The production efficiency of herbicides in palm oil plantation in Sumatera and Kalimantan

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Abstract. The presence of weeds in palm oil plantations have been widely known to result in a decrease in the quantity and quality of fresh fruit bunches (FFB), disruption to plant growth, increased pest and disease attacks, disruption of water use, and in general will increase the cost of farming. These systemic risks have been mitigated with the use of herbicides. The economic use of herbicides has a positive impact on reducing production costs, especially saving labor costs and time during land clearing and plant maintenance so as to increase farmers’ income and profits. The efficiency of palm oil production by using herbicides and other weed control alternatives and the determinants were analyzed with a production efficiency approach. Production functions explain the technical relationship between a number of inputs used with output in a production process in palm oil sector. The regression method was carried out by utilizing survey data of palm oil farmers in Indonesia's palm oil plantation centers in Riau-, Jambi, Central- and West Kalimantan-Provinces. The results showed that the factors which significantly affect production efficiency of the sample consisting of age planting, glyphosate dosage, paraquat dosage, KCl fertilizer, and Dummy land area. Meanwhile, the use of paraquat, glyphosate, KCl, and urea was considered non optimal. Hence, it is recommended to add the use of herbicides to attain the optimization of production.

1. Introduction

Indonesia has been recognized as the leading exporter of CPO (crude palm oil) and various processed products of palm oil in the world. Indonesia has tremendous potential in developing this sector due to the fact that the Indonesian climate is suitable for production as well as high economic efficiency in plantations. In addition, a strong traditional culture to support livelihoods also contributes significantly to the development of palm oil as a sector that is export oriented.

The share of Indonesian palm oil plantations increased to 41% in terms of area and contributed 36% to the formation of national production. An increasing share of People's Plantations has provided employment to many small farmers, with more than 6.7 million tons of palm oil produced by smallholders, thus contributing greatly to increasing the income of rural populations [1]. Even so, the productivity figures of community palm oil plantations are around 2 to 3 tons/ha, while private large palm oil plantation companies reach 4 tons/ha. According to the Center for Agriculture Data and
Information System of the Secretariat General of the Ministry of Agriculture, in 2017 the productivity of national palm oil plantations reached 3.8 tons/ha, or on average during the 1995-2017 period the productivity of palm oil plantations only grew 0.72%. This condition is lower than the productivity of Malaysian palm oil plantations which has reached 10 tons/ha [1].

One of the strategic factors that can affect productivity is weeds, the presence of weeds in palm oil plantations can result in a decrease in the quantity and quality of fresh fruit bunches (FFB) production, disruptions to plant growth, increased pest and disease attacks, disruption to water use, and in general will increase farming costs. In various food crops and plantations, especially palm oil, herbicides are now widely used by farmers in various regions to control weeds. This method is considered more practical and beneficial compared to other methods, especially in terms of the benefits of fewer labor and relatively shorter implementation. Based on its workability, herbicides are categorized into 2 namely contact and systemic herbicides. While based on the selectivity power is divided into selective and non-selective.

The use of herbicides is expected to gain positive economic impact in reducing production costs, especially saving labor costs and time when clearing land and maintaining plants so as to increase farmers’ income and profits. Imolame et al. [2] conducting research on the economic impacts related to the use of herbicides based on active ingredients is necessary. Furthermore, an analysis using R / C ratio to see the difference in the level of efficiency of the herbicides active ingredients. It was found that 1.5 kg of methylated herbicide has higher productivity and profit compared to other types of herbicide active ingredients in same production in Nigeria. The benefits of herbicides in improving farming efficiency are also supported by research from [3] and [4] which state that the use of herbicides can reduce the need for labor costs and provide more controlled weed management. The use of conventional techniques with a certain amount of labor input and time can reduce the efficiency of farming. In addition to workmanship that requires a long time, the results obtained are also not necessarily maximal. The use of herbicides with the right dosage and composition can control weeds well so that it does not disturb the growth of cultivated plants. Weed control using herbicides is one alternative that can be implemented by farmers because it has economical production costs and weeds can be controlled better.

