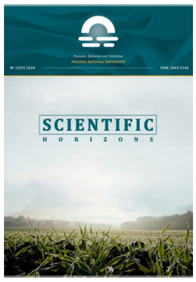
SCIENTIFIC HORIZONS

Journal homepage: https://sciencehorizon.com.ua
Scientific Horizons, 27(3), 84-96



UDC 633
DOI: 10.48077/scihor3.2024.84

Technical efficiency in several levels of adoption of garlic farming standard operating procedures in production centre in Indonesia

Dian Kurniasih*
PhD
IPB University
16680, Jl. Raya Dramaga, Bogor, Indonesia
Indonesian Center for Agricultural Standards
12550, l. Harsono RM No. 3, Pasar Minggu, Special Capital District of Jakarta, Indonesia
https://orcid.org/0009-0009-7042-0602

Yusman Syaukat
Professor, Lecturer
IPB University
16680, Jl. Raya Dramaga, Bogor, Indonesia
https://orcid.org/0000-0002-6473-3647

Rita Nurmalina
Professor, Lecturer
IPB University
16680, Jl. Raya Dramaga, Bogor, Indonesia
https://orcid.org/0000-0002-8002-9975

Suharno
PhD, Lecturer
IPB University
16680, Jl. Raya Dramaga, Bogor, Indonesia
https://orcid.org/0000-0003-2564-8092

Article's History:
Received: 6.11.2023
Revised: 31.01.2024
Accepted: 28.02.2024

Abstract. The relevance of this study lies in overcome obstacles to garlic development in Indonesia, such as low productivity and limited use of technology, which can hinder self-sufficiency and import-reducing programs. The purpose of this study was to identify the technical efficiency, the determinants of technical inefficiency, and the level of technical efficiency at various levels of adoption of the standard operating procedures of garlic farming in production centres in Indonesia. The cross-sectional data was gathered through interviews with 227 farmers chosen using a simple random selection technique. The Cobb-Douglass production function and the stochastic frontier analysis were used to determine the factors influencing garlic production, the technical efficiency level, and the determinants of technical inefficiency. The Maximum Likelihood Estimation was used

Suggested Citation:
Kurniasih, D., Syaukat, Yu., Nurmalina, R., & Suharno (2024). Technical efficiency in several levels of adoption of garlic farming standard operating procedures in production centre in Indonesia. *Scientific Horizons*, 27(3), 84-96. doi: 10.48077/scihor3.2024.84.

*Corresponding author

to analyse the data. The level of technical efficiency at various levels of standard operating procedures adoption was measured using descriptive statistical analysis. Farm size, seeds, urea and NPK fertiliser, herbicides, yellow sticky traps, family labour, mulch, and farmers' participation in garlic development programs significantly affected garlic production. The technical efficiency varied within 0.37-0.99, with a mean of 0.71. Farmers' practices and standard operating procedure adoption significantly reduced technical inefficiency. Generally, the level of standard operating procedure adoption is moderate. In the high standard operating procedure adoption group, the mean technical efficiency is 0.77, while in the moderate level group, it is 0.68. The findings of this study can be used as a model for other garlic-importing countries to enhance production and strengthen food security

Keywords: inefficiency; self-sufficiency; stochastic frontier analysis; technology adoption

INTRODUCTION

Garlic is essential in developing economic, culinary, and traditional medicine in Indonesia. Indonesia's garlic production does not meet the national consumption, leading the government to import garlic. Conversely, dependence on imports can threaten social, economic, and political stability. Increasing national garlic production can be challenging due to various problems that may arise, including efficiency and technology adoption problems. Hence, problems of technical efficiency and technology adoption must be analysed comprehensively to avoid a bias in identifying the root causes of garlic productivity.

Due to the global food crisis, every country is considering strengthening domestic food security policies instead of relying on imports (Falkendal *et al.*, 2021; Hellegers, 2022). According to the data of Center for Agricultural Data and Information (2020), the average national garlic productivity reaches 7.48 t/ha, while the average world productivity reaches 17.07 t/ha. As the biggest garlic production centre in Indonesia, Central Java Province only has an average productivity of 6.75 t/ha.

The principal issues are that the seed industry is not well-developed yet, the cultivation area tends to be narrow and scattered, the low adoption of SOP, and high inputs prices (Ricky *et al.*, 2022). Leveraging agriculture productivity can be achieved through extensification and intensification (Coomes *et al.* 2019). Extensification directly impacts agricultural production but causes deforestation and biodiversity loss. Intensification can enhance food production by increasing technical efficiency and technology adoption (Kamau *et al.,* 2023).

Technical efficiency measurement is required for policymakers to determine the strategic programs to increase productivity (Workneh & Kumar, 2023). Technologies play an important role in enhancing production, efficiency, reducing risks, and ensuring the delivery of high-quality agricultural products (Kale *et al.*, 2022). SOP of garlic cultivation consists of technology components from 11 aspects of cultivation, i.e., land preparation, land management, plant spacing determination, use of seed, planting and basic fertilisation, mulch, follow-up fertilisation, water irrigation, plant maintenance, pest control, and harvest and post-harvest handling (Directorate General of Horticulture, 2016).

The Stochastic Frontier Analysis (SFA) and the Cobb Douglass production function are most widely used to measure technical efficiency (Hakim *et al.*, 2021). Previous study using this approach mentioned that the value of technical efficiency of garlic was below 100%. G. Rabbani and B. Ahmad (2021) found that the average of technical efficiency of garlic production in Ethiopia and Bangladesh were 73%, and 69% respectively. These results imply opportunities to increase outputs by 7-31% using the available technology. S. Kune and A. Hutapea (2018) and K. Seran *et al.* (2020) conducted a technical efficiency research of garlic farming in East Nusa Tenggara Province. Technical efficiency values were above 90%. These studies only provide information regarding the estimation of technical efficiency. The determinants of technical inefficiency and how technology impacts technical efficiency were not provided.

The study of technical efficiency in Central Java Province conducted by W. Prayogo and L. Wihastuti (2023) found that the technical efficiency of garlic farming is above 0.60. Factors detrimental to technical efficiency included farmers' age, education, farmer experience, family size, and training. The information about technology adoption was not provided. Moreover, the information about distribution of technical efficiency at each level of SOP adoption was not provided.

This study fills this information gap, allowing decision-makers to get a comprehensive description of productivity problems. Based on the description above, the purpose of this study was to establish the technical efficiency of garlic farming, the variables that affect the technical inefficiency, and the technical efficiency of garlic farming at different stages of standard operating procedure adoption in Temanggung Regency, Central Java Province, Indonesia.

