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Increasing the growth and yield of eggplant (*Solanum melongena* L.) plants by applying chicken manure and PGPR (*Plant Growth Promoting Rhizobacteria*) on ultisols

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***Abstract*— *The land's low physical and chemical carrying capacity has impacted the low productivity of eggplant plants grown in ultisol soil. Therefore, using chicken manure and PGPR is highly recommended to increase plant productivity. This research aims to determine the appropriate chicken manure dosage and PGPR concentration for cultivating eggplant plants on this land. The experiment used a split-plot design by placing chicken manure doses in the main plot: (0%, 50%, and 100%) of the recommended dose. PGPR concentrations were placed in sub-plots: (without PGPR, 15 ml PGPR/L of water, and 30 ml PGPR/L of water). The experiment was repeated three times. F test at 5% is used to determine the existence of interactions or significant effect of treatment. Differences between treatments were considered Honestly Significant Difference (HSD) value at 5%. The study showed no significant interaction between chicken manure and PGPR on all observed growth and harvest parameters. However, each factor had a significant effect on growth observations: fresh root weight/plant, leaf area, and total dry weight of plants, and yield observations: fresh weight of fruit consumed/harvest plot and fresh weight of fruit consumed/ha. Application of 100% chicken manure can increase the fresh weight of eggplant fruit/ha by 7.27 t ha^{-1} (38.55%) and 18.47 t ha^{-1} (233.72%) from 50% and 0% chicken manure. In the PGPR treatment, to get a fresh weight of the maximum consumption fruit of 19.62 tons ha^{-1} requires the optimum PGPR concentration of 3.11 ml/ L water.*

***Keywords*— chicken manure, eggplant, PGPR, Ultisol**

I. INTRODUCTION

Various environmental conditions influence soil characteristics, such as climate, topography, and vegetation cover. Sukarman (2021) states that soil characteristics such as morphology, chemistry, physics, mineralogy, and soil biology are formed due to differences in soil types and environmental conditions in the region. Proper and wise handling is needed in connection with these problems.

Indonesia is known as an agricultural country with great opportunities to develop various types of food crops. However, 78% of its total land area is dry land. Dry land is sub-optimal, with low water availability as the main limiting factor [1]. As a result, plants will experience a lack of water, which can disrupt carbohydrate synthesis. Water plays a role in regulating the opening and closing of stomata. Therefore, when plants experience a lack of water, the plant's stomata will close, which is a form of plant adaptation to prevent more water loss from the soil and plants [28]. This reaction is detrimental to plants because it decreases the rate of plant photosynthesis [5]. This condition is exacerbated by the dominance of soil that is included in the ultisol order. Soil included in this order has a low ability to store and hold water [14]. Therefore, to achieve high soil productivity, it is necessary to improve the physical properties of the soil through the application of organic materials. Based on the results of the initial soil analysis, it was found that the content of soil organic matter (2.24%), and soil C-organic (1.30%) was low. Whereas organic matter is an important component of soil, it can affect the soil's physical, chemical, and biological quality. Organic matter derived from the decomposition of living things (plants and animals) has a major impact on improving soil structure, nutrient content, and microbial activity [31]. Physically, organic matter can improve soil structure and water-holding capacity, thus allowing better root penetration and development. Biologically, organic matter encourages the growth of soil organisms and is useful for helping the plant nutrient cycle [18]. On the other hand, high intensity of solar radiation will also spur a lot of N loss through the volatilization process, resulting in low soil N content. Nitrogen is included in the group of essential nutrients for plants whose needs are higher than other nutrients. This is because N plays a role as a component of chlorophyll, both chlorophyll-a($C_{55}H_{72}O_5N_4Mg$), and chlorophyll-b ($C_{55}H_{70}O_6N_4Mg$), both of which play a role in carbohydrate synthesis (13). As a result, when plants experience N deficiency, most of the leaves that have formed will turn yellow, which decreases the rate of plant photosynthesis. Meanwhile, based on the results of the initial soil analysis, it was found that the total N content of the soil was low, around 0.10%. Due to these problems, N fertilization is highly recommended. However, continuous N application can damage the soil structure. The soil becomes denser and harder so the process of plant root development is disrupted [31]. Therefore, to reduce the use of N, the PGPR application is needed.

PGPR is a group of living bacteria that colonize the rhizosphere area, and these bacteria can provide and mobilize the absorption of nutrients in the soil [3]. According to [14], the microbial population is mostly located around the plant root area *(rhizosphere*) compared to other zones. This is because plant roots produce substances that contain secondary metabolites such as sugars and amino acids which function as an energy source for microbes. These bacteria are useful in plant physiological processes because they can act as biological fertilizers, biostimulants, and bioprotectants [17]. As a biofertilizer, PGPR plays a role in facilitating uptake and increasing the availability of nutrients, especially N for plants in the rhizosphere through nitrogen fixation, dissolution of mineral nutrients, mineral organic compounds, and phytohormone production [25]. Given the important role of PGPR in the availability of N, information on the right concentration of PGPR in eggplant cultivation is very much needed.

