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# Impact of grafting on local coffee production based on People's plantations in Bengkulu Province of Indonesia

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**ABSTRACT:** Shoot grafting (grafting) on plants is a cultural technology that reduces production time compared to new planting methods. This has changed the habits of local coffee farmers, who previously carried out plantation activities only when entering the harvest season, to become more intentional because, generally, the nature of grafting coffee requires intensive attention and care to continue to bear fruit throughout the season. This research aims to analyze the impact of applying grafting to local varieties of coffee plants, especially in smallholder plantations, on the resulting production. Multi-stage sampling was used to choose326 coffee farmers divided into two farming groups, namely 120 farmers from the group of farmers who have implemented shoot grafting (as the treatment group) and 206 farmers who have not implemented shoot grafting or as the control group. The probity model estimates the probability of grafting and then chooses a matching algorithm. In the matching process between covariates, the nearest neighbor without replacement (NN) technique is a matching process for each covariate with only one chance. The results show that grafting technology has not significantly impacted the production of locally cultivated coffee. However, applying top grafting technology influences the number of plants and farmer experience.
**Keywords:** family farms; shoot grafting; changes in agricultural systems;

## Impacto da enxertia na produção local de café baseada em plantações populares na Província de Bengkulu, Indonésia

**RESUMO**: A enxertia de brotos em plantas pode ser considerada como uma técnica de manejo cultural para reduzir o tempo de produção quando comparado aos novos métodos de plantio. A adoção dessa técnica, provocou uma mudança nos hábitos dos cafeicultores locais na Indonésia; antes, esses produtores realizavam atividades de manejo apenas no início da época de colheita; agora, precisaram se tornar mais intensivistas, visto que a enxertia do café exige atenção e cuidados frequentes para continuidade da produção de frutos ao longo do ano. temporada. Esta pesquisa tem como objetivo analisar o impacto da aplicação de enxertia em variedades locais de café na Província de Bengkulu (Indonésia), especialmente em plantações de pequenos agricultores e nas suas produções resultantes. A amostragem ocorreu em vários estágios e foi usada para escolher 326 cafeicultores, divididos em 2 grupos agrícolas, sendo: i) 120 agricultores que implementaram a enxertia de brotos (como grupo de tratamento); ii) 206 agricultores que não implementaram a enxertia de brotos. Um modelo probabilidade foi usado para estimar a probabilidade de enxerto e, em seguida, escolher um algoritmo de correspondência. No processo de emparelhamento entre covariáveis, foi empregada a técnica do vizinho mais próximo sem substituição (NN), que indica que o emparelhamento para cada covariável possui apenas uma chance. Os resultados mostram que a aplicação da tecnologia de enxertia provou não ter impacto significativo na produção do café cultivado localmente na Indonésia; porém, a aplicação da tecnologia de enxertia de topo, mostra influências no número de plantas e na experiência do agricultor.
**Palavras-chave**: propriedades rurais familiares; enxertia; mudanças nos sistemas agrícolas.

## 1. INTRODUCTION

Coffee is an export commodity for world plantation products. Indonesia is a coffee producing country with a production area of 1.2 million hectares; with this potential, it should be able to become the world's main supplier of coffee (WIDYANTINI, 2019; PRAJANTI et al., 2020). Various research and plantation sector policies that directly touch the coffee commodity in Indonesia have still not been able to increase national coffee production (SARVINA et al., 2021), where 99 percent is controlled by smallholder farmers with limited capital capabilities, especially in efforts to develop coffee plants in the regions. Existing capital limitations are exacerbated by the slow pace of information received by farmers and the lack of production facilities (ASHADI et al., 2023).

Bengkulu as a robusta coffee producing area in Indonesia, is known as one of the robusta coffee golden triangle areas on the island of Sumatra (TAWAKAL et al., 2022). It is

hardly unexpected that Bengkulu's local farmers rely mostly on coffee for their livelihood. Local farmers' ability to produce coffee is still considerably below the average for the country, even though it is their primary source of income and their work (BYRAREDDY et al., 2019). This results in the condition of the plantation appearing unkempt. This condition occurs due to local coffee farmers' habits and lack of understanding of sustainable cultivation systems (VELTEN et al., 2015). And environmentally friendly, namely agriculture that provides economic benefits through abundant production that the next generation can inherit. In general, local farmers only carry out production activities during the harvest season and ignore the timing of the production process, especially fertilization. The production results are far from the potential production that can be achieved, but sometimes, coffee plants have production beyond expectations, even without intensive care.