MATERIALS AND METHODS

Sample size, sampling methods, and data collection. The study was conducted in Temanggung Regency, Central Java Province, Indonesia, from October to November 2022. The selection of sample areas and farmer groups was carried out purposively. Temanggung Regency is the largest garlic production centre in Indonesia, which contributes 27.52% to national production (Centre for Agricultural Data and Information, 2020). The research was conducted in seven sub-districts. One village with the largest amount of production was purposively selected from each sub-district. From each village, two farmer groups with garlic as their primary business were selected. The number of farmer samples in this study was determined based on the Krejcie and Morgan formula. The formula is as follows:

$$n = \frac{X^2 NP(1-P)}{e^2(N-1)+X^2P(1-P)}, \quad (1)$$

where n is the sample size; X^2 is the chi-square table value for 0.5 degree of freedom at the specified confidence level (3.841); N is the population size; P is the population proportion (assumed to be 0.50); e is the degree of precision (0.05).

The population of selected farmer group members is 550, and therefore the required sample size was 227 farmers. Simple random sampling technique was applied to choose sample farmers from each farmer group. The survey was anonymous and did not mention any institutions. Data was collected from farmers through structured questionnaires administered by enumerators. Interviews were conducted offline. This study also protected the privacy of respondents and their confidential personal information following the Declaration of Helsinki (2013). The respondents provided prior informed consent to fulfil the ethical requirements of scientific research in social sciences.

Analysis method of estimation of production function, technical efficiency, and technical inefficiency. The SFA method was applied to analyse the technical efficiency of garlic production. The stochastic production function assumes that the production function's error component is not simply attributable to random and unmeasured factors. It divides the error term into random and non-random components. The difference between actual production and the production frontier is attributed to inefficiency. This inefficiency can take many forms, including inefficient resource allocation, poor management practices, inadequate technology utilisation, and inefficient manufacturing processes. The SFA is given as follows:

$$Yi = \beta_0 + \beta_i X_i + \varepsilon_i, \quad (2)$$

where Yi is the outputs; β_0-β_i is the model parameters to be estimated; X_i is the production inputs; ε_i is the error term, $\varepsilon_i = -u_i + v_i$. vi is an error term that indicates a production uncertainty, assumed by i.i.d (0,); u_i is an error term that shows the effect of technical inefficiency, assumed by i.i.d (0,) and u>0, u_i is independent of v_i. Equation 2 can be modified as follows:

$$Yi = f(X_i; \beta)\exp(v_i - u_i), \quad (3)$$

where f(.) is production function.

This study uses the Cobb-Douglass production function to estimate the determinants of garlic production and its technical efficiency. The Cobb Douglass production function estimates the elasticity of production inputs (Adzawla & Alhassan, 2021). The Stochastic Frontier production function can also be used to measure the estimated value of technical efficiency according to the following formula:

$$TE_i = \frac{Y}{Y^*} = \frac{f(X_i;\beta)\exp(v_i - u_i)}{f(X_i;\beta)\exp(v_i)} = \exp(-u_i), \quad (4)$$

where TE_i is the farmers' technical efficiency; Y is the frontier output; Y^* is the farmers' observed output. Technical efficiency is typically expressed as a ratio between 0 and 1, where 0 stands for no efficiency or complete inefficiency, and 1 stands for perfect efficiency or optimal use of inputs. The next analysis is regressing a set of factors on $-u_i$ as follows:

$$-u_i = \delta_0 + \sum_{n=1}^{k} \delta_i Z_i + e_i, \quad (5)$$

where Z_i is the vector of determinants of technical inefficiency; δ_0 is the parameter estimates of the model; δ_i is the coefficient estimates of Zi; and e_i is the error term.

Parameter estimation in the SFA model and technical inefficiency using the Maximum Likelihood Estimation (MLE) method in the Frontier 4.1 program. An empirical model of SFA that is converted into a natural logarithm is given as follows:

$$LnY=\beta_0+\beta_1 LnX_1+\beta_2 LnX_2+\beta_3 LnX_3+\beta_4 LnX_4+\beta_5 LnX_5+\beta_6 LnX_6+\beta_7 LnX_7+\beta_8 LnX_8+\beta_9 LnX_9+ \\ +\beta_{10} LnX_{10}+\beta_{11} LnX_{11}+\beta_{12} LnX_{12}+\beta_{13} LnX_{13}+\beta_{14} LnX_{14}+\beta_{15} D_1+\beta_{16} D_2+(vi-ui), \quad (6)$$

where Y_i is the garlic output (kg); β_1 – β_{18} are the parameters to be estimated in the model; X_1 is the Farm size (ha); X_2 is the seeds (kg); X_3 is the urea (kg); X_4 is the ZA (kg); X_5 is the NPK (kg); X_6 is the SP36 (kg); X_7 is the organic fertiliser (kg); X_8 is the dolomite (kg); X_9 is the pesticides (l); X_{10} is the fungicides (l); X_{11} is the herbicides (l); X_{12} is the yellow sticky trap (pcs); X_{13} is the family labour (man days of work); X_{14} is the hired labour (man days of work); D_1 is the dummy of plastic mulch (1 if yes, 0 if no); D_2 is the dummy of farmers' participation in government and importer programs (1 if yes, 0 if no).

Empirical model of technical inefficiency was calculated as follows:

$$u_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 + e_i, \quad (7)$$

where u_i is the technical inefficiency; $\delta_0 - \delta_9$ are the parameters to be estimated in the model; Z_1 is the farmers' age (years); Z_2 is the education level (years); Z_3 is the farmers' experience in garlic farming (years); Z_4 is the perception of activeness in the farmer group (pts); Z_5 is the perception of extension activity (pts); Z_6 is the adoption level of SOP (pts); Z_7 is the dummy of land ownership (1 if owned by farmer, 0 if rented); Z_8 is the dummy of credit access (1 if there is an access, 0 if there is no access); Z_9 is the dummy of gender (1 if male, 0 if female).

Determination of the level of adoption of SOP and other social variables with a Likert scale score. Social variables such as adoption level of SOP, participation in farmer groups, and perception of extension performance were also collected. The Likert scale was used in the questionnaires to measure farmers' attitudes, opinions, perceptions, or behaviours. The data obtained from the questionnaire with a Likert scale is ordinal and must be converted into interval data through a successive application. Classification of the adoption level of SOP, participation in farmer groups, and perceptions of extension performance were determined by formula as follows:

$$Class\ Interval = \frac{Highest\ value\ (HV) - Lowest\ value\ (LV)}{Number\ of\ classes}. \quad (8)$$

In this study, the accumulative scores achieved in social variables were classified into three classes: High, moderate, and low, as presented in Table 1.

