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Technical Efficiency and Production Determinants of Household-scale Grape Farming in an Agritourism Village of Ciganjeng, Pangandaran, Indonesia

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Abstract. The establishment of a tourist village with grapes as a tourist attraction in a suboptimal area is strongly influenced by the level of efficiency, both technically and economically. Suboptimal land in Pangandaran Regency is characterized by dryness, so inefficiency in input use can lead to low production and productivity levels in grape cultivation. Furthermore, the presence of a tourist village has an impact on the social life of the local community. The purpose of this study was to determine the factors that influence grape cultivation as an agritourism activity. In addition, to measure the technical and economic efficiency of grape cultivation at the household scale. The method used in this study was parametric statistics with the Stochastic Frontier Analysis approach. The sample was selected through purposive sampling, comprising 60 respondents who cultivate plants. The research respondents were selected with the criteria of farmers who have grown grapes for more than 2 years. The results showed that the level of efficiency of grape cultivation in the yard has a technical efficiency value of 0.856. Factors that influence the level of technical efficiency are the number of trees, the amount of manure, the amount of growth fertilizer, and labor. Meanwhile, the socioeconomic factor that influences the level of technical inefficiency is the age of the farmer. The age of the farmer has a significant impact on the level of inefficiency in grape cultivation activities. The recommendation from this research is that input subsidy programs, such as compost fertilizer, should continue to be provided to grape farmers. Comparative studies with other tourist villages should be conducted to obtain market information. Additionally, training programs for the young generation in grape cultivation should be implemented to maintain agrotourism.

Keywords: agritourism; Cobb-Douglas; grape; stochastic frontier; **t**echnical efficiency

INTRODUCTION

Agriculture-based village tourism products offer significant potential, particularly those with high sales value. One example is commercial fruit, which is attractive for educational and recreational purposes. Grapes are a highly sought-after fruit with a high sales value. The selling price of grapes ranges from 100,000 IDR to 200,000 IDR, depending on the type of grape. Grape production has increased significantly from 2021 to 2023, reaching 13,405 tons (Badan Pusat Statistika, 2025). Official data on grape production volumes for 2025 has not been recorded. In addition to the high selling price of grapes, another factor that tourism village operators must consider is the level of production per grapevine. However, tourism village operators must pay attention to the production level per vine. Therefore, measuring the efficiency of grape cultivation is necessary to determine the level of efficiency. According to Chaira et al. (2024), inefficient agricultural activities will cause farmers to lose opportunities to increase their income.

The grape cultivation process in West Java Province uses organic fertilizer (cow manure) and non-organic fertilizers. Grape cultivation is different from other fruit crops. Grape cultivation requires installation to protect against direct sunlight (Tian et al., 2019). The planting medium can be directly in the ground or in pots. Both media require attention in terms of fertilizer application, installation, and appropriate planting distance. The application of manure and planting distance significantly affect crop yields (Purba et al., 2018). The application of organic and non-organic fertilizers must be considered at the correct dosage to produce maximum output. A suitable dosage for applying organic and non-organic fertilizers is a ratio of 1:0.1 (Prawira et al., 2025).

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Furthermore, the use of grape seeds also affects harvest yields (Gundai & Sumiarta, 2019). The installation media for grape cultivation are closely related to the costs involved. The size of the installation will be adjusted according to the land area. The use of production factors will also influence the efficiency of grape cultivation. Grape cultivation in West Java Province is mainly carried out on idle land or in home gardens. One example is Ciganjeng Village in Pangandaran Regency, which utilizes yard space for grape cultivation.

The use of stochastic frontier analysis (SFA) is not only for measuring the efficiency of various commodities, but also for identifying the factors that can influence it. Measuring efficiency in grape commodities using SFA can determine the level of technical, allocative, and economic efficiency. Previous researchers have stated that technical efficiency can be assessed under various assumptions (Asatryan et al., 2024). Tree age, land area, and type of certified seeds are the required assumptions. Land used for grape cultivation is mainly used on large plots. Meanwhile, this research was conducted in the yard by utilizing empty land with pots in each yard. Grape cultivation is used as a tourist attraction, specifically in Ciganjeng Village, Pangandaran Regency, West Java Province. This area cultivates grapes in every yard to attract tourists.