To enable coffee growers to continue producing throughout the growing season with the limited infrastructure and facilities already in place, the government has undertaken several initiatives to alter coffee farmers' practices and methods of coffee farming. Shoot grafting is a cultural technology for coffee plants to cut production time compared to new planting methods (KURNIAWAN et al., 2022). Local farmers usually carry out shoot grafting to rejuvenate old coffee plants that are no longer productive to get new plants that produce faster and have superior characteristics than the parent plant. Grafting aims to increase local coffee production, hoping it can make coffee farmers more focused and intent on running their coffee plantation business. Due to the nature of grafting coffee, it requires intensive attention and care to continue bearing fruit throughout the season. Apart from that, shoot grafting on coffee plants is the government's effort to maintain regional coffee supplies and preserve the (natural) environment as an effort to prevent the transfer of commodity functions from coffee plants to other crops that are considered more profitable for farmers, such as orange plants and Kali Fornia papaya.

This research analyzes the impact of applying grafting to local coffee plants, especially on smallholder plantations, on production. This research is expected to provide information, solutions, and common ground in overcoming fundamental problems in local coffee cultivation by farmers, especially in Bengkulu province and coffee farmers in general.

## 2. MATERIALS AND METHODS

Bengkulu was chosen as a research area purposively (TAHERDOOST, 2016). Apart from being a coffee producing region in Indonesia, Bengkulu is also known as the golden triangle area of robusta coffee on the island of Sumatra. Method Multi-stage sampling was used to choose 326 coffee farmers who were divided into two groups, namely 120 farmers from the group of farmers who had applied grafting as the treatment group and 206 farmers who had not applied graft or what is known as strip coffee in the control group, using the formula (WILLIAM et al., 1977) as follows:

$$n_0 = \frac{\text{WITH}^2 pq}{\text{It is}^2} \quad (01)$$

Z is the t value from the normal table (1.96) at the 95% confidence level, p is the likelihood that the respondent has measurable characteristics, q is (1 p), or the likelihood that the respondent does not have measurable characteristics, and e is the 5% significance level. In this case, n0 is the necessary sample size.

The sample size can be computed as follows, assuming that 50% of respondents possess the measurable attributes:

$$n_0 = \frac{(1.96)^2(0.5)(0.5)}{(0.05)^2} = 384 \quad (02)$$

801 coffee farmers have applied grafting and are included in the treatment group in producing condition, and 1375 farmers have not implemented grafting or strip coffee as the control group. The appropriate sample size using the equation (Cochran, 1977) to correct for a small limited population size is:

$$n = \frac{n_0}{1+(\frac{n_0-1}{N})} \quad (03)$$

The proportion of each group of coffee farmers is determined by an equation developed by (Ackoff, 1973) in (Taherdoost, 2016), aimed at ensuring that each stratum is adequately represented with the formula:

$$p_{ij} = \frac{N-n_{ij}}{N} \quad (04)$$

where: P = Portion of sample population; n = Number of members of the population (sample); N = Total population of the region; i-j = Total population of each group who were interviewed using a list of questions (questionnaire) that had been prepared.

Primary data were obtained from respondent farmers who were selected and interviewed from the areas covered in the survey during the 2021-2022 harvest season, starting from October 2022 to April 2023. Secondary data were collected before and during the survey as supporting data in the research obtained from various literature, related departments, and agencies with the data needed for research.

Descriptive research describes phenomena, the current state of the subject, and the object of research based on facts. This research prioritizes what rather than why or how something happens; therefore, observations and surveys are carried out to collect data (NASSAJI, 2015).

Propensity score matching was utilized to see how grafting affected production (PSM). To better analyze the achievement results, the propensity score matching method matches subjects or members of the treatment group with the condition of the non-treatment group as a control using either the propensity score value, the probability of the treatment group, or both, using observable characteristics. Rosenbaum; Rubin (1983) was the first to provide this PSM approach. D'Agostino Jr (1998), Haviland et al. (2007), Rubin (2001), Stuart (2010) and Austin (2011) further enhanced it.

This study used a probity model to estimate the probability of applying graft grafting. With the following probity model:

$$P\ (Y; =1\ |\quad (05)$$

The first has to do with the variables that will be included in the model and the model that will be utilized for estimation. Table 2 provides an overview of the model used probit regression to match PSM scores with variables.