Table 1. *Score classification of social variables*

Variables	Number of questions	Number of point scales	Accumulative Score		Classification		
			Min	Max	Low	Moderate	High
Adoption of SOP	52	*3-point scales* 3: Always apply; 2: Apply sometimes; 1: Never apply	52	171	52-91.6	91.7-131.3	131.4-171
Perception of activeness in farmers' group	8	*5-point scales* 1: Strongly disagree; 2: Disagree; 3: Neither agree nor disagree; 4: Agree; 5: Strongly agree	8	36	8-18.6	18.7-29.3	29.4-36
Perception of extension performance	16	*5-point scales* 1: Strongly disagree; 2: Disagree; 3: Neither agree nor disagree; 4: Agree; 5: Strongly agree	16	89	16-40.3	40.4-64.7	64.8-89

Source: *compiled by the author of this study*

According to Table 1, farmers are classified as having high SOP adoption when they score 131.4-171 pts, medium adoption when they score 91.7-131.3 pts, and low adoption when they score 52-91.6 pts. The perception of activeness in the farmers' group is categorised as high when farmers score 29.4-36 pts, medium when they score 18.7-29.3 pts, and low when they score 8-18.6 pts. The perception of extension performance is categorised as high when farmers score 64.8-89 pts, moderate when they score 40.4-64.7 pts, and low when they score 16-40.3 pts.

Definitions and measurements of variables. Table 2 presents potential explanatory variables for production and inefficiency functions, along with the expected outcome sign for each variable.

Table 2. *Summary of variables and expected outcome*

Variables	Definition	Measurements	Expected outcome
Production Function			
Output	Amount of garlic production	Kilogram (kg)	
Farm size	Total area cultivated of garlic	Hectare (ha)	+
Seeds	Amount of garlic seed	Kilogram (kg)	+
Urea fertiliser	Amount of garlic urea fertiliser	Kilogram (kg)	+
ZA fertiliser	Amount of ZA	Kilogram (kg)	+
NPK fertiliser	Amount of NPK	Kilogram (kg)	+
SP36 fertiliser	Amount of SP36	Kilogram (kg)	+
Organic fertiliser	Amount of organic	Kilogram (kg)	+
Dolomite	Amount of dolomite	Kilogram (kg)	+
Pesticides	Volume of pesticides liquid	Litre	+

Table 2. Continued

Variables	Definition	Measurements	Expected outcome
Fungicides	Volume of fungicide liquid	Litre	+
Herbicides	Volume of herbicide liquid	Litre	+
Yellow sticky trap	Amount of yellow sticky trap	Sheet	+
Family labour	Amount of family labour	Man-days	+
Hired labour	Amount of hired labour	Man-days	+
Mulch	1 if use mulch, 0 otherwise		+
Participation in gov. or importer program	1 if participate, 0 otherwise		+
Inefficiency Function			
Age	Length of time the farmer has lived	Years	-
Level of education	Number of years of formal education	Years	-
Farmer experience in garlic farming	Number of years of farming	Years	-
Perception of activeness in farmers group	Farmer perception of activeness in group	Points	-
Perception of extension performance	Farmer perception of extensionist performance	Points	-
Adoption of SOP	SOP adoption by farmer	Points	-
Land ownership	1 if landowner, 0 otherwise		-
Credit access	1 if farmer has an access, 0 otherwise		-

Source: *compiled by the authors of this study*

Definition and measurement variables provide a clear understanding of the data and the methods used for measurement. The mean and standard deviation of each variable, except for the dummy variable, are determined. The mean value indicates the equal distribution of values in a particular data set, while the standard deviation helps to understand the distribution and variability of measurement variables.

RESULTS AND DISCUSSION

Distribution of outputs, inputs, and socioeconomic characteristics. Table 3 presents the distribution of output and inputs in one garlic planting season in Temanggung Regency. Table 3 shows that farmers produced an average of 6.87 kg/ha of dry garlic. The average seeds used is 854.75 kg. The fertilisers used by the farmers were 257.66 kg of urea, 429.25 kg of ZA fertiliser, 331.25 kg of NPK fertiliser, 132.81 kg of SP36 fertiliser, and 13,601.31 kg of organic fertiliser. The dolomite used was 1,289.59 kg. Farmers use pesticides at 7.25 l and fungicides at 6.38 l.

The average number of yellow sticky traps used was 42.03 sheets per ha. The number of family labourers is 621.81, and the hired labour is 135.03 man-days per ha. The use of inputs for fertiliser production is generally still inadequate compared to the amount recommended in the SOP. Meanwhile, Table 4 shows data on the socio-economic characteristics of farmers.

Table 3. *Descriptive statistics of the distribution of output and inputs of garlic farming in Temanggung Regency*

Variables	Sample Distribution				Conversion per ha
	Mean	Standard Deviation	Min	Max	
Output	2,198.85	1,175.39	500.00	4,980.00	6,871.41
Farm size	0.32	0.14	0.10	0.70	1.00
Seeds	273.52	182.25	40.00	775.00	854.75
Urea fertiliser	82.45	41.60	17.00	175.00	257.66
ZA fertiliser	137.36	75.75	25.00	350.00	429.25
NPK fertiliser	106.00	55.52	25.00	290.00	331.25
SP36 fertiliser	42.50	22.69	8.00	100.00	132.81
Organic fertiliser	4,352.42	1,997.58	1,500.00	8,000.00	13,601.31
Dolomite	412.67	190.37	100.00	850.00	1,289.59
Pesticides	2.32	0.81	1.10	4.50	7.25
Fungicides	2.04	1.14	0.01	5.00	6.38
Herbicides	2.32	1.25	0.50	5.00	7.25
Yellow sticky trap	13.45	7.30	3.00	35.00	42.03
Family labour	198.98	99.79	25.00	421.00	621.81
Hired labour	43.21	36.05	5.00	127.00	135.03

Source: *the results of the authors' own research*

Table 4. *Descriptive statistics of the distribution of social characteristics of garlic farmers in Temanggung Regency*