On that basis, it is very important to conduct a comprehensive study to assess the impact of the use of herbicides on the efficiency of palm oil production. Analysis of the efficiency of palm oil production using herbicides and the factors that influence them are approached with a production efficiency approach. The production function explains the technical relationship between a number of inputs used and outputs in a production process. Analysis of production efficiency was carried out by conducting a survey of respondents of farmers and companies in the centers of Indonesian palm oil plantations. Based on regional aspects, the centers of palm oil plantations are highly concentrated. Nearly 70% of palm oil plantations are located in Sumatera and 30% are located on Kalimantan Island. The Provinces of Riau, North Sumatra and Central Kalimantan are the 3 centers of palm oil production in Indonesia, with palm oil plantations reaching 2.5, 1.5 and 1.25 million ha [1]. This paper examines the significance of herbicides in increasing palm oil production. More specifically, this paper attempts to: (1) Identify patterns of herbicide use among palm oil farmers; (2) Analyzing the efficiency of herbicide use in palm oil; (3) Analyze the factors that affect palm oil production.

2. Methods
The research was conducted using a survey method in several producing regions in mid 2019. Sampling was conducted by purposive sampling method on 175 farmer respondents consist of 35 immature palm oil plantations (TBM) and 140 mature palm oil plantations (TM). The data were analyzed qualitatively and quantitatively. Qualitative analysis was used to describe the circumstances related to the research problems that cannot be described quantitatively. Quantitative analysis was performed with the Cobb-Douglas function and analysis of efficient use of factors of production.
### Table 1. Type of farmer and the numbers of respondents.

| Regions                | Types of Farmers | Numbers of Farmers |
|------------------------|-------------------|--------------------|
| Riau                   | TBM               | 35                 |
|                        | TM                | 35                 |
| Jambi                  | TM                | 35                 |
| West Kalimantan        | TM                | 35                 |
| Central Kalimantan     | TM                | 35                 |

The Cobb-Douglas production function is a function or equation that involves 2 or more variables, where one variable is called the dependent variable (Y) and the other is called the independent variable (X). The settlement of the relationship between X and Y can be solved by regression. In this study, the production function model used is as follows:

\[
Y_i = b_0 + b_1 age_i^2 + b_2 age_i + b_3 g\text{liesat}_i + b_4 paraquat_i + b_5 KCL_i + b_6 UREA_i + b_7 land_i + e_i
\]

where:

- **Y** = output (Kg)
- **age** = squared of plant age (years)
- **age** = plant age (years)
- **g\text{liesat}** = dosage of glyphosate used (L/year)
- **paraquat** = dosage of paraquat used (L/year)
- **KCL** = numbers of KCl used (kg/year)
- **UREA** = numbers of urea (kg/year)
- **land** = land area (ha)
- **b_0** = intercept
- **e_0** = error term

Parameter \( \beta_1 \) can be interpreted as elasticity of production for each production factors. So the elasticity of production for production factors is expressed by the magnitude \( \beta_1, \beta_2 \) and \( \beta_3 \). The value of marginal product (VMP) for an input equal to the price of inputs and can be written: \( VMPxi = Pxi \). Where \( xi \) was input (or product), and \( P \) was price of input (price of product). \( (VMPxi / Pxi) > 1 \) means the use of inputs \( x \) is not yet efficient, to achieve efficient, input \( x \) should be increased. \( (VMPxi / Pxi) < 1 \) means the use of inputs \( x \) is not yet efficient, to achieve efficient, efficient input \( x \) needs to be reduced.

### 3. Results and discussion

#### 3.1. Patterns in using herbicides
Herbicide is one of the chemical compounds that can help farmers overcome weed problems. In general, the experience of using herbicides for weed control in general ranges from 1 to 10 yr, however many farmers have had very long experience using herbicides, some have even reached up to 30 yr, especially farmers with moderate land ownership (Table 2). The data in the table also shows that most farmers had 1 to 5 yr experiences in using herbicides on small and medium category of land ownership. An exception occurs for farmers with land ownership of more than 4 ha where 39\% of the sample farmers were using herbicides between 11-15 yr.
Table 2. Number and Percentage of Farmers Based on Experiences Using Herbicides in Several Land Ownership Categories.