II. MATERIALS AND METHODS

2.1 Description of the study area

Field research was carried out on farmer's land in Kasin Village, Karang Ploso subdistrict, Malang City, East Java. Geographically, the experimental area is located at an altitude of 535 m above sea level, with ultisol soil type. Climatologically, the average daily temperature ranges between 23°C - 31°C with an average rainfall of 2,457 mm/year [8]. Chemically, the total N-soil, K-soil, soil organic matter, and soil C-organic content are in the low category, respectively 0.13%, 0.13 me 100 g^{-1}, 2.24%, and 1.30%. Except for P_2O_5 Olsen is in moderate status (12.27 ppm). The soil includes a dusty clay texture with proportions of sand (8%), dust (49%), and clay (43%)

2.2 Research material

The planting material used was eggplant seedlings of F1 variety that were 14 days old after sowing and had formed 2 to 4 perfect leaves. Seeds were obtained from PT East West Seed Indonesia. Polybag measuring 5 cm x 5 cm for seeding, *plant growth promoting rhizobacteria* (PGPR), chicken manure, N fertilizer (in the form of urea: 46% N), phosphorus fertilizer (in the form of SP-36: 36% P_2O_5), and potassium fertilizer (in the form of KCl: 60% K_2O). The dose of an-organic fertilizers applied is based on the initial soil analysis results and the level of N, P, and K requirements of eggplant plants. According to [21] the level of N requirements ranges from 150 - 200 kg N ha^{-1}; P fertilizer: 100 -150 kg P_2O_5 ha^{-1}, and K fertilizer ranges from 60 - 100 kg K_2O ha^{-1}. Calculating fertilizer requirements refers to equation 1 [30].

$$N = \frac{A2 - B}{A1 - A2} = \frac{N - XA}{XA - XB}$$

Where:

N: the nutrient dose that must be added according to soil criteria (kg ha^{-1})

A_1: the top content of the total soil N range (%): 0,5%

A_2: the lowest content of the total soil N range (%): 0,21%

B: the total N content of the soil (%): 0,10%

X_A: the highest value of the required dose of N plants (kg ha^{-1}): 200 kg N ha^{-1}

X_B: the lowest value of the required dose of N plants (kg ha^{-1}): 150 kg N ha-^{1}

Based on equation 1 above and the experimental plot area is 5.67 m^2, the fertilization dose that must be given is as presented in Table 1. Meanwhile, the chicken manure analysis results are presented in Table 2, and the dose of chicken manure that must be applied is presented in Table 3. The calculation of chicken manure needs refers to [31] as follows:

$$\frac{\%\ \text{recommendation}}{\text{N content of chicken manu}} \times \text{N fertilizer dose/ plot}$$

Where:

The plot size:5.67 m^2

N fertilizer dose per plot: 0.269 kg

N content of chicken manure: 0.88 %

Table 1. The dose of N, P, and K fertilizer that must be applied

Source of fertilizer	The dosage of fertilizer applied		
	Kg ha^{-1}	Kg/plot	g/plant
N	218,97	0,124	1,97
(Urea)	476,01	0,27	4,29
P_2O_5	144,70	0,08	1,27
(SP_{36})	401,94	0,23	3,65
K_2O	232,00	0,13	2,06
(KCl)	386,6	0,22	3,49

Table 2. Status of physical and biological properties of chicken manure

No.	Parameters	Values	Units	Methods
1	C-organic	6.12	%	SNI 7763 :2018
2	Organic matter	10.55	%	SNI 7763 :2018
3	C/N	6.95	-	
4	Water content	25.11	%	SNI 7763 :2018
5	Macronutrients:			
	Nitrogen	0.88	%	SNI 7763 :2018
	P_2O_5	12.52	%	SNI 7763 :2018
	K_2O	0.36	%	SNI 7763 :2018
6	Supporting materials	0.31	%	SNI 7763 :2018

Criteria:

Soil properties	C-organic (%)	C/N	Nitrogen (%)	P_2O_5 (%)	K_2O (%)
Very low	< 14.50	-	< 0.60	< 0.30	< 0.20
Low	14.50 – 19.50	< 10.00	0.60 – 1.00	0.30 – 0.80	0.20 – 0.50
Medium	19.60 – 27.00	10.00 – 20.00	1.10 – 2.00	0.90 – 1.70	0.60 – 1.30
High	≥27.10	≥ 20.00	≥ 2.10	≥ 1.80	≥ 1.40

Table 3. The dose of chicken manure to be applied

Recommended dose (%)	The dose of chicken manure applied		
	Per hectare (ton)	Per plot (kg)	Per planting hole (g)
100	53.9	30.6	485
50	26.95	15.3	242.5

2.3 Experimental design

The experiment used a split-plot design by placing chicken manure doses in the main plot: (0%, 50%, and 100%) of the recommended dose. PGPR concentrations were placed in sub-plots: (without PGPR, 15 ml PGPR/L of water, and 30 ml PGPR/L of water). The experiment was repeated three times. F test at 5% is used to determine the existence of interactions or significant effect of treatment. Differences between treatments were considered Honestly Significant Difference (HSD) value at 5%. Regression analysis is used to explore relationships between two or more variables observed.