Variable	Sample Distribution			
	Mean	Standard Deviation	Min	Max
Age	43.99	9.76	21.00	84.00
Level of education	8.19	2.71	3.00	16.00
Farmer experience in garlic farming	9.89	7.08	2.00	31.00
Perception of activeness in farmers group	24.03	4.62	8.00	35.98
Perception of extension performance	59.47	11.84	22.00	87.84
Adoption of SOP	124.61	97.87	97.87	160.49

Source: *the results of the authors' own research*

Table 4 shows that the average garlic farmer is 43 years old, which is considered a productive age for managing their farm effectively. On average, farmers have 8 years of education and a relatively extensive experience in garlic farming, spanning almost a decade. The mean score for the perception of activeness in the farmers' group variable is 24.03, indicating a moderate level. However, there is still room for improvement in farmers' participation, particularly in terms of attending regular group meetings. Most farmers do not hold group administrative positions. Unfortunately, farmers rarely can attend government-organized training sessions. The mean score attained by farmers for the perception of extension performance variable is 59.47, which falls within the moderate category as presented in Table 1. Farmers perceive extension workers to be effective communicators, motivators, and educators, but they still need to improve their facilitation skills. The average score for the SOP adoption variable is 124.61, which is also classified as moderate in Table 1. Farmers have not yet fully implemented the technological components of the SOP.

Maximum likelihood estimation results for production function model parameters. Due to the stochastic frontier production function using the MLE method estimation as presented in Table 5, the value of MLE Log Likelihood (132,662) is greater than the value of OLS Log Likelihood (116,118). This suggests that estimating the production function using the MLE method is better at describing conditions in the field than the OLS method. The Sigma Squared coefficient obtained is 0.0192, which is indicating that the error term inefficiency (μi) is normally distributed. The value of Gamma (γ) of 0.999 indicates that 99.99% of the variation of residual in the model comes from inefficiency (μi), which farmers can control. The remaining 0.01% is caused by a random error in measurement/noise (vi) in the form of production risks that farmers cannot control, such as weather and pest attacks. This finding shows that technical inefficiency is vital in explaining the garlic production level farmers in Temanggung Regency achieved. The LR test value for the one-sided error (number of restrictions = 10) obtained from the model is 33,088. This value is greater than the value of the mixed chi-square distribution X^2 (0.01,10)=28.856, which is contained in the Upper and Lower Bounds Table for The Critical Value for Jointly Testing Equality and Inequality Restriction (Shi, 2020). It means that the model can describe the effect of technical inefficiency in garlic farming.

Table 5. *Results of Stochastic Frontier Analysis Production Function with MLE*

Variables	Parameters	Coefficients	Standard Error	T ratio
Production Function				
Constanta	β_0	4.042	0.234	17.310^a
Farm size	β_1	0.113	0.042	2.680^a
Seeds	β_2	0.098	0.032	3.036^a
Urea fertiliser	β_3	0.100	0.031	3.266^a
ZA fertiliser	β_4	0.044	0.030	1.476^{ns}
NPK fertiliser	β_5	0.402	0.037	10.884^a
SP36 fertiliser	β_6	0.014	0.028	0.500^{ns}
Organic fertiliser	β_7	0.023	0.032	0.724^{ns}
Dolomite	β_8	0.023	0.023	1.016^{ns}
Pesticides	β_9	0.036	0.038	0.936^{ns}
Fungicides	β_{10}	0.016	0.015	1.070^{ns}
Herbicides	β_{12}	-0.045	0.022	-2.069^b
Yellow sticky trap	β_{12}	0.077	0.028	2.721^a
Family labour	β_{13}	0.066	0.030	2.210^b

Table 5. Continued

Variables	Parameters	Coefficients	Standard Error	T ratio
Hired labour	β_{14}	0.009	0.018	0.514 [ns]
Dummy of mulch	β_{15}	0.045	0.027	1.698[c]
Dummy of participation in gov. and importer programs	β_{16}	0.091	0.023	3.939[a]
Sigma squared (σ^2)		0.0192		7.086
Gamma (γ)		0.9999		14.295
Log Likelihood function-OLS				116,118
Log Likelihood function-MLE				132,662
LR test for the one-sided error				33.088

Note: *a: statistically significant at 1% (2.601); b: statistically significant at 5% (1.972); c: statistically significant at 10% (1.652); ns: not statistically significant*
Source: *the results of the authors' own research*

Table 5 shows that farm size significantly affects garlic production with an elasticity of 0.113, which means that a 1% increase in the land area can increase garlic production by 0.113% (ceteris paribus). Land has a relatively large production elasticity indicating that land expansion is an effective strategy for increasing garlic production. The average land ownership by farmers is only 0.32 hectares. Even though garlic is cultivated in narrow and scattered areas, farm size significantly impacts production because farmers grow garlic on the slopes of the Sindoro and Sumbing mountains, which are rich in humus. This result contradicts the findings of I. Ali *et al.* (2019), who state that fragmented land has a negative impact on production. The study mentioned that farmers did not use best fertilisation and land processing technology, which is causing a soil infertility. Seeds significantly affect garlic production, with an elasticity of 0.098. Every 1% increase in seed usage can increase production by 0.098% (ceteris paribus). This finding supports previous research from F. Rahmawati and Jamhari (2018) that shows that increased garlic production in Karanganyar Regency can be achieved by using more quality seeds. Both studies found that farmers often produce seeds from their previous harvests, which can affect the quality of the seeds. The quality of seeds depends on a range of factors, including their physical appearance, genetic purity, and freedom from pests and diseases.

The production factor of urea fertiliser has a significant impact. Every 1% increase in urea use can increase production by 0.1% (ceteris paribus). This finding supports the results of C. Mina *et al.* (2021) on garlic commodities in Pakistan and F. Chekol *et al.* (2023) in Northwest Ethiopia. The nitrogen content in Urea fertiliser is vital in vegetative growth because it can increase the ratio of shoots to roots, determining tuber formation. However, using elemental N in conditions that exceed the requirements can cause the thickening of the stems and rotting of the tubers during storage (Geisseler *et al.*, 2022). NPK fertiliser has a positive impact. Increasing 1% of NPK, production will increase 0.402% (ceteris paribus). The content of the macro elements Nitrogen, Phosphorus, and Potassium in NPK fertiliser plays a role in the formation of bulbs of up to 80% in garlic and shallots (Shukla *et al.*, 2018). These findings contradict the results of F. Rahmawati and Jamhari's (2018) study, which mentioned that no fertiliser significantly increased garlic production. The variables that impacted garlic production were land, seed, and liquid pesticides.