| Land Ownership       | Experience in using Herbicides (years) | Number of Farmers | Percentage |
|----------------------|----------------------------------------|-------------------|------------|
| Small (<2Ha)         | 1-5                                    | 10                | 43.48      |
|                      | 6-10                                   | 7                 | 30.43      |
|                      | 11-15                                  | 3                 | 13.04      |
|                      | 16-20                                  | 3                 | 13.04      |
|                      | 21-30                                  | 0                 | 0.00       |
| Medium (2-4 Ha)      | 1-5                                    | 25                | 29.76      |
|                      | 6-10                                   | 19                | 22.62      |
|                      | 11-15                                  | 13                | 15.48      |
|                      | 16-20                                  | 13                | 15.48      |
|                      | 21-30                                  | 13                | 15.48      |
| Large (>4 Ha)        | 1-5                                    | 4                 | 17.39      |
|                      | 6-10                                   | 8                 | 34.78      |
|                      | 11-15                                  | 9                 | 39.13      |
|                      | 16-20                                  | 2                 | 8.70       |
|                      | 21-30                                  | 0                 | 0          |

The importance of the application of herbicides on palm oil for TM and TBM farmers was to control weeds in the pikul market (area between plant oil plantation that be used for transportation of harvesting, fertilizing, pest control etc.) and weed clearing disc around plants plantations. As many as 46% of respondents were chosen to use herbicides to clear weeds in the pikul market and 31.4% used herbicides to clean disc around the crop to produce farmers (TM). For TBM farmers, aside from being used to control weeds at the pikul market, 44% of respondents stated that herbicides were also used to clean dishes around the plants (Table 3). The data in Table 3 showed that the use of herbicides to clean discs is lower than in TBM farmers. Mature plants usually have canopy closure, so that weeds that grow on discs are less than in immature plants.

Table 3. Purposes of herbicides application.

| No | Purpose of Herbicides Application | TM Farmers | TBM Farmers |
|----|----------------------------------|------------|-------------|
| 1  | Land Clearing                    | 7.9%       | 5%          |
| 2  | Weed Control in *Pasar Pikul*    | 46.1%      | 44%         |
| 3  | Clearing epiphytic plants        | 14.5%      | 1%          |
| 4  | Weed Clearing disc around plants | 31.4%      | 44%         |
| 5  | Others                           | 0.2%       | 6%          |
Facts on the field also showed farmers often mixing herbicides, both with other herbicides and with other chemicals. 72% of TM farmers and 75% of TBM farmers mix herbicides with other active compounds to eradicate weeds. The main reason for respondents to mix herbicides was to control weeds faster. As many as 42.3% of TM farmers’ respondents believed that mixing would control weeds faster. Likewise, as many as 60% of TBM farmer respondents believe that mixing would control weeds faster (Table 4).

Table 4. Reasons for mixing herbicides.

| No | Reasons for Mixing                      | TM Farmers | TBM Farmers |
|----|-----------------------------------------|------------|-------------|
| 1  | Cost Saving                             | 8.5%       | 10%         |
| 2  | More effective in controlling weeds     | 42.3%      | 60%         |
| 3  | Weeds do not regrow easily              | 35.9%      | 0%          |
| 4  | Others: Destroy wooden weeds            | 42.3%      | 30%         |

The behavior of farmers in choosing the size of herbicide packaging is related to land ownership. The majority of farmers with small and medium land ownership categories buy herbicides in 5 L packaging size. Meanwhile, the purchase of herbicides with a package size of 20 L is common by farmers in the category of large land ownership. There is a phenomenon that the greater the area of palm oil cultivated the greater the size of the herbicide packaging purchased by farmers (Table 5).

Table 5. Packaging size of herbicides bought by farmer based on land ownership.

| Land Ownership | Packaging Size (Liter) | Total | Percentage |
|----------------|------------------------|-------|------------|
| 0.5            | 0,00                   | 0     | 0          |
| 1.0            | 8,00                   | 38    | 0          |
| 5.0            | 13,00                  | 62    | 0          |
| 20.0           | 0,00                   | 0     | 0          |
| 0.5            | 0,00                   | 0     | 0          |
| 1.0            | 10,00                  | 14    | 0          |
| 5.0            | 52,00                  | 71    | 0          |
| 20.0           | 11,00                  | 15    | 0          |
| 0.5            | 0,00                   | 0     | 0          |
| 1.0            | 0,00                   | 0     | 0          |
| 5.0            | 8,00                   | 40    | 0          |
| 20.0           | 12,00                  | 60    | 0          |

The application frequency of herbicides to control weeds reached twice per year depending on the state of the land. In general, small and medium scale farmers applied herbicides 1 to 2 times. The
frequency of application 3 times is rarely done by small farmers, while 16% and 23% of farmers with medium and large land ownership applied herbicides up to 3 times. This shows that large farmers with strong capital support were more intensive in controlling weeds using herbicides. This difference is indicated to be related to the age of the palm oil plantations. Old-age plants and canopies cover each other using herbicides not as intensely as plants whose canopy has not covered each other and most farmers with large land holdings are relatively young.

