a *machete* to cut the peduncles of the clusters, a plastic drawer for depositing loose fruit, and a rake to recollect the fruits scattered on the floor.

In order to to perform the operation of harvest, Arias *et al*. (2009) proposed the following steps:

- Search for mature palm bunches.
- Prune leaf supporting the cluster.
- Cut the bunch.
- Cut the peduncle of the bunch if this exceeds 5 cm.
- Recollection of the bunch and loosened fruit before and during the fall of the cluster and deposit on the equipment intended for lifting.
- Cut of leaf and placement in the interlining or the *palera*.
- Transfer the harvested fruit to the point of collection

According to Padilla (2004), the harvest crew spends 24-36% of their time searching for palms with mature clusters. This can be previously solved by dedicating a person to locate those clusters with a flag marking the palm. This activity reduces up to 12% searching for the clusters, while improving performance and increasing in 1% extraction rate in the beneficiation plant due to the optimal maturity of the harvested bunches.

It is common that with the hit of the cluster when it falls to the ground some fruits get separated creating the need to give an additional time to recollect them, when letting advance the ripeness time of the clusters due to a larger cycle of harvesting (harvest cycle is defined as the time between a harvest and the next one in the same batch), the number of loose fruits increases getting an amount of 300 of them per cluster, with the consequent loss of time picking them up, and the loss of oil due the fruits which are left (Chisco, 2006).

Fedepalma-Cenipalma (2006) stated that the harvest with a criteria of 5detached fruits it become 10 or more fruit on the ground, due to the impact of the cluster when it falls. The first fruits which separate are the external ones, those containing up to 48% oil by weight.

Alfonso *et al*. (2011) found that gathering detached fruits on the plate takes a while between 40 and 64 s per palm, representing between 36 to 48% of the total operation time of the harvest. The same author in Guaicaramo, province of Meta (Colombia) assessed a kind of basket that supported the stipe of the palm, recollects the bunch and the lost fruits that fall at harvest time.

On the north coast of Colombia it was evaluated a *jama* similar to a coffee strainer, with a diameter of 1 m, which was placed under the cluster to harvest with the expectation that this fall into it with the loose fruits. The result obtained from this implement presented great efficiency, but problems were generated in high-rise palms and increased the danger for the operator who manipulates it (Mendoza, 1995).

The general objective of the research was to evaluate the efficiency of two methods of harvesting the fruits of the oil palm in the Oleaginosas Las Brisas Company located in Puerto Wilches (Santander, Colombia) in order to design a strategy for improvement of future implementation of better process with the use of "pepero" both for the company and the region.

Materials and methods

In this research, the methodological design was experimental, for which was used a single-factor completely randomized design, considering as an experimental factor the harvesting procedure for the palm. The number of treatments was two (traditional procedure and modified procedure), which were made five times each one (groups of harvest). The harvest was measured in tons per h of effective work.

The experimental study was made in batches property of Oleaginosas Las Brisas, located in the community of Puente Sogamoso, town of Puerto Wilches, province of Santander (Colombia), with the geographical coordinates 7°21' N and 74°54' W.

Materials

The implement called "pepero"

This device has of a frame constructed in wire of ¼ in, shaped as a truncated cone; divided in the central region into two equal parts to easily bend and lift using two handles on

the sides. This implement is lined in plastic fiber (material used in the wrapping of packages fertilizer) (Fig. 1 and 2). It weighs 3.5 kg and its cost, on the study date, was $40.000 Colombian pesos.

FIGURE 1. Metallic structure of the "pepero". Source: Oleaginosas Las Brisas (2013).

FIGURE 2. Covered "pepero" ready to be used in the harvesting operation. Source: Oleaginosas Las Brisas (2013).

Vegetal material of research

The plant material used in the research was the intraspecific hybrid IRHO located in batches 44/99 and 8/97of 12 years old on average at the trial time.

Information sources

The data were collected directly through field measurements and at the time of harvest. The information from the records of the plantation was processed, consultation of literature and electronic sources on the palm harvest.

Instruments for collecting information

For this purpose a format to perform data collection in the field was designed, such as: time of entry to the lot, harvested bunch weight, rest periods, and departure time.