The research problem formulation in this study is the factors that influence the determinants of grape cultivation as a tourist attraction, and whether the activity is efficient or not technically, allocatively, and economically. The purpose of this study is to determine the level of technical efficiency of grape cultivation in the yard area and to determine what factors influence grape cultivation as a tourist attraction. The urgency of this research is evident from the activities of self-help grape cultivation and the socio-economic impact of grape cultivation as a tourist attraction. The novelty of this study lies in the geographical fact that Ciganjeng Village is a suboptimal area prone to natural disasters, yet it still attempts to grow grapes on a household scale. Therefore, we wanted to identify the factors that influence grape cultivation in this village. In addition, this research substantially connects the level of efficiency of grape cultivation, which is used as an object of agrotourism. Grape farming is mainly carried out in gardens or on specific areas of land.

This research is necessary to gain knowledge about technical efficiency in farming at the household level. This is evident from the limitations of previous studies, which have not analyzed the technical efficiency of grape farming at the household level in Indonesia using the Stochastic Frontier Analysis (SFA) approach. Most previous studies have only focused on aspects of cultivation, productivity, or input use descriptively. In addition, they have not measured the extent to which farmers operate efficiently in the use of production factors. Therefore, this study was conducted to estimate the level of technical efficiency of grape farming and identify the socioeconomic factors that influence it. Thus, this study is expected to provide empirical contributions to the formulation of policies to increase the productivity and efficiency of grape farming in agrotourism-based areas.

METHODS

The research method involved determining the research location through a land survey in Ciganjeng Village, West Java Province, Indonesia. This location was selected purposively because the village is a tourist destination and all residents grow grapes in their yards. The primary data collection process involved conducting direct interviews with all residents who grow grapes. Data were analyzed using descriptive statistics to determine the distribution of various variables, as well as the program Statistical Package for the Social Sciences (SPSS) *version 18*.

These descriptive statistics are also used to determine which variables influence and which do not influence grape cultivation

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activities. Variables used in determining grapes as a tourist attraction include the number of trees, total labor, use of manure, amount of growth fertilizer applied, and amount of insecticide and fungicide. The age of the grapevines was not included in the production function. This is because the grapes were planted simultaneously by all farmers in 2023 through the P2L (Sustainable Food Gardens) program. In addition, there has been no specific extension activity on grapes in the Tourism Village by the local extension agency. Grape cultivation in Ciganjeng Village on a household scale does not involve the use of pesticides. So that pesticides are not used as a variable. Farmers use organic materials to control pests on grape plants. Fertilizer for growth also uses liquid organic fertilizer because it is more effective and increases production (Wulansari et al., 2023). Meanwhile, the inefficiency variables include age, education level, and experience in grape cultivation.

The research sampling was determined using *purposive sampling*. This is based on grapevines that have borne fruit in the past year in these households. The sample consisted of 60 families that had been cultivating grapes for more than two years. This is because grape fruiting occurs eight months after planting. According to Urdenko et al. (2021), the potential age of fruit-bearing grapes is more than one year after planting. Therefore, the sample selection in this study was based on grape plants that were more than 2 years old. According to Tian et al. (2019), the amount of input and output in the first harvest is generally higher than in the second season without any technological changes.

The concept of efficiency is the concept of using minimal input to produce maximum output. Production efficiency analysis can be conducted using parametric and non-parametric approaches (Hafiidha et al., 2024). The non-parametric approach is implemented using the Data Envelopment Analysis (DEA) method, to measure efficiency levels without assuming a specific production function. Various researchers have widely used this method on different commodities, including Chinese cabbage, pineapple, and organic coffee, in different locations. Measuring the efficiency of agricultural production will affect socioeconomic factors such as family size and land ownership. The DEA method can analyze the level of inefficiency using Tobit regression with efficiency index values limited between 0 and 1 (Muhamad et al., 2023). Measuring agricultural production efficiency will affect socioeconomic factors such as family size and land ownership. The DEA method can analyze the level of inefficiency using Tobit regression with efficiency index values limited between 0 and 1. Production efficiency measurement using SFA is used to estimate the limits of production or cost as the main variables. Additionally, it can be used to identify the level of inefficiency and the factors that influence it (Prawira et al., 2025). Parametric measurement uses Stochastic Frontier Analysis (SFA). The advantage of the frontier production function is its ability to analyze efficiency and inefficiency in production activities. Various previous studies have used SFA, including strawberries and grapes (Nalyoto & Ngaruko, 2023) and (Sapardani et al., 2023).

