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Economic Efficiency of the Use of Organic and Inorganic Fertilizers in Eggplant (*Solanum spp.*) Production in Kogi State, Nigeria

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Abstract:

Background: *Thereis a growingneed for management of soilfertilityespecially in sub – SaharanAfricawheresoil fertility decline is a pressing issue and themost serious bio-physical constraint limiting crop productivity. One way of augmentingdecline in soilfertility on agricultural land in order to achievehigherproductivityisthroughthe use of organic and inorganicfertilizers.It has been shownthatefficient allocation of scarceresources leads to higherproductivity, profits and national income. The effects of thesefertilizers on the economicefficiency of eggplant production has not been ascertained in recent time. It isagainstthisbackdropthatthisstudyiscarried out to compare economicefficiency of the use of organic and inorganicfertilizers on eggplant production in Kogi State, Nigeria.*

Materials and Methods*: A multi-stage sampling technique was used to select 120 eggplant farmers for the study. Primary data obtained through questionnaire administration were analyzed using descriptive statistics, Data Envelopment Analysis (DEA), regression analysis and Student's t-test.*

Results*: The mean technical efficiency under the constant returns to scale (TECRS) for organic fertilizer users was 0.51 while that of inorganic fertilizer users was 0.64. The mean technical efficiency under the variable returns to scale (TEVRS) for organic fertilizers users was 0.91 while that of inorganic fertilizer is 0.92. The mean allocative efficiency (AE) of organic fertilizer users was 0.49 while inorganic fertilizer users recorded a mean of 0.63. Organic fertilizer and inorganic fertilizer users recorded a mean economicefficiency (EE) of 0.257 and 0.409 respectively. Furthermore, organic fertilizer users had a mean scale efficiency (SE) of 0.56 compared to inorganic fertilizer users with a mean scale efficiency of 0.70. Majority (88.3%) of the organic fertilizer users operated at the increasing returns to scale (IRS) compared to 75% of the inorganic fertilizer users. The t-test shows that the differences in means of technical efficiency, allocative efficiency, scale efficiency, and economic efficiency of organic and inorganic fertilizer users in eggplant production were statistically significant at 5% level of significance. The coefficients of age, education, and farming experience positively influenced the economic efficiency of both organic and inorganic fertilizers users in eggplant farmers at the 5% level of significance.*

Conclusion:*The use of inorganic fertilizers in eggplant production resulted in higher technical, allocative, economic and scale efficiencies compared to the use of organic fertilizers. These differences are statistically significant at 5% level of Measurement. These results revealed the existence of high level of inefficiency among the farmers and a considerable room for improvement.*

Key Word*: DEA, Economicefficiency, Eggplant, Organic, inorganic, Fertilizer, Returns to Scale*

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I. Introduction

How to attain self - sufficiency in agricultural food production is the major policy objective of successive governments in Nigeria. In order to achieve self – sufficiency in food production, the management of soil resources cannot be over – emphasized. This is very important particularly in Kogi State which is characterized by high relative humidity, torrential rainfall and high temperatures which jointly have a limiting effect on soil fertility of the lands that are available for agriculture [22]. Declining soil fertility is the main constraint in improving the yield of annual crops resulting into dwindling productivity. Therefore, to maintain productivity of crops, management of soil fertility and soil health are very important. One of the most effective ways of raising agricultural productivity is through the application of fertilizers both organic and inorganic especially in low income countries where fertilizer use is lowest [23].Soil fertility is the ability of soil to sustain plant growth and optimize crop yield. Traditionally, in most of the permanent agricultural system, soil fertility is managed through manure, fertilizer (organic and inorganic) and other organic material [9]. Organic fertilizers are fertilizers derived from animal matter, human excreta or vegetable matter (e.g. compost manure), while inorganic fertilizer, also referred to as synthetic fertilizer, is manufactured artificially and contains minerals or synthetic chemicals [10]. Given that the most important natural resource is the soil, it is important to preserve the humus top soil and maintain or increase its organic matter content to increase the nutrient providing ability and to carry on an environment-friendly nutrient management [20]

Attaining the highest output per unit of resource used is not enough. Our goal is the attainment of the highest output without wastage of scarce resources. Thus the issue of efficiency is of great importance to economists and has remained an important subject of empirical investigation particularly in developing economies where majority of the farmersareresource-poor.Thisisbecause the scope of agricultural production can be expanded andsustainedbyfarmersthroughefficientuseof resource [24].