Collecting information procedure

The study described the harvest of palm and the role of "pepero" in increasing efficiency to collect loose fruits and, likewise, proposed the alternative of developing a model around this practice. The information was taken after harvesting data were collected.

The information gathered in the field was organized in tables and graphs, and the statistical technique of analysis of variance (ANOVA) was used to test the hypothesis:

$$H\ o: \mu\ 1 = \mu\ 2\ H\ a: \mu\ 1 \neq \mu\ 2 \qquad (T1)$$

Where $\mu\ 1$ = average yield of traditional procedure ($t\ h^{-1}$); $U\ 2$ = average yield of the process modified ($t\ h^{-1}$).

Results and discussion

Description of the traditional harvest procedure

The traditional harvest procedure consists of the following steps, as illustrated by the block diagram in figure 3.

- Search for the palm with ripeclusters. The person who cuts the palm or "cortero" has to undertake a recognition tour throw the cultivation, noting the color of the clusters and classifying these as mature then they are colored brown or have some fruits detached.
- Pruning of the leaf or leaves that support the cluster. When the cluster is classified as mature, the operator has to proceed cutting the leaf or leaves facilitating the harvest process.
- Cuttting of the mature cluster.
- Cutting of thestalk: if the portion of the stalk that persists in the cluster already cut has a length greater than 5 cm it is appropriate to eliminate this excess. The work is carried out when the cluster is resting on the ground.
- Minced and final disposition of the pruned leaves. The leaves pruned are chopped and placed in the interline.
- Collection of the detached fruits. The worker using a rake piles the loose fruits to place them on the transport.
- Positioning of detached fruit on the transport. The clusters and loose fruits are placed in the transport to be taken to the collection center.

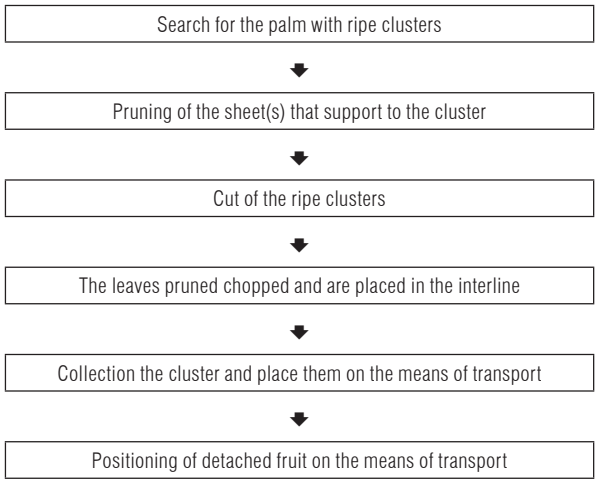

FIGURE 3. Block diagram of the traditional procedure of harvest of oil palm.

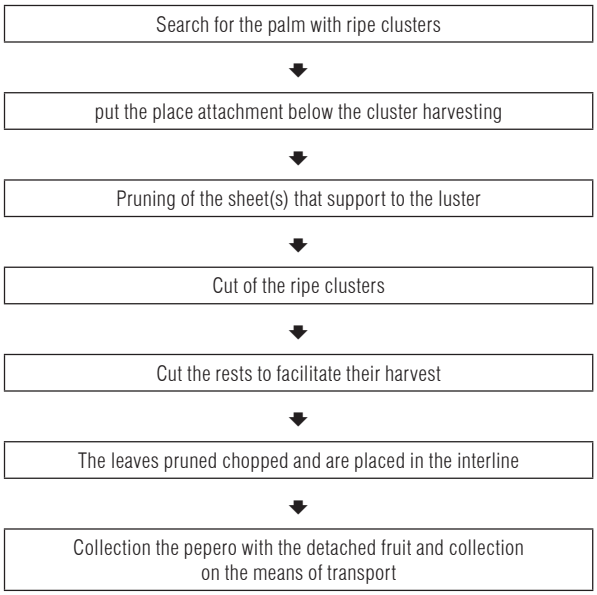

FIGURE 4. Diagram of the modified procedure of the harvest operation.

Problem with the traditional method of harvest

As reported previously by Alonso (2011), the harvesting of loose fruits takes between 40 to 64 s by palm representing between 36 to 48% of the harvest time. In addition, this task requires that the dish of the palm has to be clean and free of weeds in order to facilitate the recollection of the fruits.