Table 6. Frequency of herbicides uses based on land ownership.

| Land Ownership | Frequency/year | Numbers of Farmers | Percentage |
|----------------|----------------|--------------------|------------|
| Small (<2 ha)  | 1              | 14,00              | 61         |
|                | 2              | 8,00               | 35         |
|                | 3              | 1,00               | 4          |
| Medium (2-4 ha)| 1              | 25,00              | 31         |
|                | 2              | 42,00              | 53         |
|                | 3              | 13,00              | 16         |
| Large (>4 ha)  | 1              | 9,00               | 41         |
|                | 2              | 8,00               | 36         |
|                | 3              | 5,00               | 23         |

The farmers applied herbicide by spraying suspense or herbicide solution into the target weed. The amount of herbicide needed to control weeds at a certain unit area is called a dose. The survey results showed that farmers with small land ownership categories used a greater dose of herbicide (4.27 L/ha) compared to farmers with medium land ownership categories (3.01 L/ha) and large (3.28 L/ha) as shown in Table 7. This was related to the low level of herbicide application efficiency in small farmers. This phenomenon results in inefficient use of agricultural inputs in small farmers.

Table 7. Average dosage of herbicides based on land ownership.

| Land Ownership | Average Dosage of Herbicides (L/ha) |
|----------------|-----------------------------------|
| Small (<2 ha)  | 4.27                              |
| Medium (2-4 ha)| 3.01                              |
| Large (>4 ha)  | 3.28                              |

Weed control technology on palm oil with herbicides is not only directly related to palm oil production, but the benefits were also felt by farmers on other matters. More than 96% of palm oil farmers in the mature plant phase and 100% of the palm oil farmers in the immature plant phase gave the answer yes that the use of herbicides provides the main benefits of: speeding up weed control time, simplifying work, and saving labor costs. In addition to using herbicides, weed control could be done manually by using labor. However, respondents from TBM and TM farmers mentioned that with herbicides farmers could save labor costs. This savings could occur because if using manual labor will
require a relatively longer time. Labor wages for cleaning weeds manually are considered inefficient if. In addition, another reason chosen by respondents both TBM and TM farmers was the use of herbicides when weed control was faster and easier.

3.2. The efficiency of herbicide use in palm oil

The use of paraquat herbicides which has been widespread in the community, especially in palm oil commodities, showed the dependence of farmers on paraquat herbicides in the management of their farming businesses. Palm oil plants spread across Sumatera and Kalimantan, require considerable crop maintenance efforts in terms of labor use and maintenance costs. The existence of paraquat herbicide was very important to the efficiency of palm oil farming. Paraquat in the palm oil farming business was mostly used to control weeds in the pikul market and to clean the disk around the palm trees.

Table 8 shows the role of the paraquat on the efficient use of labor and the costs of farming palm oil plantations (TM) in Riau, Jambi, West Kalimantan and Central Kalimantan. The analysis showed that the use of paraquat herbicide in 4 locations had an impact on cost efficiency and the use of labor (HOK) which was quite high compared without using paraquat. Efficient use of labor is important, especially in supporting farmers' income incomes through low labor costs. While the efficient use of labor is related to the issue of labor availability which was less in regions such as Sumatara and Kalimantan.

| Application of Herbicides | Location               | Efficiency Cost | Efficiency HOK TK |
|---------------------------|------------------------|-----------------|-------------------|
| Weed Control, cleaning disc area around plants, etc | Riau                   | 51%             | 66%               |
|                           | Jambi                  | 43%             | 72%               |
|                           | West Kalimantan        | 46%             | 79%               |
|                           | Central Kalimantan     | 35%             | 81%               |

Further observation, the analysis showed that overall, the efficiency of labor use (HOK) was higher than the cost efficiency. This showed that the role of paraquat herbicides was very important in answering the issue of labor scarcity in regions such as Sumatera and Kalimantan. The existence of efficient use of labor in units of Workers’ Day (HOK) indicated the occurrence of time efficiency becomes faster. For the West Kalimantan and Central Kalimantan regions, the efficiency of labor use was on average 80%, while the cost efficiency is around 35-46%. Furthermore, for the Jambi and Sumatra regions, the efficiency of labor use was on average 80%, while the cost efficiency was around 35-46%.

