An analysis at the technology level of the oil palm (*Elaeis guineensis* Jacq.) plantations in the municipality of Tibu (Colombia)

Análisis del nivel tecnológico de las plantaciones de palma de aceite (*Elaeis guineensis* Jacq.) en el municipio de Tibú (Colombia)

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ABSTRACT

In the municipality of Tibu, a process of strategic alliances was started for small- and medium-sized oil palm producers with the support of a private company, the International Agency for Development (USAID), and the national government, incentivizing the creation of small-producer associations. This project has performed well in the region, generating positive effects for the region's economy. However, it has been observed that, among the small producers, some have good productivity and others have low productivity. The plantations share the same vegetative material, Dami-Las Flores, which was planted in 2005 and now has 8 years of production. The survey was conducted in October of 2013 on each of the plantations. After conducting the survey and processing the information with an evaluation matrix at the technology level, it was determined that the general technology adoption level of these plantations was 72.6%. It is recommended that the plantations increase characterization studies of the soil, conduct topographical studies, suitably prepare the soil, and design drainage systems where they are needed based on the studies.

Key words: strategic alliances, plantation audit, agronomic phases, agronomic components.

RESUMEN

En el municipio de Tibú se inició un proceso de alianzas estratégicas con pequeños y medianos productores de palma de aceite, con el apoyo de la empresa privada, de la Agencia Internacional para el Desarrollo (USAID), y el gobierno nacional, incentivando la creación de asociaciones de pequeños productores. Este proyecto ha venido teniendo en la región un buen desempeño generando efectos positivos a la economía regional. Sin embargo, se ha observado que dentro de estos pequeños productores se destacan unos por ser más productivos y se encuentran otros con producciones muy bajas. Las plantaciones tienen en común el material vegetal Dami-Las Flores, siembra 2005 y 8 años en producción. Se aplicó la encuesta en el mes de octubre del 2013, en cada una de las plantaciones. Al aplicar la encuesta y procesar la información mediante una matriz de evaluación del nivel tecnológico se determinó que el nivel de adopción de tecnología general de estas plantaciones es del 72.6%. Se recomienda a las plantaciones incrementar los estudios de caracterización de suelos, hacer los estudios topográficos, preparar adecuadamente los suelos incorporando las enmiendas y diseñar los sistemas de drenajes donde se requieran con base a los estudios.

Palabras clave: alianzas estratégicas, auditoría de plantaciones, fases agronómicas, componentes agronómicos

Introduction

The cultivation of oil palm, *Elaeis guineensis* Jacq., is one of the more dynamic agricultural activities of the country. It has provided an excellent opportunity for economic and social development. It is characterized by being a crop that is not seasonal, that is prodigious, and that provides yields over the long term, generating a stable economic activity, permanent employment, infrastructure development, and new investment in areas that lack it (Mosquera and Fontanilla, 2008; Castiblanco *et al*., 2013).

Recently, oild palm crop has been gaining influence in the Cataumbo community, especially in Tibu zona, with oil palm becoming a production alternative that counteracts the effects of illicit activities and offers the opportunity to work on a legal, profitable, and sustainable option that guarantees benefits for the future of the producers and their families.

An evaluation at the technology level requires tools for valuing and scoring the processes of a production system and identifying the critical points. Until now, the processes for oil palm crops have not been standardized or strictly followed due to the absence of reliable and systematic strategies and methodologies (Kamarulzaman and Mohayidin, 2011). However, each technical assistant, assessor, or auditor considered qualitative parameters based on their

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experience in the agronomic management of crops in order to determine if the adoption level for technology was satisfactory or not, as contrasted with the production levels (Khorramnia *et al.*, 2014). The results of the evaluation are fundamental for the improvement, modification, and implementation of new agricultural tasks and operations (Franco, 2012).

Oil palm plantations in the tropical Americas present a broad range of yields, even in the same country or region. Notably, when there are low prices with high production costs, the sustainability of the crop for many producers and their opportunities are at risk (Lukauskis, 2008).