Description of the modified procedure of harvest

Justification of the modified procedure.

The elimination of the collection of loose fruits justifies the implementation of this procedure, since the absenceof this step will reduce the harvest costs in 42% on average, and, according to Arias *et al.* (2009), this represents the 20% of the costs of sustaining the crop. Moreover, it is not required to have the plates of the palms to be clean because it is not expected to recollect the fruits from the ground.

This method consists of the same steps that of the traditional method but including the implement called "pepero", which is placed below the cluster before the court and is recollected with the detached fruits. The procedure as shown in the block diagram in figure 4 consists of the following steps:

The steps illustrated in figure 4 are carried out in the following manner:

- Search for thepalm with ripeclusters. The "cortero" walks through the batch palm to observe the coloration of the clusters and classifies these as mature if they are colored brown or have some fruits detached
- Pruning of the leaves that support the cluster. When the cluster is classified as a mature one the leaves around it has to be cut to facilitate the harvesting process.
- Positioning of implement "pepero" under the cluster at harvest. The "pepero" is placed into the plateof the palm below the bunch at harvest (Fig. 5).

FIGURE 5. View of the implement "pepero" placed on the plate of the palm below the cluster at harvest.

- Cut of the mature cluster. The mature cluster is cut using the malayo knife.
- Cut the stem of the cluster. If the cluster stem cut is larger than 5 cm it is acceptable to remove (Fig. 6).

FIGURE 6. View of the stem of the cluster, when it is larger than 5 cm should be removed.

- The leaf is minced and placed in the interline. The leaves that support the cluster already on the ground will come to chop and placed in the interline.
- Collection of the cluster and its placement in the transport. The worker collects the cluster to be placed on board of transport.

Collection of implement together with the detached fruit to be transported to the collection center.

Problems present in the modified procedure

It was expected that with the use of the implement "pepero", the fruits would fall within it avoiding devote a worker to collect them and, thus, reduce the time of the harvest in 48%. Yet it was found that a portion of the fruits fell outside the implement implying the event to employ an extra operator to pick them up and this coupled with the time required to place the implement into the plate of the palm affected negatively the efficiency of the procedure into consideration.

Comparative analysis between two procedures

Performance of harvest yield in the traditional procedure

This evaluation was carried out in five groups of harvest (each group of harvest is constituted by a "cortero" and a lifter); here it was determined the performance of each group, which was calculated by dividing the tons harvested by the actual working time spent in this activity. The best performance was the group of harvest Cootrasog 5 with 1.11 t h^{-1} and the lowest yield was the group Cootrasog 4 with 0.65 t h^{-1} of harvest (Tab. 1).

Evaluation of the yield of harvest in the modified procedure

In this procedure is included the use of the "pepero", an activity that is different from the traditional procedure. For the implementation of this procedure the work was performed with the same groups of harvest. The performance is calculated by dividing equally the tons of harvest with this procedure by the time devoted to the activity. The best performance was obtained in the group Cootrasog 5 with 0.91 t h^{-1} of harvest and the lowest performance was obtained in the group Cootrasog 3 with 0.5 t h^{-1} (Tab. 2).

Comparison of the yield in the traditional procedure against the modified procedure

The comparison between average harvest yield of both procedures was carried out, being that in the modified procedure the average yield 0.593 tons harvested per h against an average yield of 0.933 harvested in the traditional procedure, presenting a difference of 0.34 ton per h in favor of the traditional procedure (Table 3).

TABLE 1. Harvest yield to fruit of palm in the traditional procedure.

Group of harvest	Cootrasog 3	Cootrasog 4	Cootrasog 5	Hotracoop 2	Hotracoop 3
Harvest (t)	4.6	2.3	2.0	2.2	2.8
Harvest hours (h)	4.7	3.5	1.8	2.6	2.6
Harvest per hour (t h^{-1})	0.978	0.657	1.111	0.846	1.076

TABLE 2. Harvest yield to fruit of palm in the modified procedure.