Table 1. Total farmer population based on selected groups and regions.
Tabela 1. População total de agricultores baseada em grupos e regiões selecionadas.

| Region<br>District and Village | Amount<br>Coffee Farmers (KK) | Population<br>Treatment Farmers (KK) | Population<br>Control Farmers (KK) |
|---|---|---|---|
| Bermani Ulu raya | 533 | 249 | 284 |
| Dataran Tapus | 108 | 98 | 10 |
| Bandung Marga | 225 | 84 | 141 |
| Pal VII | 200 | 67 | 133 |
| Bermani Ulu | 418 | 116 | 518 |
| Pagar Gunung | 203 | 24 | 179 |
| Tebat Tenong Dalam | 141 | 18 | 123 |
| Air Pikat | 74 | 74 | 216 |
| Bermani Ilir | 502 | 267 | 235 |
| Talang Sawah | 101 | 42 | 59 |
| Embong Sido | 172 | 108 | 64 |
| Bukit Menyan | 229 | 117 | 112 |
| Tebat Kirai | 507 | 169 | 338 |
| Taba Air Pauh | 147 | 48 | 99 |
| Tebat Kirai | 227 | 45 | 182 |
| Tapak Gedung | 133 | 76 | 57 |
| Total | 2176 | 801 | 1375 |

Source: BPP (2021); and 2022 primary data.

Table 2. Description of variables in the probity model.
Tabela 2. Descrição das variáveis do modelo probabilistico.

| P (Yi) | Binary | Connect Coffee Shoots |
|---|---|---|
| | | (1 = Treatment, 0 = control) |
| Product | Continuous | Yield in 1 harvest season (kg) |
| Land area | Binary | Area owned for coffee plantations (ha) |
| Number of Plants | Continuous | Number of coffee pods that produce (btg) |
| Farmer Age | Continuous | Age of coffee plantation owner |
| Education | Continuous | 1=elementary school, 2=middle school, 3=high school, 4=undergraduate |
| Experience | Continuous | Length of coffee farming (years) |
| Number of Family Members | Continuous | Number of family members who can devote themselves to the plantation business |
| Institutional | Binary | 1=Member, 0=not member |
| Distance | Binary | Location of the garden from the house (km) |

Source: Primary data processed in 2023.



Second, when selecting a matching algorithm, several methods can be applied in the covariate matching process, such as: (1) closest neighbor matching (NNM), (3) Kernel matching, (4) Stratification matching, and (2) Radius matching. Since only the nearest neighbor without replacement was employed in this investigation, each covariate had only one chance to be matched. The closest score among the control group covariates is chosen using the NNM approach. When there are similar trends between the treatment and control groups, the matching procedure using the NNM approach works well (BECKER; ICHINO 2002). The best literature has not been identified for choosing this matching strategy.

Third, compare the distributions of the treatment and control groups to see any overlap or shared support. Several observations are disregarded at this point due to very high or low scores. Simultaneously, a balancing test was performed to ensure no significant difference in the average PSM between the treatment and control groups. The average differences between the treatment and control groups were then examined to determine differences in the outcome variables. The average effect of treatment for the treated (ATT) is the difference that shows the effect of the treatment.

The Independent Sample t-test was used for hypothesis testing to observe production variations. Independent sample t-test is a test with two samples. The principle of this test is to determine whether there is a difference in the average (mean) between two population samples by looking at the average of the two samples. With the formula:

$$t_{hit} = \frac{\underline{X_1} - \underline{X_0}}{S_P^2 \sqrt{\lfloor \frac{1}{n_1} \rfloor + \lfloor \frac{1}{n_0} \rfloor}} \quad (06)$$

$$S_P^2 = \frac{\langle n_1 - 1 \rangle S_1^2 - \langle n_0 - 1 \rangle S_0^2}{\langle n_1 + n_0 \rangle - 2} \quad (07)$$

where: X1 = average production of shoot grafting farmers; X0 = average non-top grafting production farmers; Sp = pooled standard deviations; S1 = standard deviation of grafting farmers; S0 = standard deviation of non-top grafting farmers; n1 = number of samples of shoot grafting farmers; n0 = number of samples of non-top grafting farmers; Df = na + no

## 3. RESULTS

The level of agricultural production is usually determined by the application of agricultural technology farmers use (EDWARDS; DUFFY, 2014; ULLAH et al., 2017). The usage of production facilities, including manpower, seeds, herbicides, and fertilizers, is one indicator. We highlight the findings of fertilizer use by farmers in farmer groups, both grafting coffee farmers and strip coffee farmers. From the treatment group, we found that the age of the coffee plants

used as rootstock (primary) and the coffee plants whose buds were taken as upper stem (secondary), as well as the length of time of union (grafting) between the primary stem and secondary stem, was an average of 5 years old. Meanwhile, we found that the average age of the existing plants was over 10 years for strip coffee plants or conventional coffee plants. In Figure 1, you can see the need for fertilizer for coffee plants per tree based on the age of the plant in 1 harvest season or one year; this amount is given twice in 1 year, namely at the beginning of the rainy season and at the end of the rainy season. The results in the field found that the realization given by coffee farmers in the research area of coffee plantation trees can be seen in the picture marked with blue for grafted coffee and red for strip coffee.