The data analysis method used in this study was the Stochastic Frontier Version 4.1 method. SFA was used to identify factors influencing productivity, estimate technical efficiency, and technical inefficiency. This function is used to obtain the results of factors that influence grape cultivation activities in Ciganjeng Village, West Java Province, as a tourist attraction. Data analysis was performed using the Cobb-Douglas production function equation. The equation was then transformed into natural logarithm (Ln) form (Equation 1).

$$\ln Y = Ln\,\beta_0 + \beta_1 Ln\,X_1 + \beta_2 Ln\,X_2 + \beta_3 Ln\,X_3 + \beta_4 Ln\,X_4 + \beta_5 Ln\,X_5 + \beta_6 Ln\,X_6 + V_i - U_i \ldots (1)$$

Description :
Y = amount of grape production (Kg)

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β_0 = constant/intercept
X_1 = number of trees (trees)
X_2 = amount of manure (Kg)
X_3 = amount of growth fertilizer (Kg)
X_4 = pesticide (Liter)
X_5 = insecticide (Liter)
X_6 = labor (HOK)
B_1, ….. β_6 = estimated regression parameters
Vi = random error
Ui = technical inefficiency
Expected parameter coefficiency : β_1, ….. β_6 > 0

The units used above are based on conditions in the area, where the grape crops cultivated by all respondents are not based on land area. Kilograms are used to ensure greater accuracy and representativeness in assessing grape crop efficiency. Each tree has a distinct production potential, varying according to its age, cultivation techniques, fertilization practices, and environmental conditions. Table 1 illustrates that the use of measurements was based on field conditions. The growth fertilizers used were KNO3, MKP, and humic acid. The amount of fertilizer used is mixed with water in a very low ratio, so that the growth factor of the fertilizer is unified. There was no distinction between male and female laborers. Grape production data was taken from previous harvests for a single harvest period.

Table 1. Definition of Variables in Grape Cultivation

No	Variable	Scientific Definition	Measurement
1	Number of trees (X_1)	Total number of productive grapevines cultivated by farmers on their land.	Trees
2	Amount of Manure (X_2)	Total solid organic fertilizer derived from livestock manure and used to improve soil structure.	Kilogram (Kg)
3	Amount of Growth Fertilizer (X_3)	The amount of fertilizer dissolved in water and applied to leaves or soil that plants use for fruit formation is easily absorbed.	Kilogram (Kg)
4	Pesticide (X_4)	The amount of chemical or organic substances used to prevent and control plant diseases caused by fungi, bacteria, or viruses.	Liter (Lt)
5	Insecticide (X_5)	The amount of active ingredients used to control insect pests on grapevines during both the vegetative and generative phases	Liter (Lt)
6	Labor (X_6)	The number of working hours used in the grape cultivation process, namely, pruning, fertilizing, watering, and harvesting	HOK
7	Grape Production (Y)	The total amount of grape harvest obtained by farmers in one growing season	Kilogram (Kg)

The next step is to measure the efficiency level of grape cultivation using the equation by Coelli et al. (2005) in Monica et al. (2021) with Formula (2).

$$TE = \frac{Y_i}{Y_i^*} = \frac{f\,(X_i, \beta)\exp(\,V_i - \,U_i\,)}{f\,(X_i;\,\beta\,)\exp(V_i)} = \exp\,(-U_i\,)\,..(2)$$

Where :
TE = Technical efficiency

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Y_i = Observed output
Y_i* = Output frontier

There is a hypothesis that can be used to describe whether grape cultivation in the agrotourism of Ciganjeng Village, West Java Province, is technically efficient or not, as follows :

H_0 : TE = 1, meaning that farming grape cultivation activities are efficient.