Eggplant (*Solanum spp*.) is an herbaceous plant which originated in Southeast Asia and India. This plant belongs to the Solanaceae family, so morphologically similar to potatoes, tomatoes, and peppers [4]. It produces fruits that are white to dark purple with varying size, from long to round egg-shaped, from which it gained the name eggplant [11]. It is a tropical/semi-tropical vegetable that thrives between 75 to 80 °F. Above 90 and below 65°F is detrimental to the growth of the plant [21]. Well-drained sandy loam and clay loam with rich organic matter and slightly acidic level (pH 6.0-6.5) are considered the best soils for its growth (Food and Agriculture Organization, [7].The fruits can be eaten raw as a vegetable. It could also be boiled, fried and stuffed before consumption. Consuming high amounts of garden eggs has been found to be beneficial for people with glaucoma because it lowers the eye pressure [8, 18]. Similarly, eggplant contains nutrients such as dietary fiber, folate, ascorbic acid, vitamin K, niacin, vitamin B6, pantothenic acid, potassium, iron, magnesium, manganese, phosphorus, and copper [25].

Although fertilizer usage is expected to increase the productivity of crops, it is unknown whether the use of organic fertilizer is economically beneficial when compared with inorganic fertilizer. Despite the benefits of eggpant, optimum yield of the crop has not been attained in Nigeria. For instance, Top eggplant producing countries of China, India, Egypt, and Turkey, recorded yield of 40,960.3kg/ha, 18,903.6/ha, 24,596.7/ha, and 34,461.6/ha, respectively [6]. In Nigeria, [12] reported a yield of 16.1 and 15.1t/ha for fresh fruit in 2017 and 2018 respectively. This means that eggplant farmers in Nigeria are not obtaining maximum yield from their enterprise.Previous studies that examined productivity and efficiency in eggplant production such as [16], [17], [1] , among others used marginal analysis, Total Factor Productivity (TFP), Stochastic Frontier Analysis and Ordinary Least Square (OLS) regression analysis. This study used Data Envelopment Analysis (DEA) to compare economic efficiency of organic and inorganic fertilizer users in eggplant production in the study area.

II. Material And Methods

This study used cross – sectional data to compare economic efficiency of eggpant farmers that used organic and inorganic fertilizers in Kogi State, North Central Nigeria, for the 2021 cropping season. A total of 120 eggplant farmers (made up of male and females) were study.

Study Design: Descriptive Design

Study Location: This study was carried out in Kogi State, North Central Nigeria

Study Duration: May – July, 2021

Sample size: 120 farmers

Sample size calculation: The population for this study were all the eggplant farmers in Kogi State. A multi – stage sampling technique was used to select respondent farmers for data collection. In the first stage, two (2) LGAs were purposively selected out of the twenty one (21) local governments in the state based on the concentration of eggplant farmers and their level of production. The LGAs selected were Ajaokuta and Bassa LGAs. In the second stage, three districts known for eggplant production were purposively selected from each LGA, this gives six (6) districts for the study. Two (2) eggplant farming communities were randomly selected from each district, giving a total of twelve (12) eggplant farming communities in the third stage. In the fourth stage, 10 (ten) eggplant farmers were randomly selected from each of the farming communities, making a total of one hundred and twenty (120) eggplant farmers (respondents) for the study.

Subjects & selection method: The sample size for this study is 120 eggplant farmers. From this, 60 farmers each that used organic and inorganic fertilizers respectively were randomly selected for interview.

Procedure methodology

The questionnaire was the main instrument for data collection. Both closed and open – ended questions were used to elicit further comments from the respondents. The questionnaire was divided in sections and is comprised of questions relating to socio – demographic characteristics of the farmers such as age, farm size, education, farming experience, household size, among others; inputs used and output obtained as well as their prices. The questionnaire was validated by experts in crop production and agricultural economics and was administered by trained enumerators.