In this study, herbicides significantly adversely affect garlic production, with an elasticity of -0.045. Adding 1% herbicide will reduce production by 0.045% (ceteris paribus). The negative effect of herbicides on production output is caused by farmers' use in the long term and the amount that exceeds the threshold, causing resistance. This result differs from the results of C. Mina *et al.* (2021) who stated the positive impact of using herbicides. The herbicide will increase production yield by up to 10%. The use of yellow sticky traps to reduce fly pest populations affecting production with an elasticity of 0.077. Increasing yellow sticky traps by 1% can increase production by 0.077% (ceteris paribus). This results aligned with M. Pobozniak *et al.* (2020). Yellow sticky traps are effective in reducing the population of leafminer flies, fruit flies, whitefly, aphids, and thrips which can reduce the yield potential of garlic by up to 80%.

Family labour input has a positive impact with an elasticity of 0.066. Increasing the number of family labour by 1% can increase production by 0.066% (ceteris paribus). I. Ali *et al.* (2019) also found that family labour has a positive relation with garlic production, but not at a significant level. The positive influence of family labour is caused by a high availability level in each garlic cultivation phase compared to hired labour. The commitment and responsibility of family labour are also higher than that of workers outside the family because of a greater sense of belonging.

Plastic mulch significantly affects garlic production, with a coefficient of 0.045. Silver and black plastic mulch function to maintain soil moisture, prevent soil erosion and compaction, regulate soil temperature, and suppress the growth of weeds that disturb plants. The study of R. Iqbal *et al.* (2020) on 13 agricultural commodities stated that mulch could increase yields by up to 20%. The dummy variable of farmer participation in government programs and importers was proved give a positive impact on garlic production with a coefficient of 0.091. Farmers taking part in government programs and importers receive seeds, fertilisers, pesticides, mulch, capital, and technical assistance. This finding corroborates the study of B. Septiana *et al.* (2022) and S. Saraswati *et al.* (2022) which state that input and output policies simultaneously increase farmers' production and income.

Estimation of technical efficiency. The MLE method with the Frontier 4.1 application estimates the value of technical efficiency the farmer achieves, as shown in Table 6.

Table 6. *Level of technical efficiencies*

Technical efficiency level	Frequency	Percentage (%)
0.00-0.40	1	0.4
0.41-0.50	4	1.8
0.51-0.60	25	11.0
0.61-0.70	95	41.9
0.71-0.80	59	26.0
0.81-0.90	32	14.1
0.91-1.00	11	4.8
Total farmers	227	100
Mean	0.71	
Min	0.37	
Max	0.99	

Source: *the results of the authors' own research*

The farmers achieved a mean of technical efficiency of 0.7. The lowest value of 0.37 and the highest value of 0.99. Most farmers achieve technical efficiency values of 0.61-0.70 and 0.71-0.80. The average value achieved shows that there is still a 29% chance for farmers to increase their frontier production limits with the same technology. Variations in the values for achieving technical efficiency illustrate the level of adoption of different technologies. The study from F. Rahmawati and Jamhari (2018) in Karanganyar Regency produced a technical efficiency value of 0.61 in garlic farming with intercropping patterns. A. Wardani and D. Darwanto (2018) using the SFA method, found an average value of technical efficiency for garlic farmers in the Kledung sub-district, Temanggung Regency of 0.81. The technical efficiency of garlic studies using the SFA method in other countries shows varying results. P. Kumar *et al.* (2018) reported that the technical efficiency of garlic farmers in Madhya Pradesh, India reached 0.72. C. Mina *et al.* (2021) found that garlic farmers in the Philippines reached a technical efficiency 0.8.

Determinants of the technical inefficiency of garlic farming. Technical inefficiency was identified simultaneously through the MLE method on the Cobb-Douglas production function. Table 7 shows that only the variables of farming experience and the level of SOP adoption significantly affect the technical inefficiency of garlic farming.

Table 7. *Estimation of the determinants of technical inefficiency of garlic farming*

Variables	Parameters	Coefficients	Standard Error	T ratio
Constanta	δ_0	3.412	0.690	4.945^{a}
Age	δ_1	0.012	0.066	0.178^{ns}
Level of education	δ_2	-0.006	0.036	-0.165^{ns}
Farmer experience	δ_3	-0.033	0.019	-1.756^{c}
Perception of activeness in farmers group	δ_4	0.033	0.082	0.403^{ns}
Perception of extension performance	δ_5	0.017	0.070	0.245^{ns}
Adoption of SOP	δ_6	-0.654	0.156	-4.194^{a}
Dummy of land ownership	δ_7	0.017	0.042	0.408^{ns}
Dummy of credit access	δ_8	-0.018	0.027	-0.660^{ns}
Dummy of gender	δ_9	-0.058	0.090	-0.648^{ns}

Note: *a: statistically significant at 1% (2.599); b: statistically significant at 5% (1.971); c: statistically significant at 10% (1.652); ns: not significant*
Source: *the results of the authors' own research*

The farmer experience in garlic farming significantly impacts the technical inefficiency. The negative sign indicates that the longer the farmer's experience running garlic farming, the less technical inefficiency or more efficient farming. This finding corroborates the finding of F. Rahmawati & Jamhari (2018) and S. Attipoe *et al*. (2020). Based on Table 4, the average experience of garlic farmers is nine years. Experience teaches farmers the best cultivation practices so that farmers have the most efficient input use combinations to produce maximum output. In addition, farmers who have been cultivating garlic for a long time have a more open attitude towards ever-evolving technologies that allow them to produce a better yield.

The variable of adoption of SOP for garlic cultivation also significantly affects technical inefficiency at the 99% confidence level with a coefficient of -4.194. The negative sign describes that the higher the adoption rate of SOP, the lower the technical inefficiency. These results aligned with research results study of A. Wardani and D. Darwanto (2018). The adoption of technological components contained in SOPs can increase the efficiency of using production inputs. Table 3 indicates that the average garlic farmer adopts SOP at a moderate level with a value of 124 points. Technological aspects of SOP, especially in land management, variety selection, use of seeds, fertilisation, plant maintenance, pest control, and harvest and post-harvest, can increase the potential productivity of the varieties used. Variables of age, education level, activeness in farmer groups, farmers' perceptions of extension performance, land ownership, credit access, and gender do not significantly affect technical inefficiency.