H_1 : TE ≠ 1, meaning that farming grape cultivation activities are inefficient.

The hypothesis needs to be tested using a one-sample t-test. The test is conducted at a 95% or 90% confidence level, or a significance value of 0.05 or 0.01. The testing criteria are as follows.

- ✓ If the significance value is < 0,05/0,1 the calculated t-value is > the table t- value, then H_0 is rejected and H_1 is accepted.
- ✓ If the significance value is > 0,05/0,1 the calculated t- value is < the table t- value, then H0 is accepted and H_1 is rejected.

The next step is to identify the technical inefficiency factors, with the following formula (3):

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \varepsilon_i \quad \ldots\ldots(3)$$

Where :
U_i = technical inefficiency
δ_0 = constant
δ_i = estimated coefficient vector
Z_i = vector for independent variables such as socio-demographic variables and access to support services. Where Z_1 = age (years), Z_2 = education level (years), Z_3 =cultivation experience (years), i_i = random error that defines the intersection of a normal distribution with a mean and variance of zero.

Age and education level factors were used to determine the extent to which grape farmers could absorb information related to the newly implemented grape cultivation training. Experience was used as a variable to determine the success of farmers in producing grapes. This is because the planting time is almost the same for all farmers, so it is estimated that the intensity of extension services will be the same for all grape farmers. Extension activities are only carried out once by the local farmer group leader and have not been carried out continuously. Technical inefficiency can be seen in.

Technical inefficiency = 1- (exp – Ui) = 1- (observed output/maximum possible output)

Excpected parameter coefficients : $\delta_1, \delta_2, \delta_3, \delta_4 < 0$ (Negatif)

The results of production efficiency calculations need to be tested to confirm whether there is an inefficiency effect in the model or not (Nurjati et al., 2018). The hypotheses used are as follows :

H_0 : $\sigma_u^2 = 0$ (no inefficiency effect)

H_1 : $\sigma_u^2 \neq 0$ (inefficiency effect exists)

Then, the LR value is compared with the critical value (χ^2) from the Kodde and Palm table, known as the Chi-Square Test (Orea & Álvarez, 2019). The test criterion used is one-sided LR error > χ^2 restriction (Kodde and Palm table), then H_0 is rejected, but if the one-sided LR error value is < χ^2 restriction (Kodde and Palm table), then H_0 is accepted. The hypotheses used to test each factor suspected of affecting inefficiency are as follows:

H_0 : The independent variables in the technical inefficiency effect model individually do not affect the level of inefficiency in the production process.

H_1 : The independent variables in the technical inefficiency effect model individually affect the level of inefficiency in the production process.

Basis for decision making:

a. If t-count ≥ t-table, then H_0 is rejected and H_1 is accepted.
b. If t-count ≤ t-table, then H_0 is accepted and H_1 is rejected.

Estimation of all parameters $\delta_1 - \delta_3$, variance ui and vi using the Maximum Likelihood Estimation (MLE) method in Frontier 4.1 software. Referring to Battese and Corra (1977) in Coelli (1996), data processing using Frontier 4.1 software produces variance in the form of the following parameters.

$$\sigma^2 = \sigma_v^2 + \sigma_u^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$\Upsilon = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

The variance value in the above formula is used to find the gamma value γ,

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with a distribution of $0 \leq \gamma \leq 1$. A γ value close to one indicates that the error term only comes from inefficiency (ui) and not from noise (vi). If the γ value is close to zero, it means that the entire error term is the result of noise (vi), such as weather, pests, and so on. If the log likelihood value of the MLE method is greater than the log likelihood value of the OLS method, then the production function using the MLE method can be said to be good and in line with field conditions. A slight variance or sigma-square (σ^2) value, or one close to zero, indicates that the inefficiency error term (ui) is usually distributed.