Data Envelopment Analysis (DEA) was used to obtain estimates of the technical efficiency (TE), allocative efficiency (AE), economic efficiency (EE) and scale efficiency (SE) of the farmers. DEA is a non-parametric, deterministic procedure for evaluating the frontier and employs the best practice frontier [3]. The DEA has an advantage over the stochastic frontier analysis (SFA) because it is less sensitive to misspecification error and does not require any specific functional form to be selected. DEA has been widely studied, used, and analyzed by academics to evaluate firm performance using efficiency measurements.

The technical efficiency (TE) score of a given farmer n is obtained by solving the following input oriented linear programming (LP) problem:

$$TE_n = min\ \theta_n \quad (1)$$

Subject to (s.t.)

$$\sum_{i=1}^{1} \lambda_i x_{ij} - \theta_n x_{nj} \leq 0 \quad (2)$$

$$\sum_{i=1}^{1} \lambda_i y_{ik} - y_{nk} \geq 0 \quad (3)$$

$$\sum_{i=1}^{1} \lambda_i = 1 \quad (4)$$

$$\lambda i \geq 0 \quad (5)$$

Where:

i = 1 to I farmer; j = 1 to J inputs; k = 1 to K outputs; x_{ij} = the amount of j used by farmer i; x_{nj}= amount of input j used by farmer n; y_{nk} -= amount of output k produced by farmer i; y_{nk} = amount of output k produced by farmer n; λi = non negative weights for i farms; θ_n= a scalar ≤ 1 that defines the TE if farmer n. If θ_n = 1, it means the farmer is technically efficient and if the value is less than one, it means a technically inefficient farm with the level of technical inefficiency equal to 1 – $TE_{n.}$

The EE score for a given farmer n is obtained by solving the following input-oriented DEA model to obtain the minimum cost:

$$MC_n = min\lambda_i x^*_{nj} \sum_{j=1}^{J} p_{nj} x^*_{nj} \quad (6)$$

Subject to

$$\sum_{i=1}^{J} \lambda_i x_{ij} - x^*_{nj} \leq 0 \quad (7)$$

$$\sum_{i=1}^{1} \lambda_i y_{ik} - y_{nk} \geq 0 \quad (8)$$

$$\sum_{i=1}^{1} \lambda_i = 1 \quad (9)$$

$$\lambda i \geq 0 \quad (10)$$

Where:

MC_n= the minimum total cost for farmer *n*;$p_{nj=}$ the price for input j for farmer n; x^*_{nj} = the cost minimizing level of input *j* for farmer n given its input price and output levels; all other variables are as previously defined.

The economic efficiency (EE) for each farmer *n* can then be estimated using equation (11) below:

$$EE_n = \frac{\sum_{j=1}^{J} P_{nj}\, x^*_{nj}}{\sum_{j=1}^{J} P_{nj}\, x_{nj}}$$

Where:

The numerator is the minimum total cost obtained for farmer *n* based on eqs. (6) to (10) and the denominator is the actual total cost observed for farmer *n*. When EE_n = 1, the farm is economically efficient and ifEEn< 1 implies the farm is economically inefficient.

EE for each farm can also be estimated as a product of TE and AE, as expressed below:

$$EE_n = TE_n \times AE_n \quad (12)$$

The allocative efficiency (AE) score for farmer *n* can be estimated given both TE and EE for the farmer as follows:

$$AE_n = \frac{EE_n}{TE_n} \quad (13)$$

Where:

EE_n = economic efficiency calculated for farmer *n* using Eq. (11) and TE_n = technical efficiency calculated for farmer *n* using Eqs. (1) to (5). When the value of AE_n = 1, the farmer is allocatively efficient and an AE_n< 1 means it is allocatively inefficient.

The scale efficiency (SE_n) for a farmer n is estimated as follows:

$$SE_n = \frac{TE_{CRS\,n}}{TE_{VRS\,n}} \quad (14)$$

Where:

TE_{CRSn} = technical efficiency of a farmer n under constant returns to scale and TE_{VRSn} = technical efficiency under variable returns to scale. When $SE_n = 1$, it means the farm is operating at an optimal scale and when $SE_n < 1$, it implies the farm is scale inefficient. Scale inefficiency arises as a result of the presence of increasing returns to scale (IRS) or decreasing returns to scale (DRS).