Similar to the palm oil plantations in TBM, the cost efficiency and labor are also quite high compared without using paraquat herbicides. Paraquat on immature palm oil plantations was also largely used for controlling weeds in the pikul market and cleaning dishes around palm oil trees. For TBM in Riau, the efficiency of labor use was on average 61%, while the cost efficiency was around 55%.
3.3. Factors that affect palm oil production

FFB production in mature crops is influenced by the use of inputs or factors of production used, whether or not it is significant to the production of FFB or whether it is efficient or not the use of each production input. The results of the analysis at 4 locations (Table 10) showed that factors that significantly influence FFB production at 5% significance level were (1) dose of glyphosate, (2) dose of paraquat use, (3) KCL fertilizer and (4) land size. Plant age has a significant effect on FFB production at a significant level of 15%. Meanwhile other factors such as the amount of urea fertilizer use were not statistically significant for FFB production.

Overall the average age of palm oil (TM) in the 4 locations was around 14.3 yr or was in a phase of decreasing. Palm oil plants are aging and the quality is decreasing. This can be seen from the coefficient value of the negative value of the Age Squares of Plants, which is -38.11, the older the productivity, the lower the productivity.

For the plant age variable which is positive and has a significant effect, it means that the growing age of the plant has a significant effect on FFB production. This was especially true in the areas of West Kalimantan and Central Kalimantan where the average age of plants is around 9 yr, namely the age of plants is still in the productive phase, when the age of the plant increases productivity will increase, ceteris paribus. While the average age of plants in Riau and Jambi was around 20 yr.

Table 10. Factors affecting palm oil production.

| Variable Name                  | Coefficient | Std. Error | t-Statistic | Prob.     |
|--------------------------------|-------------|------------|-------------|-----------|
| Constant                       | -30199.68   | 9464.52    | -3.1908     | 0.0018    |
| Square of Plant Age (year)     | -38.11      | 34.61      | -1.1012     | 0.2729    |
| Plant Age (year)               | 2013.76     | 1251.07    | 1.6096      | 0.1100**  |
| Dosage of Gliphosate (L)       | 798.16      | 312.10     | 2.5574      | 0.0118*   |
| Dosage of Paraquat (L)         | 902.94      | 433.44     | 2.0832      | 0.0393*   |
| KCl Fertilizer (kg)            | 3.24        | 1.03       | 3.1406      | 0.0021*   |
| Urea Fertilizer (kg)           | 3.14        | 2.69       | 1.1661      | 0.2458    |
| Land (ha)                      | 16541.17    | 1220.19    | 13.5563     | 0.0000*   |
| R-squared                      | 0.832388    | 0.832388   | F-statistic | 87.26275  |
| Adjusted R-squared             | 0.822849    | 0.822849   | Prob(F-statistic) | 0.00000 |

The use of systemic or glyphosate herbicides on palm oil plants was positive and has a significant effect on FFB production. This showed that if the glyphosate dose is increased, then weeds and other pests will be reduced so that nutrients can be better absorbed by palm oil plants which have an impact on increasing FFB production. The average dose applied at 4 locations was around 1.9 L/ha, while the recommended dosage of glyphosate for low-level weeds such as Ottochloa nodosa, Paspalum

Table 9. The efficiency of herbicide use in palm oil.

| Application of Herbicides                        | Location | Efficiency | Cost | HOK TK |
|--------------------------------------------------|----------|------------|------|--------|
| Weed Control, cleaning disc area around plants, etc | Riau     | 55%        | 61%  | 3.3    |
conjugatum and others is around 1.5 to 2 L/ha. Medium type weeds such as Mikania micrantha, Borreria sp, Axonopus compressus with a dose of 2 to 3 L/ha and high types of weeds including Cynodon dactylon and Panicum repens, control could be at a dose of 4 to 6 L/ha.

As is the case with glyphosate, the use of paraquat in palm oil plants was positive and has a significant effect on FFB production. This shows that if the dose of the paraquat was increased, then weeds and other pests would be reduced so that nutrients can be better absorbed by palm oil plants which have an impact on increasing FFB production. The average dosage of paraquat applied at 4 locations was around 2.8 L/ha, while the recommended dosage of using paraquat for narrow leaf weeds could be sprayed at a dose of 2.5-5 L/ha.