RESULTS AND DISCUSSION

Ciganjeng Village is a wine-based tourism village located in Padaherang District, Pangandaran Regency, covering an area of 750 hectares with a population of 4.389, the majority of whom are farmers. There are approximately 200-300 houses in the village, all situated close to one another. Sixty of these houses grow grapes in their front yards. Not all houses grow grapes due to the limited space in their yards. Based on Table 2, the descriptive characteristics of the respondents, categorized by their education level, show that 53.33% have completed high school and university. The average level of education is 11,11 years with a standard deviation of 3,33. This suggests that the people in the village already possess a high level of education and recognize its importance. To ensure that grape cultivation activities do not encounter obstacles in training and guidance.

Based on the average age of respondents, it is 48.45 years with a standard deviation of 11.02. Based on this standard deviation value, it shows that the age of respondents is quite diverse. This indicates that the age of grape farmers falls within the active age range and is expected to remain productive. Labor is the most critical input in grape production, especially for small-scale farmers. The results show that the average number of family dependents is 3,55 with a standard deviation of 1.13, which means that four people can be used as labor in the household and not diverse. Grape cultivation in tourist villages largely relies on family labor. This is because planting for fertilization requires independent work. This is similar to potato farming activities in Chilga, Ethiopia (Wassihun et al., 2019). Respondents' experience in grape farming averaged 2.65 years with a standard deviation of 0,45. This suggests that there is no significant difference in the respondents' experiences with grape cultivation.

Table 2. Demographic Characteristics of Respondent Households

Characteristic	Unit	Mean	Std. Dev.
Age of Head of Household	Year	48,45	11,02
Number of Dependents	People	3,55	1,13
Education Level	Year	11,11	3,33
Experience	Year	2,65	0,45

Source: Field survey data, 2025

Based on the results of this study, Table 3 shows that the average amount of grape production in each yard was 31,4 kg in one harvest at the last harvest time. On average, seven grape trees were planted in each yard. The grape cultivation process is carried out using soil and manure. The amount of manure used is 40.83 kg per harvest, while the use of growth fertilizer is 5.88 kg. This finding aligns with previous research, which indicates that horticultural cultivation activities utilize more manure (Nuraniputri et al., 2017). The use of manure in grape cultivation is more varied compared to other variables. This is seen from the standard deviation value, which is greater than the mean value. The solid fertilizers used are manure and NPK Grower. Each farmer uses different solid fertilizers depending on the initial fertilization dose. Fertilizer use is highly dependent on the condition of the land where it will be used over the years. Grape

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cultivation requires a planting medium that is rich in soil nutrients.

Based on the standard deviation values in Table 3, the variable of manure used is more varied than the other variables. This illustrates that the use of manure by each respondent depends on the number of trees they own. The next highest standard deviation value is the use of insecticides. This means that the amount of insecticide used by respondents varies significantly compared to other variables. The average use of insecticides and fungicides required is 3.83 and 0.39 liters until the grapes bear fruit. Pesticides are used when the plants begin to be attacked by pests. The proportion of pesticides is higher because the land in Ciganjeng Village is suboptimal, with increased pest attacks resulting from flooding and prolonged drought.

Table 3. Statistics of the grape production function analysis variables

Input	Rate-rate	Std. Dev
Production quantity (kg)	31,40	24,34
Number of trees (Trees)	6,91	6,59
Amount of solid fertilizer (Kg)	40,83	27,50
Amount of growth Fertilizer (Kg)	5,88	1,74
Insecticide (Lt)	3,83	13,18
Fungicide (Lt)	0,39	0,32
Total Labor (HOK)	24,46	3,28

Source: Data processing results, 2025

These measurements should not be used as a benchmark for grape farmers (Lubis et al., 2016). The labor required is 24,46 HOK. Labor is not necessarily male, but is limited to the installation of grapes and the creation of growing media. Other activities, such as planting, fertilizing, spraying pesticides or insecticides, and pruning, can be performed by women. This is because grapes are grown in their own yards.

In addition, the tolerance value can be used to describe the presence or absence of correlation between each variable used. Based on the tolerance values for grape cultivation at Ciganjeng Agrotourism, as shown in Table 4, it can be seen that grape cultivation in the tourist village of Pangandaran exhibits a correlation between each variable, with no multicollinearity. This is evident from the Tolerance value of each variable being greater than 0,01 with an average Tolerance value of 0,7 (1/VIF) from Table 4.