The OLS was used to examine factors affecting TE or EE of rice farmers. It is expressed as follows:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (15)$$

Where:
Y = EE scores; $\alpha =$ constant; $\beta_1 \ldots\ldots \beta_4$ = parameters to be estimated; X_1 = age; X_2 = household size; X_3 = education ; X_4 = experience ; X_5 = extension access ; ε = error term.

Statistical analysis

The Data Envelopment Analysis (DEA) Program (DEAP 2.1) byTim Coelli was used to analyze the data and to obtain estimates of TE, AE, SE and EE scores of the farmers. The computer program STATA was used to obtain ordinary least regression estimates of the factors affecting economic efficiency of the farmers while Student's *t*-test was used to ascertain the significance of differences between mean values of TE, AE EE and SE of farmers that used organic and in organic fertilizers.

III. Result

Technical, Allocative and Economic Efficiency Indexes of Eggplant Farmers

Table no 1 presents the summary statistics of technical, allocative, economic and scale efficiency indexes of eggplant farmers. From Table 3, the technical efficiency are presented under constant returns to scale (TECRS) and variable return to scale (TEVRS). The mean (overall) *TECRS* for organic fertilizer users is 0.51 with a minimum of 0.017 and a maximum of 1.0 compared to the inorganic fertilizer users with a mean of 0.64 and a minimum and maximum TECRS of 0.029 and 1, respectively. The mean *TEVRS* (pure) for organic fertilizers users is 0.912 with a minimum of 0.524 and a maximum of 1; while eggplant farmers that used inorganic fertilizer recorded an average *TEVRS* of 0.924 with a minimum and maximum values of 0.433 and 1, respectively. The mean allocative efficiency of organic fertilizer users is 0.491 with a minimum of 0.174 and a maximum of 1 compared to the inorganic fertilizer users which is 0.63 with a minimum of 0.013 and a maximum of 1.0.

Table no 1: Summary of Technical, Allocative And Economic Efficiency Indexes of Eggplant Farmers

Class	TECRS		TEVRS		Alloc. Eff.		Eco. Eff.		Scale Eff.	
	Org.	Inorg.	Org.	Inorg.	Org.	Inorg.	Org.	Inorg.	Org.	Inorg.
1	5	11	38	40	1	1	1	1	5	12
0.9 - 0.999	4	2	5	3	0	1	0	1	7	10
0.8 - 0.899	3	10	3	8	5	1	1	1	4	9
0.7 - 0.799	6	6	6	2	5	22	0	6	6	4
0.6 - 0.699	7	6	4	5	6	12	2	5	8	4
0.5 - 0.599	4	5	4	1	10	9	3	3	3	4
0.4 - 0.499	8	5	0	1	8	10	5	13	7	4
0.3 - 0.399	6	6	0	0	16	4	8	6	6	4
0.2 - 0.299	6	3	0	0	8	0	12	14	3	4
0.1 - 0.199	11	6	0	0	1	0	28	10	11	5
Total	60	60	60	60	60	60	60	60	60	60
Mean	0.513	0.64	0.912	0.924	0.491	0.63	0.257	0.4085	0.56	0.699
Min	0.017	0.029	0.524	0.433	0.174	0.013	0.01	0.0132	0.02	0.029
Max	1	1	1	1	1	1	1	1	1	1

Source: Field Survey 2021 and DEAP 2.1

The mean economic efficiency among organic fertilizer users is 0.257 with a minimum of 0.01 and a maximum of 1.0, compared to the average economic efficiency of 0.409 with a minimum of 0.013 and a maximum of 1.0. Table 3 further shows that organic fertilizer users had a mean scale efficiency of 0.56 compared to inorganic fertilizer users with a scale efficiency of about 0.70.