The small producers of the Tibu region have responded favorable to this business opportunity but have seen varying production amounts despite the fact that they have the same access to credit, use the same supplies, and have the same soil, weather, and technology, giving rise to the present evaluation at the technology level of the oil palm crops in production in this region of the country.

The technical quality management given to crops throughout their lifecycleis recovered from the production in the short-, medium-, and long-terms. This is due to the fact that raceme production starts at 24 months after the palm is planted in the field and that this production process is permanent and continues throughout the useful life of the crop (Bernal, 2003).

In order to increase the yield of oil palm, it is imperative that the mindset of "little effort" that exists in the management of many producers be changed to a planned, demanding, and precise management of the crops with adoption of technology, continuous comparison with more advanced producers, and an inclination for innovation; that is to say, a profound change in the production management of the palm business is needed (Fedepalma, 2008; Khorramnia *et al.*, 2014). Toward this aim, organized management must be promoted among small producers, otherwise it will be very difficult for them to attain the high standards of production and low cost of production that allow for survival in the periods of low prices if they continue to act alone (Fairhurst, 2012).

The production of oil palm per hectare is highly associated with the yield that can be obtained for the production of fruit racemes, which depends on the technology found on the plantation (Fedepalma, 2012a; Kamarulzaman and Mohayidin, 2011)

An evaluation at the technology level is a process of control and supervision that contributes to the creation of a culture of continuous improvement based on discipline and organization, revealing failures in the structures or vulnerabilities that exist in each of the agronomic phases of the crop (CIMMYT, 1993).

This process has also been called technology diagnosis and is focused on the description of the technology process of crops through auditing. In this case, the auditors described the technology level used by the producer in order to differentiate the different agronomic tasks and agricultural operations of the crop; however, this depended on the person's experience and knowledge of the desirable conditions for each task or operation. The description was carried out in a field visit which offered the opportunity to systematically observe the outcomes of the agronomic tasks (Franco, 2012).

It is important to carry out a technology diagnosis on a plantation to describe the technology being used in order to produce and know the production levels that can be reached with its implementation and thereby strengthen the capacity for technology innovation and adoption by the producers with the aim of overcoming the problems of pests and diseases that affect palm cultivation (González, 2012).

The scoring of the tasks and operations was carried out with field evidence; that is to say, the manner of execution was not audited but their status or quality was audited at the time of the field visit (Ardón, 2003).

The average oil palm yield varies significantly within the regions, between the regions, and between the producers (Lukauskis, 2008; García, 2014). Production is a parameter for measuring efficiency with the expression of the production potential of a crop, according to the results of the agronomic management, the climatic conditions, and the soil of the planted area. The production of a palm crop is measured in terms of tons of racemes of fresh fruit harvested per hectare per year (Arias, 2009).

According to García-Tenorio Ronda (2014) a high production will almost always be linked to the use of a high technology level, while a low production will almost always be linked to low adoption of technology. In order to determine if the crop presented a good production level, the following ranges were considered (Franco, 2012):

Crops of 3 to 7 years: 20 t ha^{-1}- year
Crops of 8 to 10 years: 20 - 25 t ha^{-1}- year

Crops of 11 to 20 years: 26 - 30 t ha^{-1}- year

Crops > 20 years: 22 - 26 t ha^{-1}- year

According to Muñoz and Aldana (2012), the description of technology used by a producer can be used to make comparisons with other producers, which can help achieve better production and agronomic results.

Considering that innovation in addition to being an economic phenomenon, is also a complex social phenomenon, it is determined that innovation is knowledge in distributed interactive and collective action, which results in meta invention and meta innovation (López-Isaza, 2013).

This means that palm growers can be proactive in terms of production even though there are still many obstacles to overcome (Fedepalma, 2011a).

Everything that can be done should be done in order to close the production gap. The use of tools such as crop auditing can help to practically solve this problem, revealing the technology levels used by good producers and transferring them to other producers (Sagastume *et al*., 2006).

The general objective of the present study was to analyze the technology level of the oil palm plantations (*E. guineensis*) in the municipality of Tibu (Colombia).