2.4 Research implementation

The initial activity of the study was soil cultivation, which aimed to obtain crumbly and loose soil. The application of organic matter (chicken manure) was given one week after soil cultivation, each amounting to 0.485 g, and 242.5 g/planting hole, for 100% and 50% of the recommended dose (Table 3). Chicken manure put into the planting hole was then stirred with the soil and left for one week to remove toxins. Transplanting is done when the plants are 14 days after sowing, and 2-4 perfect leaves have formed by placing 1 eggplant seedling in each planting hole. P fertilizer in the form of SP_{36} is applied 1 week before planting the entire dose (3,65 g/plant**)**, while N (urea) and potassium (KCl) fertilizers are given in stages. In the first stage, 1/3 of the dose is given when the plants are 7 days after transplanting, and the rest (2/3) is applied when the plants are 30 days after transplanting. Fertilizer is applied to a depth of 7 cm at a distance of 5 cm from the plant. PGPR was given in stages, first at the same time as transplanting (0; 5 ml PGPR/L water; 10 ml PGPR/L water), second when the plants were 14 days old after transplanting (0; 5 ml PGPR/L water; 10 ml PGPR/L water), and third when the plants were 28 days old after transplanting (0; 5 ml PGPR/L water; 10 ml PGPR/L water).

2.5 Data collection

Observations were carried out destructively by taking 3 sample plants/treatments at 30 days after transplanting (DAT), 40 DAT, 50 DAT, and 60 DAT, and at harvest time (70-80 DAT) including growth parameters (root fresh weight, leaf area, and total dry weight of plants), and yield parameters including fruit set, and fresh weight of fruit consumed/ha.

2.5.1 Root fresh weight

Observation of the fresh weight of the roots was carried out by weighing all the roots after they were separated from the base of the stem and cleaned from the soil, using an analytical balance.

2.5.2 Leaf surface area

Leaf surface area was measured using LAM type LI-3100 C for fully opened leaves, excluding young and old leaves. Leaf samples were placed on a glass lens in an unfolded or non-overlapping position. All leaf samples from three sample plants per treatment were recorded and then averaged. The leaf surface area value is based on the average value of the measurements multiplied by the correction factor. The correction factor is found by dividing the actual paper area measurement value (for example 100 cm^2) by the paper area value that has been measured with LAM, for example, 80 cm^2. So the correction factor value is 80 cm^2 / 100 cm^2 = 0.8

2.5.3 Total dry weight of plants

Measurement of the total dry weight of plants using an OVL oven, type 12. Roots, stems, leaves, and tubers must be separated before drying. This is because each plant part requires a different drying time to achieve a constant dry weight. The plant parts that have been separated are placed in a cement bag and then placed in the oven. Weighing was carried out using an analytical balance after a constant dry weight was achieved, and all plant parts were added.

2.5.4 Fruit set

Fruit set is a ratio between the number of fruits and the total number of flowers formed **2.5.5 Fresh weight of fruit consumed/ha**

The fresh weight of consumption per hectare is obtained by converting the fresh weight of consumption per harvest plot to hectares (ha) [31] through an equation 2:

$$\frac{\text{1 ha land area}}{\text{harvest plot area}} \text{ X fresh weight consumption per harvest plot} \times \text{correction factor}$$

Meanwhile, the correction factor is obtained by multiplying the area of the experimental plot (5.67 m^2) by the number of experimental plots (27) divided by the total area of land used (243.19 m^2) [30].

III. RESULT AND DISCUSSION

3.1 Result

3.1.1 Growth parameters

3.1.1.1 Fresh weight of roots/plants

Analysis of variance showed no significant interaction between chicken manure and PGPR treatments on the fresh weight of the root/plant. However, each factor has a significant effect on the variables (Table 4).

Applying 50% and 100% chicken manure resulted in fresh root weights that were not significantly different and were heavier by 1.91 g (61.22%) and 2.96 g (94.79%) compared to the treatment without chicken manure only reached 3.12g. In the PGPR treatment, the use of PGPR 15 and 30 ml/L water was able to produce fresh root weights that were 1.48 g (41.57%) and 2.06 g (57.94%) heavier than the treatment without PGPR, and both produced fresh weight of roots was not significantly different.

3.1.1.2 Leaf surface area

There was no significant interaction between chicken manure and PGPR on the leaf surface area variable. However, each factor had a significant effect on the variable. The average leaf surface area at various chicken manure doses and PGPR concentrations is presented in Table 5.