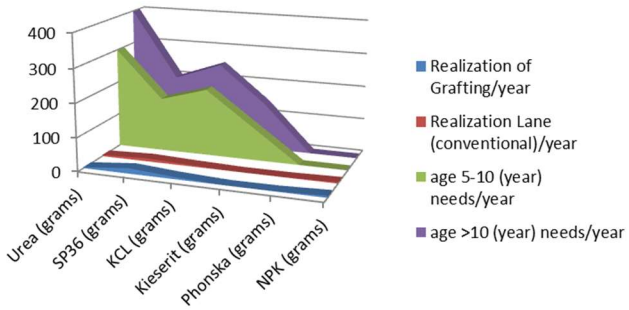


Figure 1. Need and realization of chemical fertilizer use.
Figura 1. Necessidade e concretização do uso de fertilizantes químicos.

In this research, the object of research is focused on the application of grafting technology in the cultivation of coffee plants (CARR; LOCKWOOD 2011). The production in question is the amount of dry coffee beans (green beans) farmers produce in kilograms in one harvest season. To determine the level of production from coffee plantation businesses produced by coffee farmers who have implemented grafting technology, it will be compared with the production of coffee farmers who have not implemented the technology in question or the community known as striped coffee (BUDIMAN et al., 2019; LIMBONGAN; FADJRY, 2013).

The results in Figure 2 show that farmers who apply grafting coffee technology have greater or dominant quantities than farmers who do not apply it with an average production amount above 1101 kg/season/farm. However, at an average production amount below 1100 kg/season/farming, the number of farmers who do not apply shoot grafting technology (strip coffee) likewise does not show a big difference at an average production above 1701 kg/season/farming where, the two groups of farmers, both those who apply and those who don't apply, look the same. This is in line with what was stated by Ruzzante et al. (2021) that although agricultural technology is promoted as an effective way to increase productivity, its benefits remain low. The impact of crop variety, maintenance, and seed certification constitutes a major error in adoption reporting (WOSSEN et al., 2019).

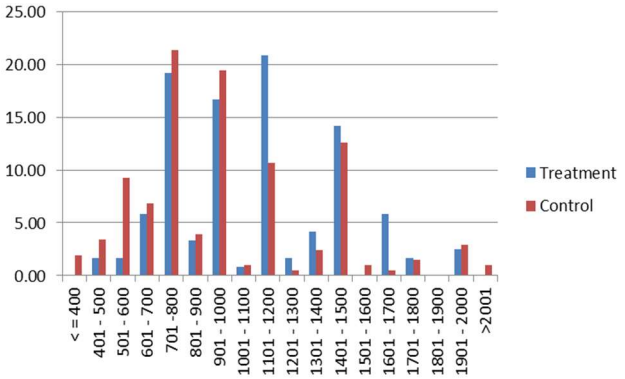


Figure 2. Average production achievements by plantation system group.
Figura 2. Resultados médios de produção por grupo de sistema de plantação.

The comparison of the average production of treatment group farmers and control group farmers in the coffee plantation business being operated is presented in Table 3.

The productivity of coffee plantations among farmers who got treatment and control farmers is displayed in Table 3. By comparing the nearest propensity value for each responder in the treatment group with the control group in a single match, the Nearest-Neighbor (NN) method of PSM was used to calculate the impact of applying graft grafting. The difference value between the treatment group and the control group is called the Average Treatment Effect on the Treated (ATT) value, and it is generated based on the comparison. This ATT value represents the difference between the treatment and control groups.

From the picture above, you can see the relationship between grafting coffee farmers as the treatment group, coffee farmers who have not applied grafting or the control group on coffee plants cultivated based on production. The equality of production produced between the two groups of farmers is seen based on the closeness of the production produced by the group that received treatment to the control group, ranging from 1 to 100 kg. As a rule of thumb, the amount of production obtained from the control group must not exceed the number of treatment groups or the amount. The production obtained by farmers from the control group was the same as the treatment group. The following can be seen in Table 4.