Materials and methods

The municipality of Tibu is located in the northern part of the department of Norte de Santander (Colombia) with an area of 2,768 km^2 and a population of 39,997 inhabitants distributed as follows: 33% urban and 67% rural. The area is divided into three special precincts and nine annexed precincts with 186 districts. This zone is characterized as a tropical moist forest with an annual precipitation of between 2,200 and 2,800 mm, an average maximum temperature of 28 to 32°C, a relative humidity of 82% and an altitude that varies from 75 to 120 m a.s.l.

The districts of this study included Serpentino, Refineria and M-24, located in the Tres Bocas precinct of the municipality of Tibu, and contained the agroecological characteristics for the development of oil palm crops.

According to a report from the agronomic department of Promotora Hacienda Las Flores de Tibu, seven small oil palm producer associations have been established in the zone selected for this study through social and strategic alliance projects, with a potential area of 5,100 ha, of which 4,700 ha have been planted.

For this study, a methodology was developed for the evaluation at the technology level of the oil palm production system, which started with a rigorous selection of the producers and, with the use of a survey (audit), presented the operations they carry out in the production process of this species, showing which ones were better in comparison to the others as evidenced by the state of the plantations and the production obtained.

The source for the primary information was the producers who were responsible for the plantations selected for the evaluation at the technology level.

Archives and documents from studies of the associations and the department of agronomy of the Promotora Hacienda Las Flores were used as a source for secondary information, which facilitated access to information for completing the forms and scoring each of the producers.

The guide for technologies in the oil palm agro-industry published by Cenipalma was used as a supporting document; furthermore, information provided by Fedepalma, Cenipalma and Sena as a result of a special cooperation agreement called "establishment, transfer, and implementation of good agricultural practices" which contains the evaluation of production parameters of small oil palm producers affiliated with *Unidades de Asistencia, Auditoria Técnica Ambiental y Social* (UAATAS abbreviation in Spanish) was also used; this evaluation reported the technology balance indices for each agronomic phase (Fedepalma, 2010).

In the present study, the information of the oil palm plantations was collected in 2013 using a tool called "format for the evaluation of the technology level of producing oil palm crops" and produced by Cenipalma in 2009 for auditing oil palm plantations, a methodological guide that provides key elements for carrying out auditing processes: primary general diagnosis, scoring, and evaluation of the level of technology adoption of a crop of producing oil palm (Fedepalma, 2011b).

Auditing can be defined as "a systematic process that consists of obtaining and objectively evaluating evidence of the technology level of the agronomic management of producing oil palm crops in order to determine the degree of correlation that exists between said level and the desirable conditions of the crop with subsequent communication of the results to interested parties as carried out by independent, qualified personnel in compliance with technical procedures and requirements” (Fedepalma, 2010).

The sampled population in this study was defined as part of those listed in the seven associations established in the studied districts. Two associations were selected (Asopalcat Uno and Asopaltibu) due to their age and stable production. These associations possess a planted area of 1,500 ha. The studied districts contain 640 ha that correspond to 63 producers or plantations, of which a sample of 20 plantations planted in the year 2005 and consisting of 221 ha was selected. These plantations are 8-years-old and the vegetative material is Dami Las Flores; the minimum area was 10 ha and the maximum area was 20 ha with a plant density of 143 palms/ha, planted in triangles with a distance of 9 x 9 m.

The producers were selected and an agricultural association was established; subsequently, an oil palm production project was created, which was presented to a bank to know the amount of available credit. Once approved, there were only six months to carry out and demonstrate the establishment of the project plantation, which required eight months to secure the material. Once the credit was received, the other activities related to the cultivation of oil palm were initiated.

The information compiled in the forms was interpreted using the values of each of the components and transforming them into a resulting percentage, called the technology balance index (TBI) for each component with the following formula:

$$\text{Technology balance index (TBI)} = \frac{\textit{current score}}{\textit{maximum score}}\ x\ 100 \qquad (1)$$

Using this formula, the technology balance index was calculated for each component in the establishment phase of the crop (Fig. 1).