Returns to Scale of Eggplant Farmers

The returns to scale of eggplant farmers in the study area is presented in Table no 2

Table no 2: Returns to Scale of Eggplant Farmers

	Organic		Inorganic	
Class of Scale Eff.*	**Freq.**	**Perc.**	**Freq.**	**Perc.**
IRS	53	88.33	45	75
CRS	5	8.33	12	20
DRS	2	3.33	3	5
Total	60	100	60	100

* CRS: Constant Returns to Scale; IRS: Increasing Returns to Scale; DRS: Decreasing Returns to Scale

Source :Computed from DEAP 2.1

The result as shownin Table no 2 revealed that majority (88.3%) of the organic fertilizer users operated at the increasing returns to scale (sub-optimal) compared to 75% of the inorganic fertilizer users in eggplant production. This result implies that majority of the eggplant farmers in Kogi State are operating below the optimal level and therefore would benefit from an increase in scale. Table no 2 further showed that 8.3% and 20% of the organic and inorganic fertilizer users in eggplant production were operating at a constant return to scale; that is, these percentage of farmers operated at optimal size. Also, 3.3% and 5% of the organic and inorganic fertilizer users were operating at a decreasing return to scale; this implies that only 3.3% and 5% of the organic and inorganic fertilizer users in eggplant production operated above the optimal level.

T-test of Difference in Mean

The t-test of difference in mean among eggplant farmers (organic and inorganic fertilizer users) is presented in Table no 3. The result shows the differences in means of technical efficiency, allocative efficiency, scale efficiency, and economic efficiency of organic and inorganic fertilizer users in eggplant production were statistically significant at the 5% level of measurement.

Table no 3: T-test of differences in TE, AE, SE and EE scores of Eggplant Farmers

Type of Fertilizer used	TE	AE	SE	EE
Organic	0.513	0.491	0.560	0.257
Inorganic	0.640	0.630	0.699	0.409
T-stat(two-tail)	-2.335	-4.410	-2.480	-3.756
T- critical (two-tail)	1.980	1.982	1.980	1.981
Remarks	Significant	Significant	Significant	Significant

Source: Computed from DEAP 2.1

Factors Affecting Economic Efficiency of Eggplant Farmers

The summary statics of socio-demographic variables used in the regression analysis is presented in Table no 5.

Table no 4 : Descriptive Statistics of Socio - Demographic Variable used in Regression Analysis

	Organic				Inorganic			
Variable	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.
Age	25	65	42.20	9.22	34	65	45.58	7.51
Household Size	3	12	5.70	2.06	3	10	5.33	1.40
Education	6	20	10.22	3.91	6	18	10.78	2.60

Experience	3	18	6.35	3.36	3	15	6.60	3.43

Source : Field Survey,2021

The factors affecting economic efficiency of organic fertilizer users in eggplant production is presented in Table no 5 while Table no 6shows the factors affecting economic efficiency of inorganic fertilizer users in eggplant production. The coefficient of multiple determination (R^2) value of 0.449 and 0.111 in the organic fertilizer users' model and inorganic fertilizer users' model, respectively, indicates that 45% of changes in the economic efficiency of organic fertilizer users in eggplant production was explained by variables included in the model, while the remaining 55% is attributed to error term. Also, about 11% of changes in the economic efficiency of inorganic fertilizer users was explained by variables included in the model, while the remaining 89% is attributed to the variables not included in the model represented by the error term.

The results presented in Tables no 5 and Table no 6 shows that all the variables included in the model have similar sign for both organic and inorganic fertilizer users. In line with the *a priori* expectation, the coefficients of age, education, and farming experience were positively signed among both organic and inorganic eggplant farmers; while family size and extension access have inverse relationship with economic efficiency among both organic and inorganic fertilizer users. Age and education were however statistically significant at 1% in influencing economic efficiency among organic fertilizer users in eggplant production while farming experience was statistically significant at 5% in influencing economic efficiency among inorganic fertilizer users.

Table no 5: Factors affecting economic efficiency of eggplant farmers using org. fertilizer

Variable	**Coeff.**	**Std. Err.**	**T-value**	**Prob.**
Constant	-0.254	0.121	-2.100	0.040**
Age	0.007	0.002	3.030	0.004***
Family Size	-0.013	0.011	-1.220	0.229
Education	0.026	0.006	4.730	0.000***
Farming Exp.	0.000	0.007	0.010	0.993
Extension Access	-0.045	0.056	-0.800	0.429
Model				
R2	0.4494			
Adj.R^2	0.3984			
F-stat.(5,54)	8.81			
Prob. F-stat.	0.0000			
No of Observ.	60			

Source: Field survey and STATA13 **p< 0.05, ***p < 0.01

Table no6: Factors affecting economic efficiency of eggplant farmers using inorg. fertilizer