Based on the results of stochastic frontier data analysis, the Cobb-Douglas production function in grape farming at Ciganjeng agrotourism in West Java Province is as follows:

$$Y = 1,632 + 0,567X_1 + 0,917\ X_2 + 0,134\ X_3 - 0,778\ X_4 - 0,868X_5 + 0,142\ X_6 + Vi - Ui$$

Table 4. Grape cultivation tolerance value

Variables	VIF	1/VIF
Ln tree	1,648	0,606
Ln solid fertilizer	1,778	0,562
Ln growth fertilizer	0,614	1,628
Ln insecticide	2,341	0,427
Ln fungicide	1,233	0,811
Ln Labor	3,277	0,305
VIF rate	1,815	0,723

Source: data processing results (2025)

The results of the analysis in Table 5 show that the sigma-squared (σ^2) and gamma (γ) values obtained from the analysis are 1.522 and 0.999, respectively. A (σ^2) value greater than zero indicates that there is an influence of technical inefficiency on the model. The (γ) value shows the contribution of technical efficiency in the total residual effect. The (γ) value in this analysis, which is 0.999, indicates that 99.9% of the total residual effect or error term is caused by technical inefficiency. In comparison, the other 0.1% is caused by other random errors such as weather, climate, pests, and diseases.

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Grape cultivation does not require a large area of land because the planting medium used is plastic pots/polybags. Therefore, the variable in this study is the number of grape vines cultivated by farmers. Increasing the number of seedlings cannot directly increase production because it requires an 8-month process to bear fruit. This is consistent with previous research on various commodities, such as the technical efficiency of red onion in Cilacap (Monica et al., 2021), the efficiency of strawberry in Purbalingga (Wijayanti et al., 2020), the technical efficiency of strawberry in Pakistan (Tariq et al., 2018), the technical efficiency of potato in Ethiopia (Wassihun et al., 2019), and the technical efficiency of corn in Tasikmalaya (Mulyana et al., 2020).

Table 5. Stochastic Frontier Production Function of Grape Farming with MLE Method

Variables	Estimated sign	Coefficient	t-value	Significance
Intercept	+	1,632	2,441	
Number of trees	+	0,567	1.838	Sig 10%
Amount of solid Fertilizer	+	0,917	2,162	Sig 5%
Amount of growth Fertilizer	+	0,134	8,741	Sig 10%
Insecticide	-	0,778	-0,220	Non sig
Fungicide	-	0,868	-0,573	Non sig
HKSP	+	0,1421	1,711	Sig 10%
Sigma – squared	+	1,522	1,522	Sig 10%
Gamma	+	0,999	1,069	Non sig
Log-likelihood function OLS	-41,973			
Log-likelihood function MLE	-31,016			
LR Test of the sided error	21,914			

Source: research data processing, 2025

The log likelihood value of the MLE method is -31.016, which is greater than the log likelihood value of the OLS method, -41.973. This is in accordance with the statement by Gultom et al. (2014), which states that if the log likelihood value obtained using the MLE method is greater than the log likelihood value obtained using the OLS method, then the production function using the MLE method is more consistent with the conditions in the field. The LR test value is 21.914, which is then compared to the ($\chi 2$) value from the Kodde and Palm table. The ($\chi 2$) value obtained from the Kodde and Palm table is 3.84. This value is smaller than the LR test value. This indicates that H_0 is rejected and H_1 is accepted, meaning that the value of $\sigma 2 \neq 0$, which suggests the presence of an inefficiency effect.

Based on the data from the stochastic frontier production function for grape farming, as estimated using the MLE method in Table 5, there are several significant and insignificant variables. The variables of the number of trees, solid fertilizer, growth fertilizer, and labor are significant, while insecticide and fungicide are not significant. This illustrates that insecticides and fungicides are insignificant factors because their use is very minimal or even rarely carried out. Research by Urdenko et al. (2021) stated that the use of insecticides is ineffective. Pest attacks can be overcome organically by cleaning or spraying sugar water. This may also be due to the knowledge and skills of farmers in grape cultivation activities are very influential (Sapardani et al., 2023). This is evident in Table 5, which presents the Stochastic Frontier production function for grape cultivation using the MLE method.