The agronomic phases of the oil palm crops were considered and each of their components were scored based on the methodology proposed by Cenipama (Franco, 2012). In order to apply the forms, the auditors conducted visits to each of the plantations to make the information reliable. Table 1 presents the agronomic phases that were evaluated in the auditing forms for the plantations along with the maximum scores possible.

In the present study, a database was created for the information that was complied, providing the technology balance indices for each of the plantations.

TABLE 1. Agronomic phases of a producing crop and the maximum score possible.

Agronomic phase of the crop	Maximum points possible
Establishment	20
Work ethic	10
Nutritional management	30
Vegetative sanitation management	25
Harvest and production	15
Total points	100

Source: Franco (2009).

Once all the information was tabulated for all of the plantations, the level of technology adoption of each of the plantations and the value for the group were established. Subsequently, the technology level was related to the average obtained production for each of the plantations for the last three years of production and the results were scored using Tab. 2 as a reference, which presents the productivity scoring scale along with the age of the plantations in Tibu.

TABLE 2. Productivity scoring scale for Tibu, taking into account the age range of the plantations.

Score	Evidence	Number of points
Maximum	The productivity range for palm in crops with more than 7 years: more than 30 t ha^{-1} - year	10
Intermediate	The productivity range of palm for crops with more than 7 years: 21 to 30 t ha^{-1} - year	5
Minimum	The productivity range of palm for crops with more than 7 years; less than 20 t ha^{-1} - year	0

Result and discussion

The process of strategic alliances is improving for small- and medium-sized producers in the Tibu region. In this agronomic phase, the establishment of the crop presented a deficient technology adoption score for the studied components: soil characterization, topographical studies, and soil preparation, with 0%, and 30%, respectively; a medium score for the agronomic management unit design (AMUD); and a score of 50% for the drainage and irrigation design component. There was only one acceptable score: 60% for the establishment of cover. In general, the score for technology adoption was deficient with respect to the establishment phase of the plantations.

The technology balance index for each of the components of the work ethic phase of the crop (Fig. 2). In this agronomic phase, there was a notably deficient technology adoption score for the pruning component: 48.75%. The frond cleaning component had a medium score of 57.5%.

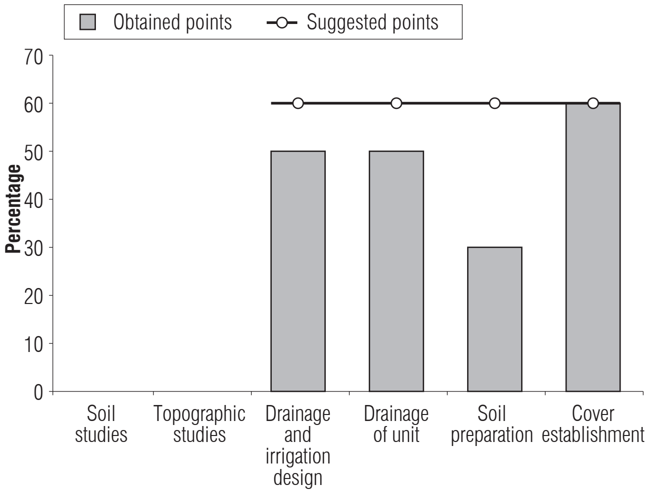

FIGURE 1. Technology balance index for the components of the agronomic phase of establishment of oild palm in Tibu (Colombia).

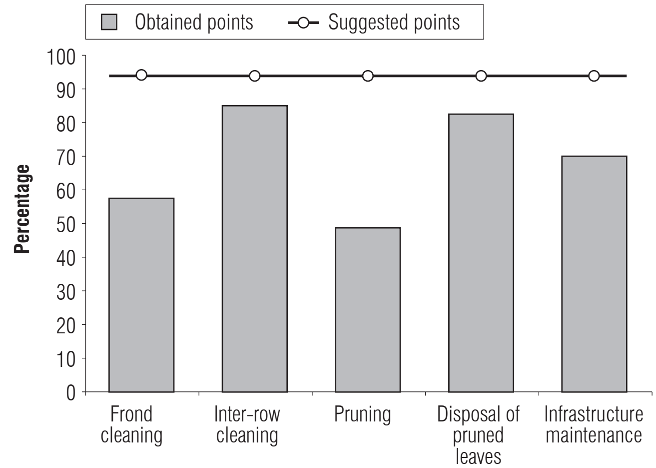

FIGURE 2. Technology balance index for the components of the agronomic phase work ethic for the crop of oild palm in Tibu (Colombia).