Variable	**Coeff.**	**Std. Err.**	**T-value**	**Prob.**
Constant	-0.039	0.262	-0.150	0.884
Age	0.005	0.004	1.110	0.271
Family Size	-0.022	0.023	-0.980	0.332
Education	0.021	0.012	1.730	0.089
Farming Experience	0.020	0.010	2.050	0.046**
Extension Access	-0.091	0.107	-0.850	0.397
Model				
R^2	0.111			
Adj. R^2	0.029			
F-stat.(5, 54)	1.350			
Prob. F-Stat.	0.258			
No of Observ..	60.000			

Source: Field survey and STATA13 **p < 0.05,

IV. Discussion

The TE scores revealed that 18.33 percent and 8.33 percent of eggplant farmers attained full technical efficiency for farmers that used inorganic and organic fertilizers respectively while the mean TE were 0.64 and 0.513 for farmers that used inorganic and organic fertilizers respectively. The differences in these TE scores between farmers' groups was statistically significant at 5 percent.These scores imply that inefficiencies exist in eggplant production and leaves a considerable room for improvement. Thus an average eggplant using organic and inorganic fertilizer can improve his/her efficiency by 48.7 percent and 36 percent respectively under the constant returns to scale. The TE scores obtained by these eggplant farmers are comparable to those recorded by [19] but comparably lower to those recorded by [2], [13] and [14]. A mean allocative efficiency of 49.1 percent and 63 percent were obtained by farmers that used organic and inorganic fertilizers respectively. Only 1.67 percent of the farmers in both groups achieved full allocative efficiency. Thus the farmers can still improve their allocative efficiency by 50. 9 percent and 37 percent respectively by using inputs in a cost minimizing ways. The mean economic efficiency scores of 25.7 percent and 40.85 percent by organic and inorganic fertilizer users respectively imply the presence of inefficiency. [2] had earlier reported a mean allocative efficiency and economic efficiency scores of 61 and 52 percent respectively. The significant differences in TE, AE and EE scores obtained could be attributed to the differences in yield which could be traceable to the types of fertilizers used by the farmers holding other factors constant. It has been shown that inorganic fertilizers releases nutrients to the soil faster and in required proportions when compared to organic fertilizers.

Results of the regression analysis of the factors influencing economic efficiency of eggplant farmers revealed that the positive sign for age, education, and farming experience implies that an increase in these variables will increase the economic efficiency of both organic and inorganic fertilizer users in eggplant production. It has been shown that farming experience comes with age and it is expected that productivity increases with years of experience. The findings of this study on farming experience agrees with [14] who reported similar sign among eggplant producers in Uyo Metropolis, Nigeria.The longer the years of farming experience, the more the knowledge acquired, the more efficient the farmer is expected to be. Experienced eggplant farmers are likely to make better economic decisions to enhance productivity and income. This finding support previous evidence by [5] that age influences the ability of farmers to adopt new technology for efficiency gains.

The coefficient of education is in line with the *a priori* expectation. Educational attainment of the farmers facilitates easy training, access to information, understanding and adoption of modern farm practices thereby enhancing their productivity and profitability. This finding is in line with [2] who found that the level of education attained by a farmer increases his economic efficiency in eggplant production.

The inverse relationship between householdsize, extension access and economic efficiency implies that an increase in number of persons in a household and access to extension services will decrease economic efficiency in eggplant production. Depending on household composition, household size is expected to be a potential source of family labour for the farmer. In a situation where majority of the household members are dependent and contributes insignificantly to production, could have negative consequences on economic efficiency of the farmers. The negative relationship between extensionaccess and economic efficiency is not in line with the *a priori* expectation. The result of this study on extension access could be associated with the low farmer - extension ratio in Nigeria and the study area specifically. Contact with extension agent is expected to facilitate training, information dissemination and adoption of improved or modern farming techniques. The finding of this study on extension access contradicts earlier believeby [15] that extension service increases productivity and efficiency of farmers.

V. Conclusion

Based on the findings of this study, the mean technical, allocative and economic efficiency scores of eggplant farmers that used inorganic fertilizer were higher than those obtained from farmers that used organic fertilizer and the differences in technical, allocative and economic efficiency scores were statistically significant at 5% level of significance.

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