Table 5 shows that the narrowest leaf surface area was obtained in the treatment without chicken manure, an average of 288.62 cm^2.The application of chicken manure has an impact on increasing the size of the leaf surface, respectively 203, 71 cm^2 (70.58%) for a dose of 50%, and an area of 354.25 cm^2 (122.74%) for a dose of 100% when compared with treatment without chicken manure. The leaf surface area showed no significant difference at 50% and 100% chicken manure doses. In the PGPR treatment, the narrowest leaf surface area was obtained without PGPR, with an average area of 395.46 cm^2. The application of PGPR caused an increase in the leaf surface area, respectively 111.76 cm^2 (28.26%) for 15 ml and 125.48 cm^2 (31.73%) for a concentration of 30 ml PGPR/L water, both of which showed no significant difference.

3.1.1.3 Total dry weight of plants

Analysis of variance showed that there was no significant interaction between chicken manure and PGPR in the observation of the total dry weight of plants. However, the total dry weight of the plant is influenced by these two factors. The average total dry weight of plants at various chicken manure doses and PGPR concentrations is presented in Table 6.

Table 6 shows the same pattern of results on the total dry weight of plants at all observation ages, and the highest was obtained in the application of 100% chicken manure, which was around 13.76 g/plant. Reducing the dose of chicken manure, from 100% to 50%, without chicken manure caused a reduction in the total dry weight of the plants produced, respectively by 27.62% (3.80 g) and by 60.10% (8.27 g). A reduction of 44.82% (4.46 g/plant) also occurred when the chicken manure dosage was reduced from 50% to no chicken manure. In the PGPR treatment, a higher average dry weight of plants was obtained by applying 15 ml and 30 ml PGPR/L of water, respectively 10.54 g, and 10.99 g/plant. These two values were still higher, 37.78% (2.89 g) and 43.66% (3.34 g) compared to the treatment without PGPR which only reached a weight of 7.65 g/plant.

Table 4. Average fresh root weight per plant at various chicken manure doses and PGPR concentrations at all ages of observation

Treatment	Average fresh root weight per plant (g) at age of observation (DAT)			
	30	40	50	60
Chicken manure dosage (% recommendation)				
Without chicken manure	0.47 a	1.54 a	3.99 a	6.47 a
50%	0.79 b	2.01 ab	6.73 ab	10.60 b
100%	1.20 c	2.51 b	8.38 b	12.22 b
HSD 5%	0.25	0.79	2.75	3.64
CV-a (%)	18.36	23.45	25.75	22.24
PGPR Concentration:				

Without PGPR	0.59 a	1.49 a	4.43 a	7.74 a
15 ml PGPR/L water	0.92 b	2.08 b	6.52 b	10.64 b
30 ml PGPR/L water	0.96 b	2.48 b	8.14 b	10.91 b
HSD 5%	0.24	0.53	1.66	2.49
CV-b (%)	23.87	21.14	20.82	20.35

Note: Numbers accompanied by the same letter in the same treatment and at the same age are not significantly different in the 5% HSD test. DAT: the day after transplanting

Table 5. Average leaf surface area at various chicken manure doses and PGPR concentrations at all ages of observation

Treatment	. Average leaf surface area (cm^2/plant) age of observation (DAT)			
	30	40	50	60
Chicken manure dosage (% recommendation)				
Without chicken manure	51.10 a	182.04 a	390.01 a	531.26 a
50%	122.50 b	367.84 b	681.18 b	797.48 b
100%	146.21 b	466.12 b	1003.98 c	955.15 b
HSD 5%	44.54	104.20	235.39	198.44
CV-a (%)	24.87	18.31	20.26	15.52
PGPR Concentration:				
Without PGPR	93.11 a	234.52 a	577.46 a	677.19 a
15 ml PGPR/L water	12054 b	404.38 b	704.52 b	799.42 b
30 ml PGPR/L water	10616 ab	377.10 b	793.19 b	807.29 b
HSD 5%	25.70	101.71	123.99	120.16
CV-b (%)	19.19	23.90	14.26	12.56

Note: Numbers accompanied by the same letter in the same treatment and at the same age are not significantly different in the 5% HSD test. DAT: the day after transplanting, ns: no significant effect

Table 6. The average total dry weight of plants at various chicken manure doses and PGPR concentrations at all ages of observation

Treatment	. Average total dry weight of plants (g/plant)/ age of observation (DAT)			
	30	40	50	60
Chicken manure dosage (% recommendation)				
Without chicken manure	0.33 a	1.23 a	8.84 a	11.54 a
50%	0.54 b	3.24 b	15.84 b	20.19 b
100%	0.78 c	4.10 c	27.77 c	22.38 b
HSD 5%	0.17	0.67	6.00	7.75
CV-a (%)	18.39	14.00	20.45	25.60
PGPR Concentration:				
Without PGPR	0.48	2.33 a	13.73 a	14.06 a

15 ml PGPR/L water	0.55	3.08 ab	18.46 b	20.08 b
30 ml PGPR/L water	0.63	3.16 b	20.26 b	19.97 b
HSD 5%	ns	0.80	3.85	3.94
CV-b (%)	24.61	22.55	17.55	17.39

Note: Numbers accompanied by the same letter in the same treatment and at the same age are not significantly different in the 5% HSD test. DAT: the day after transplanting, ns: no significant effect

3.1.2 Yield component

3.1.2.1 Fruit set

The results of the variance analysis showed that there was no significant interaction between chicken manure and PGPR in *fruit set* observations. The use of PGPR also does not significantly affect this variable. The fruit set was only affected by the dose of chicken manure, as presented in Table 7.