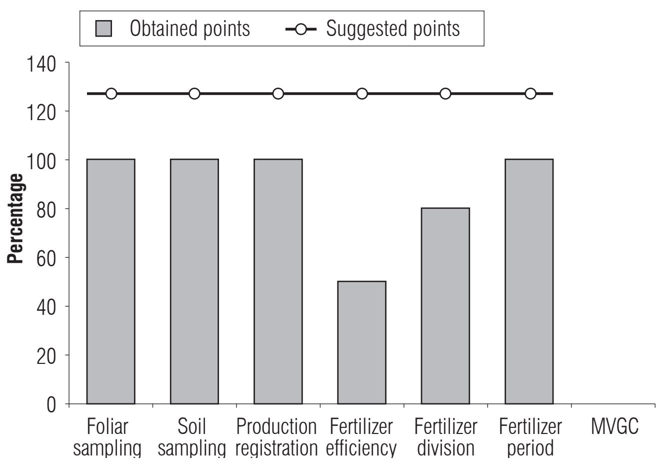

FIGURE 3. Technology balance index for the components of the agronomic phase nutritional management of oild palm in Tibu (Colombia). MVGC, measurement of vegetative growth component.

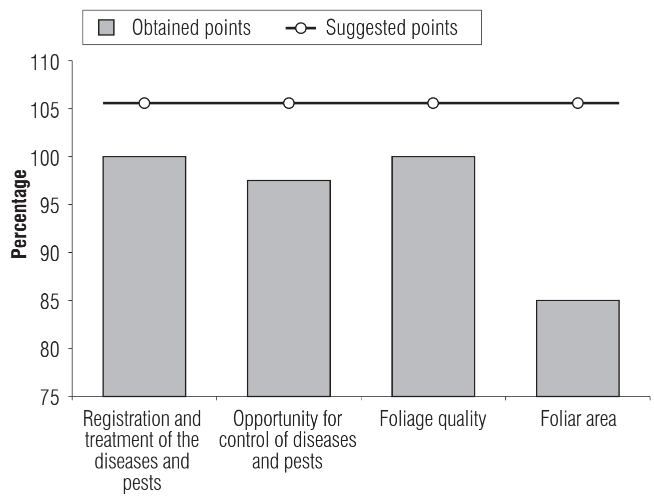

FIGURE 4. Technology balance index for the components of the sanitation management phase of oild palm in Tibu (Colombia).

The infrastructure maintenance component received an acceptable score of 70% and the disposal of pruned leaves and the inter-row cleaning components had good scores of 82.5 and 85%, respectively.

Figure 3 shows the technology balance index for each of the components of the nutritional management of the crop. A value of 0% was determined for the measurement of vegetative growth component because this task is not carried out. For the measurement of the fertilizer efficiency component, the score was 80%. In the other components, the values were excellent.

The technology balance index for each of the components of the sanitation management phase of the crop (Fig. 4). In this agronomic phase, there was a good score for technology adoption for the foliar area component and the other components all had excellent values.

Figure 5 contains the TBI of the components in the harvest and production phase of the crop, wherein a deficient technology adoption score can be seen for the harvested fruit quality component according to the reports from the evaluations carried out by the fruit quality department of the Promotora Hacienda Las Flores. The values were high for the percentages of green fruit and long peduncle, presenting a value of 38%. The technology adoption score was acceptable for the fruit collection component with a value of 68%. Notably, there was a good technology adoption score for the harvest cycle and criteria component with a value of 85% and the production component presented an excellent value of the levels of production obtained in the zone.