Harvest group	Cootrasog 3	Cootrasog 4	Cootrasog 5	Hotracoop 2	Hotracoop 3
Harvest (t)	2.0	1.1	5.1	1.4	1.6
Harvest hours (h)	3.8	1.9	5.6	3.1	3.2
Harvest per h (t h^{-1})	0.526	0.578	0.910	0.451	0.500

TABLE 3. Comparison of harvest yields of the traditional and modified procedures.

Harvest group	Cootrasog 3	Cootrasog 4	Cootrasog 5	Hotracoop 2	Hotracoop 3	Average
Traditional procedure (t h^{-1})	0.978	0.657	1.111	0.846	1.076	0.9336
Modified procedure (t h^{-1})	0.526	0.578	0.91	0.451	0.5	0.593
Difference (t h^{-1})	0.452	0.079	0.201	0.395	0.576	0.3406

TABLE 4. Analysis of variance for the two procedures in the harvest of fruits of the palm.

Source of variation	Sum of squares	Degrees of freedom	Mean square	Fc	Ft0,01(1,8)	Ft0,05(1,8)
Harvest system	0.2900209	1	0.2900209	8.5326239	11.26	5.32
	0.2719172	8	0.03398965			
Total	0.5619381	9				

In the two procedures, with a level of significance of 5% the F calculated was higher than the F of table 4. So, we rejected the null hypothesis (H0) and accepted the Ha (alternative hypothesis). It could be concluded that there were differences in the yields. This could happen because with the use the modified system not all fruits fall within the implement, implying this that it have to proceed to collect increasing with this time of harvest. When calculating the Anova for a level of 1%, F calculated was less than F of the table and, therefore, although there was a difference, this was not highly significant and, therefore, we might not accept the null hypothesis (Ho).

Evaluating each procedure it was observed that the average performance of the modified procedure was of 0.59 t h^{-1} against a value of 0.93 t h^{-1} in the traditional procedure, therefore, the best results were obtained for the modified procedure. That is the one that is currently used in the area.

Advantages and disadvantages of the modified procedure

In the current situation, where the study was conducted, it did not present special quantitative advantages with respect to the traditional procedure. It is a procedure under formation as it evaluates the palms of smaller size. The optimum maturity can improve the performance, thereby, reducing the costs of the harvest. In addition, if possible to deploy, it could eliminate at least two controls of weeds in the plate, thereby decreasing the costs of sustaining the palm cultivation.

The modified procedure of harvest did not work in very high palms and much less with broad cycles of harvest (10 or more days), because this generated more fruit loss. It could be implemented in palms under 10 years and handling short cycles of harvest (8 to 9 d). This procedure looks very promising for the harvest of the hybrid that is replacing the malm materials of the species *Elaeis guineensis* (susceptible to bud rot) because it has the tendency to retain strongly the ripe fruits.

Also, it is important to propose reduce the weight when implement "pepero", which at present weights 3.5 kg and is difficult to handle during long periods of harvest.

Conclusions

The traditional procedure of harvest which is used at the moment in the planting of oil product "Las Brisas" presents loss of time in the collection of fruits that fall to the ground as this labor occupies about 48% of the total time of harvest.

The modified procedure of harvest includes the use of an implement called "pepero" which is placed on the plate of the palm below the cluster at harvest in order that the detached fruit remain within it.

The modified procedure is not efficient because with the greater height of the palms the stronger is the impact on the ground. Such situation is compounded if the over mature cluster is harvested, having the tendency to retain less the fruits on the rachis.

The yield of the traditional procedure was 0.93 t h^{-1} compared to the yield of 0.593 t h^{-1} in the modified procedure by decreasing the efficiency of harvest in a 63% compared to the first one.

The modified procedure of harvest was not efficient in very high palms and with very large harvest cycles that were the conditions that had the palms when it carried out the study.

The modified procedure of harvest is able to improve its efficiency making some changes to its structure and

conditions of use, such as applying this method in shorter palms and short crop cycles.

It is important to decrease the weight of "pepero", because its current weight is 3.5 kg, and it could become uncomfortable in its management when working during long periods of harvest.

Due to the harvesting of loose fruits represents around of 48% of time spent during the harvest, it is important to carry out the modifications necessary for the implementation of the modified system for harvest as this will increase the efficiency of the process, decreasing costs and achieving the additional benefits that this entails.

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