KCl fertilizer is needed by palm oil plants to grow and develop and produce superior and high quality fruit in 4 locations. The results of the analysis showed that the use of KCl fertilizer amount on palm trees was positive and had a significant effect on FFB production. This showed that if the amount of KCl fertilizer was increased, it will have an impact on increasing FFB production. The average use of KCl fertilizer in 4 locations is around 1.59 kg/plant/yr. While the recommended dosage of the use of KCl fertilizer every year for palm plants is 0.4-1 kg/plant/yr.

Urea fertilizer helps palm plants for vegetative growth such as leaves, crowns, and others. The results of the analysis showed that the use of urea fertilizer in palm plants was positive and had no significant effect on FFB production. This was due to the average age of palm oil plants in 4 locations that are already old, which was around 14.3 yr. As the age of the palm oil, the addition of urea fertilizer does not affect the production of FFB. The average use of urea fertilizer in 4 locations was around 1.15 kg/plant/yr. While the recommended dosage of the use of urea fertilizer every year for palm plants is 0.8-1.2 kg/plant/yr.

The analysis of land area showed a positive sign and has a significant effect on increasing FFB production. This showed that the more extensive the land, the FFB production will increase or higher. In the 4 research locations, it was found that land with an area under <2 ha was on average smaller than the land area of >2 ha.

An input is considered to be optimum in use if the ratio of Value Marginal Product (VMP) to Input Price (Px) is equal to 1, or written VMP / Px = 1. The results of the analysis in Table 11 showed that the use of input production of paraquat, glyphosate, KCL fertilizer, urea fertilizer and the land has not been optimal or the value of VMP / Px ≠ 1. For the paraquat, glyphosate, and land values of VMP / Px > 1 which indicate the use of these inputs could still be increased to be optimal. On the other hand, for KCL and Urea fertilizer inputs, VMP / Px <1 indicates the use of these inputs was excessive or needs to be reduced in order to be optimal.

| No | Variable            | VMP / Px | Elasticity |
|----|---------------------|----------|------------|
| 1  | Dosage of Paraquat  | 13.35    | 0.14       |
| 2  | Dosage of Glyphosate| 12.95    | 0.08       |
| 3  | KCL                 | 0.65     | 0.04       |
| 4  | Urea                | 0.91     | 0.03       |
| 5  | Land                | 1.75     | 0.91       |

The elasticity of production shows the level of sensitivity of changes in total production when there is a change in the use of the amount of production inputs. A farming condition is said to be in a rational area if it is in Region II with a production elasticity of 0 <Ep <1. The results of the analysis in Table 11 show that all production inputs, paraquat, glyphosate, KCL fertilizer, Urea fertilizer, and land, have a value of production elasticity between 0 and 1 (0 <Ep <1). Furthermore, it was observed that land production inputs (Ep = 0.91) and paraquat (Ep = 0.14) have the greatest elasticity values.
compared to other production inputs. This means that the 2 inputs, both land and paraquats, if added or increased then the addition of FFB production is much greater than if adding other inputs.

4. Conclusion
The pattern use of herbicides showed that most farmers had 1 to 5 yr experience for small and medium category of land ownership. An exception occurs for farmers with land ownership of more than 4 ha where 39% of the sample farmers were using herbicides between 11-15 yr. The importance of the application of herbicides on palm oil for TM and TBM farmers is to control weeds in the pikul market and weed clearing disc around plants. Facts on the field also showed farmers often mixing herbicides, both with other herbicides and with other chemicals for controlling weeds faster. In terms of packaging size, the greater the area of palm oil cultivated the greater the size of the herbicide packaging purchased by farmers.

In general, small and medium scale farmers applied herbicides 1 to 2 times. The frequency of application 3 times was rarely done by small farmers, while 16% and 23% of farmers with medium and large land ownership applied herbicides up to 3 times. There was an indication of the low level of herbicide application efficiency in small farmers. Farmers with small land ownership categories use a greater dose of herbicide (4.27 L/ha) compared to farmers with medium land ownership categories (3.01 L/ha) and large (3.28 L/ha). The efficiency of labor use was higher than the cost efficiency for TM and TBM plants, indicating that the use of herbicides boost labor efficiency.

Factors which significantly affect production efficiency of the sample consisting age of planting, glyphosate dosage, paraquat dosage, KCl fertilizer, and dummy land area.

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