Table 7. Average fruit set at various chicken manure doses and PGPR concentrations at 60 DAT

Treatment	Average fruit set (%)
Chicken manure dosage (% recommendation)	
Without chicken manure	52.11 a
50%	63.28 b
100%	66.17 b
HSD 5%	6.88
CV-a (%)	6.78
PGPR Concentration:	
Without PGPR	59.31
15 ml PGPR/L water	61.29
30 ml PGPR/L water	60.96
HSD 5%	ns
CV-b (%)	7.97

Note: Numbers accompanied by the same letter in the same treatment and at the same age are not significantly different in the 5% HSD test. DAT: the day after transplanting, ns: no significant effect

After applying 50% and 100% doses of chicken manure, the fruit set produced was not significantly different but was significantly higher by 11.17 (21.44%) and 14.06 (26.98%) compared to the treatment without chicken manure.

3.1.2.2 Fresh weight of fruit consumed/ha

The fresh weight of consumption fruit per hectare refers to equation 2. The results of the variance analysis show that there is no significant interaction between chicken manure treatment and PGPR on the fresh weight of economic fruit per hectare. However, each factor had a significant effect on the variable. The average fresh weight of fruit consumption per hectare at various doses of chicken manure and PGPR concentrations is presented in Table 8.

Table 8. Average fresh weight of fruit consumption per hectare at various chicken manure doses and PGPR concentrations at harvest

Treatment	Fresh weight of fruit consumption per hectare (ton)
Chicken manure dosage (% recommendation)	
Without chicken manure	7.83 a
50%	18.86 b
100%	26.13 c
HSD 5%	4.01
CV-a (%)	13.56
PGPR Concentration:	
Without PGPR	14.90 a
15 ml PGPR/L water	18.32 b
30 ml PGPR/L water	19.61 b
HSD 5%	2.38
CV-b (%)	10.79

Note: Numbers accompanied by the same letter in the same treatment and at the same age are not significantly

The lowest fresh weight of fruit consumption per hectare was obtained in the treatment without chicken manure, namely 7.83 tons ha^{-1}. The application of 50% and 100% doses of chicken manure caused an increase in fresh fruit weight per hectare, respectively by 11.03 tons ha^{-1} (140%) and 18.3 tons ha^{-1} (233.72%). An increase of 7.27 tons ha^{-1} (38.55%) also occurred when the chicken manure dosage was changed from 50% to 100%. The lowest fresh weight of fruit consumption per hectare was obtained in the treatment without PGPR, which was 14.90 tons ha^{-1}. The use of PGPR as much as 15 ml and 30 ml/L of water had an impact on increasing the fresh weight of fruit consumption by 3.4 tons ha^{-1} (22.95%) and 4.71 tons ha^{-1} (31.61%), respectively, but both showed not significantly different.

3.2 Discussion

3.2.1 Fresh weight of roots/plants

The study showed that the lowest fresh weight of roots/plants was obtained in the treatment without chicken manure, namely 3.12 g, compared to the application of 50% and 100% chicken manure, which had reached a weight of 5.03 g and 6.08 g. This indicates that organic matter in chicken manure is essential in ultisol soil [27]. Ultisol soil is characterized by high clay content. The nature of clay is generally smooth and soft with a dominance of micro-sized silicate minerals [2]. In dry conditions, this soil will decompose into fine grains, filling most of the soil pore space (micro and macro) with soil grains [15]. Low soil pore percentage can reduce oxygen flow, especially in the plant root zone, disrupting the plant roots' water and nutrient absorption process [28]. On the other hand, in wet conditions, the soil is sticky, and the granules that form it easily stick together and are difficult to separate [4]. Therefore, this soil is compact and hard. As a result, the ability of the roots to penetrate the soil is disrupted, and results in the inhibition of the process of plant root development.

The results of the study also showed that the lowest fresh root weight was obtained in the treatment without PGPR, an average of 3.56 g. The application of PGPR at concentrations of 15 ml and 30 ml/L of water increased fresh root weight, to 5.04 g and 5.62 g respectively (Table 4). This is closely related to the fact that PGPR is a colony of various types of bacteria so it can play a role in improving the physical properties of soil, such as ultisol [29,4]. This is closely related to the fact that PGPR is a biofertilizer or biological fertilizer, a collection of living microorganisms that function as soil conditioners. The role of PGPR as a biological fertilizer is to transform nutrients in unavailable forms into available ones for plants with the help of compounds produced by bacteria in PGPR such as fixing N elements and dissolving P elements [25,6]. Nitrogen is one of the essential nutrients for plants and is needed in greater quantities than other nutrients. This is because N is involved in the formation of chlorophyll, both chlorophyll a ($C_{55}H_{72}MgN_4O_5$) and chlorophyll b ($C_{55}H_{70}MgN_4O_6$) which causes the photosynthetic activity to take place due to the absorption of light by chlorophyll [33]. Therefore, when plants experience N deficiency, the plant's growth rate is disrupted due to low assimilation produced. It is known that assimilate is energy, and this energy is very necessary in the process of plant growth and development. Therefore, the growth speed is in line with the amount of energy available to the plant. Based on the calculation of the availability of N nutrients, the lowest value was obtained in the treatment without chicken manure and without PGPR, which was 1.90%. Meanwhile, for the treatment without chicken manure + 15 ml PGPR,and without chicken manure + 30 ml PGPR, it was 2.83% and 5.61%, respectively. The low availability of these nutrients is the cause of the obstruction of the plant root development process.