Table 3. Average coffee production of treatment farmers and control farmers.
Tabela 3. Produção média de café dos produtores de tratamento e produtores de controle.

| No. | Description | Treatment Farmers | | Control Farmers | |
|---|---|---|---|---|---|
| | | X/Season/Farming Business | X Per Hectare/Season | X/Season/Farming Business | X/Hectare/Season |
| 1 | Production (Kg) | 1030,83 | 722,37 | 1138,75 | 856,20 |
| 2 | Land Area (Kg) | 1,43 | 1,00 | 1,33 | 1,00 |

Source: Primary data processed in 2023.

Table 4. Impact of the application of shoot connection on coffee production.
Tabela 4. Impacto da aplicação de conexão de brotos na produção de café.

| No. | D | Production (kg) | Number of Farmers | Match | Y1 | Y0 | Difference |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 350 | 1 | - | - | - | - |
| 2 | 0 | 500 | 1 | - | - | - | - |
| 3 | 0 | 600 | 3 | - | - | - | - |
| 4 | 0 | 700 | 5 | - | - | - | - |
| 5 | 0 | 800 | 4 | - | - | - | - |
| 6 | 0 | 900 | 1 | - | - | - | - |
| 7 | 0 | 1000 | 3 | - | - | - | - |
| 8 | 0 | 1200 | 3 | - | - | - | - |
| 9 | 0 | 1300 | 1 | - | - | - | - |
| 10 | 0 | 1500 | 7 | - | - | - | - |
| 11 | 0 | 1600 | 1 | - | - | - | - |
| 12 | 0 | 1800 | 1 | - | - | - | - |
| 13 | 0 | 2000 | 1 | - | - | - | - |
| 14 | 1 | 400 | 1 | (1) | 400 | 350 | 50 |
| 15 | 1 | 500 | 1 | (2) | 500 | 500 | 0 |
| 16 | 1 | 600 | 2 | (3),(2) | 600 | 575 | 25 |
| 17 | 1 | 700 | 2 | (4),(3) | 700 | 650 | 50 |
| 18 | 1 | 750 | 1 | (5) | 750 | 700 | 50 |
| 19 | 1 | 800 | 4 | (5),(4) | 800 | 744 | 56 |
| 20 | 1 | 900 | 3 | (6),(5) | 900 | 820 | 80 |
| 21 | 1 | 1000 | 3 | (7),(6) | 1000 | 975 | 25 |
| 22 | 1 | 1100 | 1 | (7) | 1100 | 1000 | 100 |
| 23 | 1 | 1200 | 2 | (8) | 1200 | 1200 | 0 |
| 24 | 1 | 1300 | 1 | (9),(8) | 1300 | 1225 | 75 |
| 25 | 1 | 1400 | 1 | (9) | 1400 | 1300 | 100 |
| 26 | 1 | 1500 | 7 | (10) | 1500 | 1500 | 0 |
| 27 | 1 | 1700 | 1 | (11) | 1700 | 1600 | 100 |
| 28 | 1 | 1800 | 1 | (12) | 1800 | 1800 | 0 |
| 29 | 1 | 2000 | 1 | (13) | 2000 | 2000 | 0 |
| TO | | | | | | | 44 |

*Source: Primary data processed in 2023.



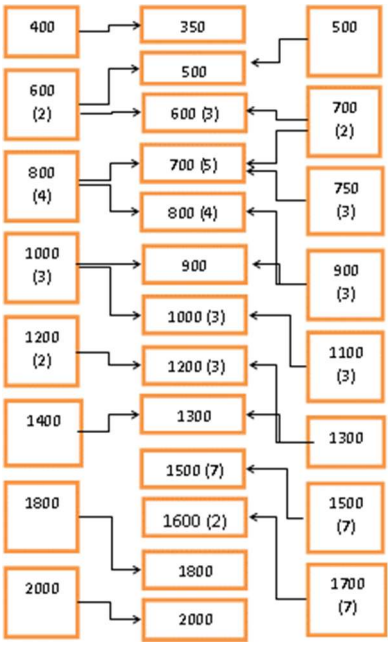


Figure 3. Relationship between NN models in propensity score matching.
Figura 3. Relação entre modelos NN no pareamento por escore de propensão.