Technical efficiency at various levels Adoption of Standard Operating Procedures. Standard operating procedure for garlic cultivation consists of 11 stages of cultivation, each of which has specific technological components recommended by the government. In general, the adoption of SOP for garlic cultivation in Temanggung Regency is in the moderate category. The total score obtained is 124 from a score range of 52-171. In detail, the classification of SOP adoption by farmers at each stage of garlic cultivation is presented in Table 8.

Table 8. *Adoption of SOP by Farmers*

Cultivation component	Number of technologies	Measuring tool scores interval		Adoption level		
		Min	Max	Achieved scores	(%)	Category
Land preparation	3	3	10	7	70	moderate
Land ploughing	5	5	16	12	75	moderate
Plant spacing	2	2	6	4	67	moderate
Seeds	5	5	16	12	75	moderate
Planting and basic fertilising	4	4	13	10	77	moderate
Mulch installation	2	2	6	5	83	high
Follow-up fertilising	6	6	19	13	68	moderate
Irrigation	2	2	7	3	43	low
Weed and soil management	3	3	10	9	90	high
Pest control	15	15	50	35	70	moderate
Harvest and post-harvest	5	5	18	14	78	high
All SOP components	**52**	**52**	**171**	**124**	**73**	**moderate**

Source: *the results of the authors' own research*

The technology components adopted by farmers in the high category are mulch use, plant maintenance, harvest, and postharvest. Farmers obtain plastic mulch both from government programs and importers programs. In the Horticultural Product Import Recommendations regulated by the Ministry of Agriculture, importers must plant as much as 5% of the proposed amount of garlic imports (Regulation of The Ministry of Agriculture, 2017). Therefore, importers collaborate with farmers to achieve the required outcome. At the maintenance stage, farmer adoption is included in the high category. Farmers regularly cultivate the land, remove weeds, and clear away plant debris. Farmers adopt technological components to facilitate uprooting in damp conditions. The subsequent process involves drying and cleaning the tubers of crop residue. Additionally, farmers sort the tubers based on quality and size, storing them with special treatment to maintain their quality.

The adoption of SOP by farmers is categorized as a moderate level at the stage of land preparation, determination of plant spacing, use of seeds, planting and basic fertilisation, follow-up fertilisation, and pest control. Garlic in Temanggung Regency can only be planted once a year during the rainy season (November-April). The type of land limit is rainfed with high humidity levels. It causes garlic farming more vulnerable to various production risks, such as excessive rainfall and pest attacks. Land preparation does not carry out intensively by farmers as well. They hack the land only once, whereas the SOP suggests that the field should be deeply ploughed and disked properly to eliminate debris and soil clods. Farmers planted garlic on the slopes of Mount Sumbing and Sindoro but disobeyed SOP's recommendation. They make broad beds of garlic aligned to the slope of the land, not across the slope. It is certainly dangerous for the sustainability of the land because it has the potential to cause erosion.

Many farmers use spacing that is not recommended in the SOP. The intercropping cultivation system of garlic with tobacco and other vegetables causes farmers to be unable to apply spacing according to the SOP recommendations. They have yet to use certified seeds as well. They use seeds from superior, high-yielding varieties such as Lumbu Hijau and Lumbu Kuning, but the quality cannot be guaranteed because they got the seeds from previous harvests. Certified seed availability is one of the obstacles for farmers trying to increase garlic productivity. Farmers still rely heavily on chemical pesticides compared to natural ingredients during the pest control phase, as recommended in the SOP. The lowest level of SOP adoption is in the watering phase. As explained previously, the garlic field in Temanggung Regency is rainfed. Farmers depend on rainfall to water their plants. Irrigation technology is needed so garlic can be planted during the off-season. Drip or sprinkler irrigation is a strategic technique to increase the cropping index to generate national garlic production. Many farmers, especially small-scale farmers, may not have the financial resources to invest in such infrastructure. A comprehensive approach that combines financial aid, infrastructure development, research, and supportive policies can help make technical irrigation more accessible and affordable for farmers, ultimately enhancing agricultural productivity and sustainability.

The previous discussion in this study stated that the adoption rate of SOP for garlic had a significant impact on the level of technical inefficiency of farmers. The coefficient with a negative sign means that the higher the level of SOP adoption, the lower the technical inefficiency of the farmers or the higher the technical efficiency. This study categorizes the technical efficiency values obtained by farmers based on their level of adoption of the SOP for garlic cultivation, as presented in Table 9.

Tabel 9. *Farmers' technical efficiency at various levels of SOP adoption*

SOP adoption level	Score intervals	Number of farmers	%	Mean of Technical Efficiency
High	131.4⩽score achieved⩽171	66	29	0.77
Moderate	91.7⩽score achieved ⩽131.3	161	71	0.68
Low	52⩽score achieved⩽91.6	0	0	0

Source: *the results of the authors' own research*

This table shows that 71% of farmers have an SOP adoption level in the medium category. The average technical efficiency achieved by this group is 0.68. Meanwhile, 29% of farmers have a relatively high SOP adoption rate. The mean of technical efficiency achieved is 0.77. The higher the adoption rate of SOP, the higher the value of technical efficiency. The technological components included in SOP for garlic cultivation can help farmers in allocating production inputs as efficiently as possible to produce greater production. The application of SOP can encourage the achievement of productivity targets above 12 t/ha, reduce yield loss to below 10%, and improve the quality of dry tubers according to market standards, namely quality level I (50%), quality II (30%) and quality III (20%) (Directorate General of Horticulture, 2016).

However, the adoption rate of SOP-GAP for garlic still needs to be improved. Based on this research, the adoption rate of SOP for garlic cultivation in Temanggung Regency is in the moderate category. The mean of technical efficiency obtained by farmers only reaches 0.71. The results of this study aligned with the findings of A. Wardani and D. Darwanto (2018), which state that the application of SOP and GAP for garlic cultivation in various production centres in Indonesia still needs to be improved. The government and other stakeholders were challenged to increase the implementation of SOP garlic through various programs and policies.

CONCLUSIONS

The key to achieving food security lies in increasing production to ensure physical and financial access to food according to people's consumption needs. However, national garlic production has not been sufficient to meet national demand, leading to price increases if the government does not implement import policies. Low production is also affected by the inefficient use of factor inputs, which can be attributed to the lack of technology application. The study discovered that the input factors that had a significant impact on garlic production were land area, seeds, urea, NPK fertiliser, herbicides, yellow lick traps, family labour, use of plastic mulch, and participation in government and importer programs. The technical efficiency level of garlic farmers has only reached 0.71, indicating that there is still room for improvement in production using the same technology.