3.2.2 Leaf surface area

Leaves are an important photosynthesis organ in plants. Therefore, the leaf surface area reflects the plant's capacity to produce assimilation [22]. Based on the experiment's results, the wider leaf surface size was obtained in the application of 50% and 100% chicken manure than without chicken manure, each covering an area of 492.33 cm^2, 642.85 cm^2, and 288.62 cm^2, respectively.

The narrower leaf surface area is related to the lower fresh weight of the roots produced. Roots are one of the plant organs that play an important role in absorbing nutrients and water for plants. When the fresh weight of the roots is low, the ability of the roots to absorb water and nutrients will be limited by the weight of the roots formed. Water for plants has a function in regulating the opening and closing of stomata. Stomata will close when water is in short supply for plants [32]. As a result, the assimilates produced are low, including Cell division, elongation, and widening. Thus, the narrower leaf surface size is greatly influenced by the low fresh weight of the roots produced. The regression analysis results prove a linear relationship between fresh root weight (X) and leaf area (Y) at various PGPR concentrations through an equation: $Y = 63.73X + 172.51$; $R^2 = 0.97$. This shows that the higher the fresh root weight, the greater the leaf surface size. The high value of $R^2 = 0.97$ means that 97% of the size of the leaf surface area is greatly influenced by the fresh weight of the roots produced.

3.2.3 Total dry weight of plants

The plant's total dry weight reflects its ability to utilize factors in its growing environment and is a function of plant organs [33]. The results showed that the heaviest total dry weight of the plant was obtained in the application of 100% chicken manure, weighing 13.76 g/plant, and showed a reduction of 3.81 g/plant (27.69%) and 8.27 g/plant (60.08%) when the dose of chicken manure was reduced from 100% to 50% and without chicken manure. This is because, in the treatment without chicken manure, the fresh weight of the roots and the surface area of the leaves produced were the lowest (Tables 4 and 5). Both variables are vital parts of the plant that can be used as a benchmark for the success of a plant. Leaves are a medium for photosynthesis activity to take place, so the surface area of the leaves describes the capacity of the plant to produce assimilates through photosynthesis [23]. Meanwhile, the speed of photosynthesis is determined by plant roots' nutrient and water uptake [7]. Moreover, this research was conducted in dry land, where the soil is dominated by dust and clay fractions, making it quite difficult for plant roots to penetrate because the soil is dense and hard [15]. Based on the soil analysis results, it was found that in the treatment without chicken manure, the dust content was the highest, which was 35%, while in the treatment of 50% and 100% chicken manure, it was only around 28.33% and 26%. The high dust content in the treatment without chicken manure causes the soil to be unable to store and hold water properly, and the soil is easily eroded which causes the soil to become infertile [34]. The reduced level of soil fertility followed by the low level of water availability, causes the growth rate to be disrupted, thus impacting the low assimilates produced [35]. While assimilates describe the total dry weight of the plant. Regression analysis shows the formation of a linear relationship between the dose of chicken manure (X) and the total dry weight of plants (Y) through an equation: $Y = 8.27 X + 5.60$; $R^2 = 0.99$. This equation explains that the higher the dose of chicken manure applied, the higher the total dry weight of the plants produced. This statement is supported by the high value of $R^2 = 0.99$, which means that the dose of chicken manure influences 99% of the total dry weight of plants.

In the PGPR treatment, the heavier total dry weight of plants was obtained in the 15 ml and 30 ml PGPR/L water treatments, respectively 10.54 g/plant and 10.99 g/plant, and the lowest was found in the treatment without PGPR, which was 7.65 g/plant. Giving PGPR up to a concentration of 30 ml, caused a decrease in dust levels, but was followed by an increase in N availability in both treatments (Table 9). The decrease in dust levels in various PGPR applications, especially at concentrations of 15 ml and 30 ml PGPR/L of water, is related to the number of bacteria in the PGPR [9]. These bacteria can act as biological agents that play a role in improving the physical properties of the soil [14]. Therefore, the more bacteria contained in the PGPR, the faster the process of changing the physical properties of the soil [10]. The soil becomes more stable, and the soil's ability to retain and store water is better than treatments without PGPR. The availability of

N nutrients also increases along with the increase in the concentration of PGPR [11]. In treatments without PGPR, the soil N content is in a low category (0.127%), while in the provision of 15 ml and 30 ml PGPR it is in moderate status, each of

which is 0,134%, and 0,147.