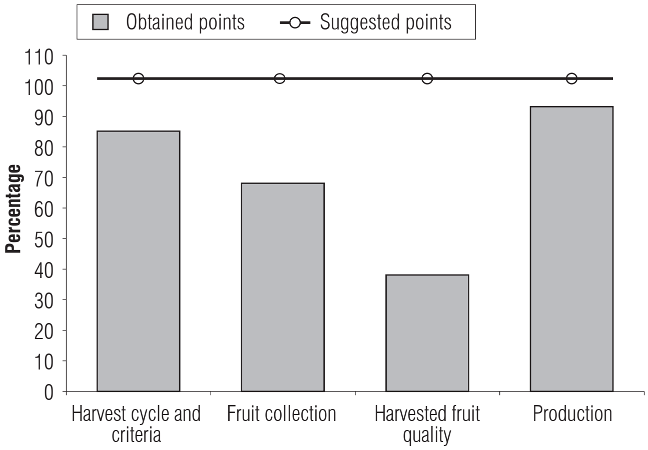

FIGURE 5. Technology balance index for the components of the harvest and production phase of oild palm in Tibu (Colombia).

FIGURE 6. General technology balance index for the agronomic phases of the oil palm plantations in the municipality of Tibu.

Knowing the differences between the producers allows for the classification of the producers according to the level of technology adoption and the respective responses in production and production costs. The benefit is obtained from the adjustment of some cultivation practices, applying successful experiences in other locations, and taking advantage of the best of what one has without the need to buy a lot of machinery or large quantities of fertilizer (Muñoz and Aldana, 2012)

A fundamental result would be the closing of the existing production gap, as compared to countries that are leaders in the oil palm agro-industry such as Malaysia and Indonesia, as a consequence of free trade (González, 2012; Khorramnia *et al*., 2014).

It was possible to determine the TBI for each of the lots using the information obtained for each lot and scoring the components and agronomic phases.

After the scoring of the agronomic phases and their components was completed, a general score was assigned to the Tibu region.

For this, the values of each of the plantations were taken and transformed into percentages, called the general technology balance index (TBI), which are shown for each of the agronomic phases of the oil palm in the municipality of Tibu (Fig. 6), with a notable general technology balance index for the establishment phase of 39%, a deficient value that is very close to the technology balance indices reported for the core palm producers of the central zone (special cooperation agreement N. 00432/12), whose values are between 38 and 49%. There were acceptable scores for work ethic, a good score for the agronomic phases of nutritional management and harvest and production, and an excellent score for the agronomic phase sanitation management due to the fact that there is commitment from the producers to the care of their plantations.

Taking into account the results provided by the formula that determined the technology balance indices, a score of 72.6% was seen for the evaluated plantations, which, according to the technology balance score scale based on the percentage attained with the sum of all the agronomic components, is a good score.

TABLE 3. Values of the general technology balance indices for agronomic phases for 4 core palm producers of the central zone and for the plantations of oild palm in Tibu (Colombia).

Agronomic phase and component	Oleaginosas Las Brisas	Oleaginosas Bucarelia	Extractora San Fernando	Palmares El Pórtico	Tibú
Crop establishment	46	41.2	49	48	39
Work ethic	75	69	74	71	68
Nutritional management	84	80.2	79	81	83
Phytosanitation management	91	92.7	97	98	98
Harvest and production	80	86.5	94	82	75
Total score for core producers	376	369.6	393	380	363
Average score for core producers	75.2	73.92	78.6	76	72.6

The technology balance index of 72.6% for the plantations in Tibu is very close to the technology balance indices reported for the core palm producers in the central zone (special cooperation agreement N. 00432/12), with a TBI of 75.2% for Oleaginosa Las Brisas, a TBI of 73.92% for Oleaginosa Bucarelia, a TBI of 78.6% for the Extractora San Fernando, and a TBI of 76% for Palmares El Portico, values higher than that obtained from the Tibu plantations.