Efficiency in farming is intricately linked to the managerial ability of farmers. Therefore, the socio-economic factors of farmers play a crucial role in reducing opportunities for inefficiency. This study proved that the experience of farmers and the adoption rate of SOPs are significant variables in reducing technical inefficiency. Farmers with more experience have greater exposure to information and technology, providing them with valuable references for their farming practices. This study showed a clear correlation between the rate of technology adoption and technical efficiency. Therefore, to develop successful garlic production programs, the government must ensure that farmers have strong managerial skills, distribute inputs efficiently, and have a mastery of technology.

At the medium level of SOP adoption, farmers achieve a technical efficiency of 0.68. At the medium level of SOP adoption, farmers achieve a technical efficiency of 0.68. This increases to 0.77 at higher levels of adoption. These findings suggest the possibility of formulating several exit strategies to enhance production and technical efficiency. The study's results are important for the Indonesian government and stakeholders in developing garlic policies within the province. This includes expanding the planting area, using quality seeds, adopting fertilisation technology and pest/disease control, improving labour skills within families, applying standard operating procedures by farmers, increasing the role of extension as a facilitator, and improving programs to empower farmers and their businesses. The focus is on increasing production, technical efficiency, and the adoption of technology. To determine national policies for garlic development in Indonesia, it is necessary to scale up this research and broaden the research locus to include all production centres in the country.

ACKNOWLEDGEMENTS

None

CONFLICT OF INTEREST

The authors of this study declare no conflict of interest.

REFERENCES

[1] Adzawla, W., & Alhassan, H. (2021). Effects of climate adaptation on technical efficiency of maize production in Northern Ghana. *Agricultural and Food Economics*, 9, article number 14. doi: 10.1186/s40100-021-00183-7.
[2] Ali, I., Xue-xi, H.U.O., Khan, I., Ali, H., Baz, K., & Khan, S.U. (2019). Technical efficiency of hybrid maize growers: A stochastic frontier model approach. *Journal of Integrative Agriculture,* 18(10), 2408-2421. doi: 10.1016/S2095-3119(19)62743-7.
[3] Attipoe, S.G., Jianmin, C., Opoku-Kwanowaa, Y., & Ohene-Sefa, F. (2020). The determinants of technical efficiency of cocoa production in Ghana: An analysis of the role of rural and community banks. *Sustainable Production and Consumption*, 23, 11-20. doi: 10.1016/j.spc.2020.04.001.
[4] Center for Agricultural Data and Information. (2020). Retrieved from https://satudata.pertanian.go.id/assets/docs/publikasi/Outlook_Komoditas_Hortikultura_Bawang_Putih_Tahun_2020.pdf.
[5] Chekol, F., Abetie, K., & Sirany, T. (2023). Technical efficiency of garlic production under rain fed agriculture in Northwest Ethiopia: Stochastic frontier approach. *Cogent Economics and Finance,* 11(2), 1-24. doi: 10.1080/23322039.2023.2242177.
[6] Coomes, O.T., Barham, B.L., MacDonald, G.K., Ramankutty, N., & Chavas, J.P. (2019). Leveraging total factor productivity growth for sustainable and resilient farming. *Nature Sustainability,* 2, 22-28. doi: 10.1038/s41893-018-0200-3.
[7] Declaration of Helsinki. (2013). Retrieved from https://www.wma.net/what-we-do/medical-ethics/declaration-of-helsinki/.
[8] Directorate General of Horticulture. (2016). Retrieved from https://hortikultura.pertanian.go.id/wp-content/uploads/2020/06/Renstra-Horti-2020-2024.pdf.
[9] Falkendal, T., Otto, C., Schewe, J., Jagermeyr, J., Konar, M., Kummu, M., Watkins, B., & Puma, M.J. (2021). Grain export restrictions during COVID-19 risk food insecurity in many low- and middle-income countries. *Nature Food,* 2, 11-14. doi: 10.1038/s43016-020-00211-7.
[10] Geisseler, D., Ortiz, R.S., & Diaz, J. (2022). Nitrogen nutrition and fertilisation of onions (*Allium cepa* L.) – a literature review. *Scientia Horticulturae,* 291, article number 110591. doi: 10.1016/j.scienta.2021.110591.
[11] Hakim, R., Haryanto, T., & Sari, D.W. (2021). Technical efficiency among agricultural households and determinants of food security in East Java, Indonesia. *Scientific Reports*, 11, article number 4141. doi: 10.1038/s41598-021-83670-7.
[12] Hellegers, P. (2022). Food security vulnerability due to trade dependencies on russia and Ukraine. *Food Security*, 14, 1503-1510. doi: 10.1007/s12571-022-01306-8.
[13] Iqbal, R., Raza, M.A.S., Valipour, M., Saleem, M.F., Zaheer, M.S., Ahmad, S., Toleikiene, M., Haider, I., Aslam, M.U., & Nazar, M.A. (2020). Potential agricultural and environmental benefits of mulches – a review. *Bulletin of the National Research Centre*, 44, article number 75. doi: 10.1186/s42269-020-00290-3.
[14] Kale, R.B., Gadge, S., Rao, B.V., Mahajan, V., & Sigh, M. (2022). *Good agricultural practices in onion and garlic production.* Retrieved from https://dogr.icar.gov.in/images/ebook/ebookdogr.pdf.