Table 9. Changes in dust and N nutrient content in various PGPR treatments.

Treatment	Changes in dust and N nutrient content from various soil analysis results			
	Early (%)	Middle (%)	Final (%)	Soil N- content (%)
0 PGPR	49	37,33	35,33	0,127
15 ml PGPR/L water	49	35,0	32,67	0,134
30 ml PGPR/L water	49	35,33	33,33	0,147

A more crumbly and stable soil condition will support the process of plant root development. In these conditions, plants will find their water and nutrients, which will cause the plants to become more responsive to environmental pressures. When plants face environmental pressures, they can make maximum use of environmental factors in their growth. When plants can cope with environmental stress, they can utilize environmental factors to their maximum [24]. A high total dry weight of a plant reflects the high ability of a plant to utilize factors in its growing environment and is a function of plant organs. Considering that the highest plant parts were obtained at 15 ml and 30 ml PGPR/L of water, higher total plant dry weight was also obtained in both treatments (Table 6).

3.2.4 Yield component

3.2.4.1 Fruit set

A fruit set is a ratio between the number of fruits and the total number of flowers formed. The results showed that the lowest fruit set value was obtained in the treatment without chicken manure, at 52.11%. Applying chicken manure at 50% and 100% doses resulted in higher fruit set values, respectively 63.28% and 66.17%. Considering that the formation of fruit sets is greatly influenced by energy availability (assimilate), the more energy available to the plant, the higher the value of the fruit set. Abscission is when flowers fail to become fruit due to insufficient nutrients or energy needed for the change process. Therefore, when plants do not have enough energy available (assimilate), then a plant's ability to produce fruit is also low. This is evident from the results of this study, where the lowest fruit set value was obtained in the treatment without chicken manure (Table 7). As a result of the lowest total dry weight of the plants produced (Table 6).

3.2.4.2 Fresh weight of fruit consumption per hectare

Determination of fresh fruit consumption is based on the weight of the fruit between 200 - 300 g/fruit. The research results showed that the highest fresh weight of fruit/hectare was obtained when using 100% chicken manure: 26.13 tons ha^{-1}. This result is 7.27 tons (38.55%) and 18.3 tons (233.71%) higher compared to the provision of 50% and 0% chicken manure. This is quite reasonable because the capacity of organic material decomposition is greatly influenced by the amount of organic material applied [12]. At high doses, the content of microorganisms increases and has an impact on increasing the rate and capacity of organic material decomposition in improving the physical properties of the soil [19]. The study showed that providing 100% chicken manure can reduce the highest dust content (around 7.13%) compared to the treatment without chicken manure. The reduced dust content causes the soil to be looser so that root penetration becomes deeper. As a result, the ability of the roots to absorb water and nutrient increase which causes an increase in the rate of plant photosynthesis.

Assimilate is a result of photosynthesis, and shows an increase in the treatment, while assimilate is a reflection of the total dry weight of the plant, and it is energy. Some energy will be stored in the sink as eggplant fruit, and some for growth. Therefore, the more assimilated produced, the more energy will be distributed to the fruit (sink) [16] The weight of eggplant fruit/plant in various chicken manure treatments is presented in Figure 1.

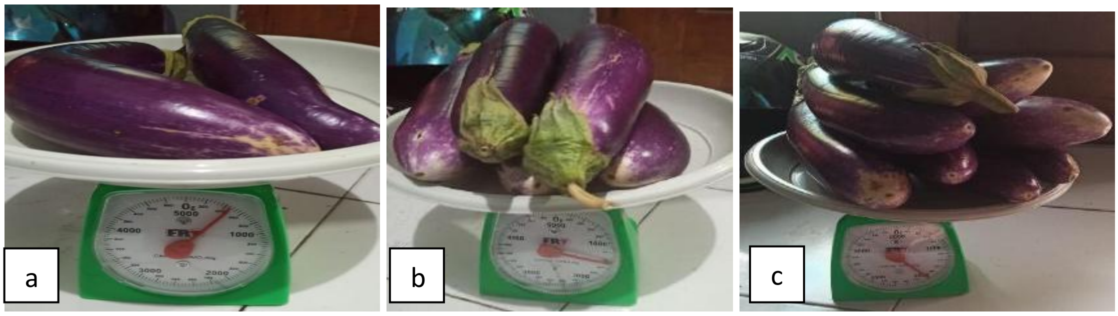

Fig.1. Fresh weight of eggplant fruit consumed in three chicken manure treatments. (a) : fresh weight of eggplant for consumption without chicken manure, (b) fresh weight of eggplant for consumption + 50% chicken manure, (c) fresh weight of eggplant for consumption + 100% chicken manure.