Table 3 compares the general technology balance indices determined in the evaluations of the agronomic phases for 5 core palm producers in the central zone, including the results of the present study, with the observation that, in the five cases where the percentages were over 70%, there was an indication that the obtained values received a good score for the adoption of technology and that they coincided with the lower values for the establishment phase and the higher values for the phytosanitation management phase.The components that had a low degree of technology adoption corresponded to studies on soil characterization, topographical studies, soil preparation, design of agronomic management units (UMAS) and design of drainage and irrigation.

In order to precipitate the improvement of the plantations that presented a low degree of technology adoption, the technology level of the more efficient plantations and more noteworthy production levels must be used as a baseline.

Consequently, more work is need to improve the technology adoption in the components of soil characterization studies, topographical studies, soil preparation, design of agronomic management studies (UAATAS), and design of drainage and irrigation. As a result, soil characterization studies and topographical studies should contract professionals to carry out these tasks, as well as the tasks of adequate soil preparation and the design of drainage systems where needed, as indicated by topographical studies (Khorramnia *et al*., 2014).

To further this goal, suitable agronomic management should be implemented that considers geographical information systems, efficient management of water resources, suitable land, and sanitation control programs. It is also of vital importance that the technical auditing and assistance units of the core palm producers, or something similar, play a principal role in accomplishing this goal (Fedepalma, 2012b).

Furthermore, better technology adoption is needed for pruning in the evaluated plantations through direct training and farmer-to-farmer technology transfers, which would help close the productivity gap using the knowledge of the technology levels achieved by the producers with good and excellent scores for the adoption of technology by other producers, by example or with demonstrations on their plantations (Castiblanco *et al*., 2013; Halbleib and Jepson, 2014).

When it is possible to apply a high level of technology in the management of soil, nutrition, water, pest and diseases, combinations that compete for water and nutrients, harvest, and other crop tasks, it is possible to have productivity around 10 t of fruit/ha between the ages of 24 and 36 months of the palms (Fedepalma, 2010).

It is important to note that the technical team must commit to the task in order to increase the TBI values, which would allow for good or excellent score for the level of technology adoption in the components of growth measurement and fertilizer efficiency measurement, which are the components that are more pertinent to the technicians. For the improvement of the plantations that presented a low degree of technology adoption in the harvest and production phase, it is necessary to continue training programs, apply ECA models (*Escuelas de Campo de Agricultores* in Spanish), continue with evaluations for fruit quality and consider the implementation of fines in the form of "fruit discounts" as done in core palm producers (Halbleib and Jepson, 2014).

Finally, it was clear that none of the palm producers have a clear idea of how much it costs to produce a kilogram of oil palm fruit; so, it is necessary to conduct a socio-business study that would motivate the producers to open their accounts and register the information corresponding to their production activities, using administrative tools offered by field schools for farmers, which teach them how to carry out tasks using the example of leading producers for each of the topics that require improvement (Halbleib and Jepson, 2014).

In terms of production for oil palm, the goal is to increase the levels by at least 50% through the generalized and systematic incorporation of technology of crops with high yield that are currently available and the addition of good practices at all levels (Fedepalma, 2011b; Kamarulzaman and Mohayidin, 2011).

Conclusions

It was determined that the general technology adoption level of the Tibu plantations was 72.6%. According to the technology score table, this score is good, with a notably high percentage of acceptance in the agronomic phase of sanitation management at 98%.

In the Individual Technology Balance Indices, only one producer received a medium score of 51%, two producers received acceptable scores of 69% and the other 17 producers received good scores with values between 70 and 90%.

In relating the technology adoption level with the average obtained production for each of the plantations, it was seen that 15% of the producers saw production that was under 20 t ha^{-1}, receiving minimum scores, 65% of the plantations had production that was between 20 and 30 t ha^{-1}, receiving medium scores, and 20% of the plantations received a maximum score with production over 30 t ha^{-1}.

None of the producers had a clear idea of how much it costs to produce one kilogram of oil palm fruit, making it necessary to conduct a socio-business study that would motivate the producers to open their books and register the financial-economic information that corresponds to their production activities.

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