In Table 4, the impact of grafting on coffee production can be seen in the difference in production after matching, shown in the ATT value of 44 kg/farm. The impact of grafting on coffee production can be seen from the difference in coffee production before matching, which was 100 kg/farm, and after matching, the difference decreased to 44 kg/farm. Based on measuring the impact of applying grafting using the psmatch2 method and the nearest neighbor method, it is known that applying grafting to coffee plants does not significantly impact farmers' coffee production, especially in the research area. In line with Wambua et al. (2021) and Anteneh et al. (2015), increasing the area of coffee cannot only increase productivity, but there is limited research on the impact of this technology at the agricultural level. The propensity score matching (PSM) method, according to Arifin (2022), evaluates a variety of matching qualities between adopters; while it indicates some variances, they are minimal.

## 4. DISCUSSION

According to the probit regression analysis findings, the quantity of plants used in a branch grafting coffee crop significantly affects its yield. The number of plants is one of the input variables in the production process in a coffee plantation business. This aligns with research (Kudama, 2019), which found that the number of trees per plot of land increases coffee production. Apart from that, experience also significantly impacts coffee production produced from the shoot grafting system. The experience in question is the length of time farmers have been running a coffee plantation business based on years, so the longer they have been running their business, the greater their desire to try new things (SILAMAT et al., 2023). The R-squared value of the

estimation findings was 0.199671. This indicates that in the model, independent variables (X1 to X9) account for 19.97% of the variation in variable Y, with other factors not included in the probity regression equation accounting for the remaining 80.03%.

To ensure whether there is a difference in production between groups of coffee farmers who received treatment and coffee farmers who did not receive treatment or control, a t-test was carried out with a confidence level of 95%.

$$SP^2 = \frac{(120-1)120313.5-(206-1)171179.3}{(120+206)-2} = -64118.67 \quad (08)$$

$$t-hit = \frac{1138.75-1030.83}{\sqrt{-64118.67^2\left(\frac{1}{120}+\frac{1}{206}\right)}} = 1.99051E\text{-}06 \quad (09)$$

The calculation results show that the t-count value is 1.00000099051, smaller than the t-table 0.005% of 2.581, so H1 is rejected, and H0 is accepted. This means that there is no difference in production between coffee farmers who use grafting technology on their cultivated coffee plants and the production of coffee farmers who do not apply grafting technology or what is better known as strip coffee.

Table 5. Probit regression estimation results.
Tabela 5. Resultados da estimação da regressão probabilistica.

| Variable | Coefficient | Std. Error | Z-Statistic | Prob. |
|---|---|---|---|---|
| Constant | 1.4705 | 2.1538 | 0.6827 | 0.4948 |
| Production (X1) | 0.0003 | 0.0007 | 0.3866 | 0.6990 |
| Land Area (X2) | 0.5651 | 0.5696 | 0.9922 | 0.3211 |
| Number of Plants (X3) | -0.0006 | 0.0002 | -2.6881 | 0.0072 |
| Farmers Age (X4) | 0.0319 | 0.0432 | 0.7388 | 0.4600 |
| Farmers Education (X5) | -0.0292 | 0.0821 | -0.3561 | 0.7218 |
| Experience (X6) | -0.0661 | 0.0279 | -2.3691 | 0.0178 |
| Number of Children (X7) | 0.1994 | 0.2080 | 0.9585 | 0.3378 |
| Number of Family Members (X8) | -0.2779 | 0.2275 | -1.2302 | 0.2186 |
| Distance From Land To House (X9) | 0.0831 | 0.1109 | 0.7490 | 0.4538 |
| R-Squared | | 0.199671 | | |

Note: Significant at alpha 5% (p-value < 0.05)

## 5. CONCLUSIONS

The application of shoot grafting technology to local coffee plants by smallholder farmers in the research area has not significantly impacted the production of cultivated coffee. This is aimed at the Average Treatment Effect on the Treated (ATT) value obtained at 44 or 0.44, which is smaller than the production difference before matching of 100 or 1, where the t-count value of 1.00000099051 is smaller than the t-table 0.005% of 2.581, which means there is no difference in production between farmers who apply grafting and farmers who do not apply grafting. However, the production obtained from the application of grafting technology carried out by coffee farmers shows an influence on the number of plants and the farmer's experience in the coffee plantation business. Applying graft grafting to coffee plants can also change the habits and patterns of focused farming and intents. Good agricultural technology is a combination of technology that does not ignore sustainability and the environment; for this reason, the use of production inputs remains important in the production process; apart from that, the use of certified superior varieties and stakeholder involvement has become a policy to meet the ever-increasing demand for coffee.

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