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The number of trees in respondents' yards has a significant effect on grape farming activities. The number of trees in each yard is determined based on the size of the yard, so respondents cannot increase the number of grape trees. The coefficient value for the number of grape trees is 0.567 and is positive. This illustrates that an increase in the number of trees in a unit will result in a 0.567-unit increase in grape production. This aligns with research by Nalyoto & Ngaruko (2023), which suggests that the number of trees can increase production if a good maintenance process is implemented.

The regression coefficient for manure amount is 0.917 and is significant at the 5% level. This coefficient value indicates that a one percent increase in manure amount will increase production by 0.917 percent (ceteris paribus). Manure is applied during land preparation, mixed with red soil at a 1:1 ratio. Fertilization with manure is only carried out once a year, when replacing the planting medium. The average use of manure is 5.91 kg/tree or 40.83 kg used by respondents. The results of this study are in line with previous studies, which indicate that the use of manure can increase sweet potato production in Agam Regency, West Sumatra Province (Leovita et al., 2017). Manure is also used to fertilize the soil and control soil acidity (Oumer et al., 2023)

Grape farming activities require more growth fertilizer. Growth fertilizer is mixed with water to form a liquid. Fertilizer spraying is carried out once a week, using a ratio of 10 grams to 1 liter of water. The types of liquid fertilizer used are NPK, MKP, KNO3, humic acid, and boron, with spraying times according to plant age. The regression coefficient of growth fertilizer is 0.134 with a significance level of 0,1. This means that a one percent increase in growth fertilizer will result in a 0.134 percent increase in production. Fertilizer is applied at a dose according to the usage rules, namely 1 liter for each fertilization. These results align with previous studies (Oumer et al., 2023; Wijayanti et al., 2020). However, this contradicts research conducted by Tariq et al. (2018) on strawberries, which found that fertilizer was not significantly related to production.

Insecticide spraying is also carried out in grape farming when the plants are 5 months old or older, or when the branches have developed a large number of leaves. Insecticide spraying is carried out to prevent insects from eating grape leaves or grape ovaries. Spraying is carried out once a week by mixing 22 ml of insecticide with 10 liters of water. Insecticides are not widely used in grape cultivation. The regression coefficient for the amount of insecticide in grape farming is -0.778 and is not significant. The average use of insecticides in the Ciganjeng grape agrotourism village was 3.83 kg. Respondents rarely spray insecticides because they do not understand the use of insecticides on grape plants. This contradicts the research by Maryanto et al. (2018), which suggests that the use of insecticides can increase production, as they can prevent leaf rot or dryness when used according to the guidelines.

Likewise, the use of fungicides has a coefficient value of -0.868 and is not significant. That means a one percent increase in fungicide will reduce production by 0.868 percent, which is not significant in grape farming. This finding aligns with other studies, which suggest that insecticides and fungicides have a negligible or negative impact on production activities (Wijayanti et al., 2020; Sarker, 2017).

The labor coefficient is negative, indicating that a decrease in grape production will occur due to an increase in labor. The grape farming Labor in this tourist village is mostly family labor. Labor utilization in grape cultivation is strongly influenced by the level of technology and knowledge applied. To date, there has been no routine training or guidance on grape cultivation techniques or innovation training. This contrasts with previous research by Prawira et al., (2025) on horticultural commodities, which found that labor is directly proportional to production volume.

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The technical efficiency value of grape farming is calculated by taking a value between 0 and 1. Based on the results of the frontier analysis, the TE value of grape farming is 0.856. This indicates that the technical efficiency of grape farming is quite high, with a value range of 0.41 to 0.988, as shown in Table 6. This indicates that 85.6% of farmers or tourism village actors can use production inputs to produce output. Farmers still have the opportunity to increase grape production by improving their technology and management skills. An increase in production will lead to a rise in community income. The results of this study indicate that 78.33% of grape farmers in Pangandaran Regency have achieved technically efficient production and 21.67% are inefficient in cultivating grapes. Several studies also show that horticultural farmers have achieved technical efficiency, including Sarker et al. (2017) on watermelon in Bangladesh with an average of 0.86; Prawira et al., (2025) on organic and non-organic coffee commodities in Bangladesh with an average of 0.887; Tariq et al (2018) on strawberries in Pakistan with an average of 0.81; and Wijayanti et al., (2020) on strawberries in Purbalingga with an average of 0.778.