[15] Kamau, H., Roman, S., & Biber-freudenberger, L. (2023). Farming for sustainable intensification. *Communications Earth & Environment*, 4, article number 446. doi: 10.1038/s43247-023-01062-3.
[16] Kumar, P.P., Khan, N., & Kumar, S. (2018). An economic analysis of garlic cultivation in Ratlam district of Madhya Pradesh. *International Journal of Agriculture, Environment and Biotechnology,* 11(2), 371-377. doi: 10.30954/0974-1712.04.2018.19.
[17] Kune, S.J., & Hutapea, A.N. (2018). Efficient use farm input of Eban local garlic in Western Miomaffo Timor Tengah Utara district. *Journal Management of Agribusiness*, 6(1), 26-33. doi: 10.24843/JMA.2018.v06.i01.p05.
[18] Mina, C.S., Catelo, S.P., & Jimenez, C.D. (2021). Productivity and competitiveness of garlic production in Pasuquin, Ilocos Norte, Philippines. *Asian Journal of Agriculture and Development,* 18(1), 50-63. doi: 10.37801/ajad2021.18.1.4.
[19] Pobozniak, M., Tokarz, K., & Musynov, K. (2020). Evaluation of sticky trap colour for thrips (*Thysanoptera*) monitoring in pea crops (*Pisum sativum* L.). *Journal of Plant Diseases and Protection,* 127, 307-321. doi: 10.1007/s41348-020-00301-5.
[20] Prayogo, W., & Wihastuti, L. (2023). *Technical efficiency analysis of the use of production factors in garlic farming for the 2022 state budget assistance program (case study of Petarangan Village, Kledung District, Temanggung regency)*. Retrieved from https://etd.repository.ugm.ac.id/penelitian/detail/227909.
[21] Rabbani, G.M., & Ahmad, B. (2021). An analysis of economic efficiency of garlic production in selected upazila of Dinapur District in Bangladesh. *BAUET Journal*, 3(1), 144-153.
[22] Rahmawati, F., & Jamhari. (2018). Technical efficiency of garlic farming with intercropping pattern in Karanganyar regency, Central Java Province. *Jurnal Agro Ekonomi,* 36(2), 135-147. doi: 10.21082/jae.v36n2.2018.135-147.
[23] Regulation of The Ministry of Agriculture. (2017). Retrieved from https://peraturan.bpk.go.id/Details/160968/permentan-no38permentanhr060112017-tahun-201.
[24] Ricky, R., Suminah, S., & Rusdiyana, E. (2022). Partnership of garlic farmers and importers in Karanganyar Regency. *International Journal of Social Science*, 1(6), 897-906. doi: 10.53625/ijss.v1i6.1913.
[25] Saraswati, S.R., Iswandi, M., & Alwi, L.O. (2022). Analysis of competitiveness and impact of government policy on shallot farming in south Buton Regency. *Jurnal Sosio Agribinis,* 7(1), 22-32. doi: 10.33772/jsa.v7i1.23226.
[26] Septiana, B., Kusnadi, N., & Fariyanti, A. (2022). Garlic competitiveness in Indonesia. *Journal of Indonesian Agribusiness*, 10(1), 40-52. doi: 10.29244/jai.2022.10.1.40-52.
[27] Seran, K.I., Kapa, M.M.J., & Pudjiastuti, S.S.P. (2020). Production efficiency of local garlic farming in west Miomaffo sub-district, East Central Timor Regency. *Buletin Ilmiah IMPAS,* 21(3), 245-252.
[28] Shi, X. (2020). *Uniform inference when parameters are subject to linear inequality constraints.* Washington: University of Washington.
[29] Shukla, Y.R., Kaushal, M., & Bijalwan, P. (2018). Studies on the effect of macro and micro nutrients on yield and nutrient uptake in Garlic (*Allium sativum* L.). *International Journal of Current Microbiology and Applied Sciences,* 7(10), 1201-1204. doi: 10.20546/ijcmas.2018.710.133.
[30] Wardani, A., & Darwanto, D. (2018). The impact of GAP-SOP on the production and technical efficiency of garlic in Temanggung Regency. *Jurnal Agro Ekonomi*, 29(2), 299-309. doi: 10.22146/ae.36468.
[31] Widyastutik, W., Setyawati, D., Dewi, F.R., & Nugraheni, S.R.W. (2022). Garlic business model development strategy: Canvas model business approach. *Jurnal Manajemen Dan Agribisnis,* 19(2), 239-250. doi: 10.17358/jma.19.2.239.
[32] Workneh, M.W., & Kumar, R. (2023). The technical efficiency of large-scale agricultural investment in Northwest Ethiopia: A stochastic frontier approach. *Heliyon,* 9(9), article number e19572. doi: 10.1016/j.heliyon.2023.e19572.

Технічна ефективність на декількох рівнях впровадження стандартних операційних процедур (СОП) для часнику у виробничому центрі в Індонезії

Діана Курнявих
Доктор філософії
Університет ІПБ
16680, Jl. Рая Драмага, м. Богор, Індонезія
Індонезійський центр сільськогосподарських стандартів
l. Харсоно РМ № 3, Пасар Мінггу, Спеціальний столичний округ Джакарти, Індонезія
https://orcid.org/0009-0009-7042-0602
Юсман Сяукат
Професор, викладач
Університет ІПБ
16680, Jl. Рая Драмага, м. Богор, Індонезія
https://orcid.org/0000-0002-6473-3647
Рита Нурмаліна
Професор, викладач
Університет ІПБ
16680, Jl. Рая Драмага, м. Богор, Індонезія
https://orcid.org/0000-0002-8002-9975
Сухарно
Аспірант, викладач
Університет ІПБ
16680, Jl. Рая Драмага, м. Богор, Індонезія
https://orcid.org/0000-0003-2564-8092

Анотація. Актуальність цього дослідження полягає в подоланні перешкод для розвитку часнику в Індонезії, таких як низька продуктивність та обмежене використання технологій, що може стати на заваді самозабезпеченню та програмам скорочення імпорту. Метою цього дослідження було визначити технічну ефективність, детермінанти технічної неефективності та рівень технічної ефективності на різних рівнях впровадження стандартних операційних процедур вирощування часнику у виробничих центрах Індонезії. Дані перехресних досліджень були зібрані за допомогою інтерв'ю з 227 фермерами, відібраними за допомогою простого методу випадкового відбору. Виробнича функція Кобба-Дугласа та стохастичний граничний аналіз були використані для визначення факторів, що впливають на виробництво часнику, рівень технічної ефективності та детермінанти технічної неефективності. Для аналізу даних було використано метод максимальної правдоподібності. Рівень технічної ефективності на різних рівнях впровадження стандартних операційних процедур вимірювався за допомогою описового статистичного аналізу. Розмір господарства, насіння, сечовина та NPK добрива, гербіциди, жовті липкі пастки, сімейна праця, мульча та участь фермерів у програмах розвитку часнику суттєво впливали на виробництво часнику. Технічна ефективність варіювалася від 0,37 до 0,99, із середнім значенням 0,71. Досвід фермерів та впровадження стандартних операційних процедур значно знизили технічну неефективність. Загалом, рівень впровадження стандартних операційних процедур є помірним. У групі з високим рівнем впровадження стандартних операційних процедур середній показник технічної ефективності становить 0,77, тоді як у групі з помірним рівнем – 0,68. Результати дослідження можуть бути використані як модель для інших країн-імпортерів часнику для збільшення виробництва та зміцнення продовольчої безпеки

Ключові слова: неефективність; самозабезпеченість; стохастичний граничний аналіз; впровадження технологій