Figure 1 shows that the highest fresh weight of fruit was obtained from the application of 100% chicken manure (Fig. 2c), followed by 50% chicken manure (Fig. 2b), and finally without chicken manure (Fig. 2a). Regression analysis proved that there was a linear relationship between the dose of chicken manure (X) and the fresh weight of fruit for consumption per hectare (Y) through an equation:

$$Y = 18.3\ X + 8.46\ ;\ R^2 = 0.99$$

This equation explains that an increase in the dose of chicken manure is still accompanied by an increase in the fresh weight of consumed fruit per hectare. This statement is supported by the high value of the coefficient of determination (R2) = 0.99, which means that 99% of the fresh weight of fruit consumed is influenced by the dose of chicken manure.

In the PGPR treatment, the higher fresh weight of fruit consumption per hectare was obtained at a concentration of 15 ml and 30 ml PGPR/L water, respectively 18.32 tons ha_{-1} and 19.61 tons ha^{-1}, and the lowest, namely 14.90 tons ha^{-1} was obtained in the treatment without PGPR. The low yield is closely related to the low initial N-soil: 0.10%. Therefore, through the PGPR application, it will be possible to facilitate the provision and increase of nutrient uptake, especially N [26]. Providing N through chemical fertilization activities is not wise, because it will only damage the soil. The soil becomes dense and hard, and N residue causes the soil to become more acidic. Under these conditions, alkaline elements such as Mg, K, and Ca become less available to plants [12]. The Mg element is the core of the chlorophyll compound, which will determine the rate of photosynthetic activity [33]. Considering the important role of PGPR, which cannot only function as a soil conditioner but is also quite good at providing nutrients for plants, the application of PGPR is highly recommended. Figure 2 shows the fresh weight of fruit/plants at various PGPR concentrations.

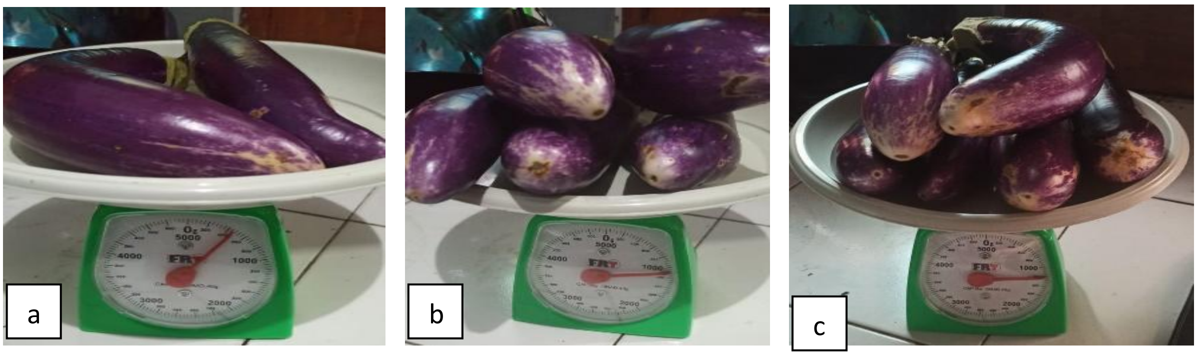

Fig.2. Fresh weight of eggplant fruit consumed in three PGPR treatments. (a) : fresh weight of eggplant for consumption without PGPR, (b) fresh weight of eggplant for consumption + 15 ml PGPR/L water, (c) fresh weight of eggplant for consumption + + 30 ml PGPR/L water

Fig. 2 shows that the fresh weight of fruit/plants produced in the treatment of 15 ml (Fig. 2b) and 30 ml PGPR/L water (Fiq.2c) is not significantly different, so regression analysis is needed to determine the optimum concentration and maximum yield. The results of the regression analysis show a quadratic relationship between the concentration of PGPR (X) and the fresh weight of fruit/hectare (Y) through an equation:

$$Y = -\ 1.067\ X^2 + 6.62\ X + 9.35;\ R^2 = 1$$

Based on this equation, it can be seen that the optimum PGPR concentration is 3.11 ml/L of water with a maximum yield of 19.62 tons of fresh fruit consumption weight/hectare.

IV. CONCLUSION

Based on the results of the study it can be concluded that to get high growth and yields in the cultivation of eggplant in ultisol soils, chicken manure and PGPR applications are very necessary. The application of 100% chicken manure can increase the total dry weight of the plant by 133.62%, and the fresh weight of fruit consumption per hectare by 233.72% than without chicken manure. In the PGPR treatment, to get a fresh weight of the maximum consumption fruit of 19.62 tons ha^{-1} requires the optimum PGPR concentration of 3.11 ml/ L water.

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AUTHOR'S CONTRIBUTIONS

Nur Edy Suminarti as the main researcher, played a role in determining the experimental design, treatment, observation parameters, observation time, and writing this manuscript.

Nurul Aini as a co-researcher, plays a role in assisting operations in the field, including determining treatment and observation

Nando Aldiansyah as a research assistant, contributes to determining the location of research, applying research in the field, and helping observation in the field, as well as data analysis.

Musofan Prasetianto contributes to writing this manuscript.

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