Table 6. Distribution of Technical Efficiency Values of Grape Farming in Pangandaran Regency

Range	Efficiency Level	Amount	Presentation
0,144 - 0,425	Inefficient	13	21,67
0,706 - 0,847	Quite efficient	17	28,33
0,847 - 0,988	Very efficient	30	50
Total		60	100
Minimal	0,411		
Mean	0,856		
Maximum	0,988		

Source: processed research results, 2025

Differences in technical efficiency values are due to differences in the initial planting time of each farmer. The longer the grapes are planted, the more grapes each tree produces. Grape production per harvest can reach 5 kg per tree, and even 10 kg per tree. This difference in production is influenced by differences in farmers' knowledge of grape cultivation. Some farmers receive guidance from farmer group leaders, while others learn independently. Furthermore, there are differences in farmers' ability to obtain production inputs, and the number of workers of working age is highly correlated with labor input.

Table 7 illustrates that the technical inefficiency factor in grape farming uses three parameters: farmer age, length of education, and length of grape farming experience. Factors suspected of influencing technical efficiency in each sample were analyzed using the technical inefficiency model of the stochastic frontier production function 4.1. If the technical inefficiency parameter value is positive, it will increase the level of inefficiency (reduce technical efficiency) and conversely (Felix et al., 2021). Based on the study's results, age is the factor that significantly influences technical inefficiency, while length of education and experience have no effect, as shown in Table 7.

Table 7 illustrates that the coefficient for farmer age is 0.0012, with a positive value. This indicates that increasing farmer age increases the level of inefficiency (reduces the level of technical efficiency). Therefore, village efforts are needed to introduce grape cultivation to the younger generation around the village. Meanwhile, the education and experience coefficients are negative. However, this value is not significant in terms

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of the level of inefficiency in grape cultivation. This illustrates that grape cultivation is not determined by the length of experience and level of education. Based on the negative coefficient value, it illustrates that the higher the level of education and the length of experience, the lower the level of inefficiency (increases the level of efficiency). This suggests that education and experience in farming can enhance the technical efficiency of farming. These results are consistent with previous research on horticultural commodities, namely (Oyetunde-Usman & Olagunju, 2019) and (Fajar et al., 2019). Therefore, education and experience are crucial for farmers in making informed decisions. Decision-making on innovative grape cultivation technology is necessary for agribusiness development in tourist villages.

Table 7. Estimation of factors influencing technical inefficiency in grape farming

Variables	Estimated sign	Coefficient	t-value	Significants
Intercept	+/-	2,623	2,534	
Age	+	0,0012	2,285	Sig 5%
Education	-	-0,0048	0,122	Non sig
Experience	-	-0,0125	0,158	Non sig

Source: data analysis results, 2025

CONCLUSION

The study concludes that grape cultivation in Ciganjeng Village, Pangandaran Regency, which serves as both a household-scale farming activity and a tourist attraction, operates at a fairly efficient level. The average technical efficiency value of 0.856 indicates that farmers are able to utilize 85.6% of their production potential, leaving opportunities for further improvement through better management and technology adoption. Among the production factors analyzed, the number of grape trees, the amount of manure, growth fertilizer, and labor significantly influenced technical efficiency, whereas insecticide and fungicide applications were not found to be significant. The high efficiency level reflects the community's capacity to integrate agricultural production with tourism development in a sustainable manner.

Several policies need to be implemented by respondent farmers and local institutions involved in grape agrotourism in Ciganjeng Village, including exchanging information with other tourist villages and conducting grape cultivation training programs for the younger generation. These activities are crucial for maintaining grape-based agrotourism in the region. Subsidies for inputs such as growth fertilizers (NPK, boron, MKP, and humic acid) are also necessary to enhance the technical efficiency of grape cultivation. In addition, support from local government agencies is needed to promote and provide knowledge on grape cultivation to the respondent farmers.

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