

Plant Growth Promoting Rhizobacteria (PGPR) Test and Several Doses of Goat Manure on the Growth and Yield of Sweet Corn (*Zea mays* L.)

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Article Info

Article history:

Received : Nov 03, 2024
Revised : Dec 21, 2024
Accepted : Jan 28, 2025

Keywords:

Goat manure;
Plant Growth Promoting
Rhizobacteria;
Sweet Corn.

ABSTRACT

Soil fertility is one of the contributing factors to the low sweet corn production in Indonesia. This study aims to determine the growth and yield of sweet corn (*Zea mays saccharata* Sturt) using the organic PGPR test and several doses of goat manure. It employed a factorial Randomized Block Design (RBD) with three replications and two treatment factors. The first factor was PGPR, categorised as follows: P₀: no PGPR (control), P₁: 20 ml/liter of water, P₂: 30 ml/liter of water, and P₃: 40 ml/liter of water. The second factor was goat manure, categorised as follows: K₀: no goat manure (control), K₁: 1 kg/plot, K₂: 1.5 kg/plot, and K₃: 2 kg/plot. The findings showed that the use of PGPR had no significant effect on the growth and yield of maize. The application of goat manure at a dose of 2 kg/plot significantly affected plant height, number of leaves, leaf area, stem diameter, flowering age, cob length, cob diameter, seeds quantity per row, cob weight per plant, and sweetness level. There was no interaction between the combination of PGPR and goat manure on the growth and yield of maize.

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1. INTRODUCTION

Sweet corn (*Zea mays saccharata* Sturt) is a crop with high commercial value that has a shorter harvest period, making its cultivation highly profitable. Sweet corn plants are increasingly growing and extensively consumed by Indonesian people. Sweet corn, abundant in carbohydrates and various nutrients (vitamins, fiber, and minerals), is favored by consumers for its unique taste and pleasant flavor (Xiao et al., 2024).

The current use of inorganic fertilizers, particularly as improperly formulated, leads to a depletion of soil nutrients, resulting in nutritional imbalances, structural degradation, and low soil microbiology. According to (Kurniati, 2020), the continuous use of inorganic fertilizers leads to soil damage, environmental pollution from residual substances, a degradation of organic materials, and a decline in microorganisms essential for nutrient provision, ultimately resulting in diminished land productivity. So as to address this issue, it is essential to make improvements through organic PGPR, acidifying the soil microenvironment and significantly affecting it to increase heavy metal tolerance in plants. The specified PGPR strain significantly contributes to the volatilization and

biomethylation of heavy metals, increasing its availability and mobilization (Sun et al., 2024). Furthermore, Yield characteristics and yield components as well as growth characteristics was strongly influenced by environmental factors (Novita & Siregar, 2024).

Goat manure is relatively accessible as a primary nutrition source in organic cultivation. Moreover, it is cost-effective, ecologically sustainable, and, most importantly, increases soil fertility while providing essential nutrients for plant growth. One of the agricultural technology innovations that can increase plant productivity while minimizing ecosystem damage involves the use of non-pathogenic bacteria derived from plant roots (*rhizobacteria*), which are classified into the Plant Growth Promoting Rhizobacteria (PGPR) group (Komansilan et al., 2023). adding fermented goat urine POC is one way to increase cucumber production as it provides balanced nutrients for plant growth and productivity. Thus, it is necessary to examine the effects of KCl fertilizer and goat urine on Japanese cucumber production (Lubis et al., 2022).

PGPR is a bacterium that lives and actively colonizes the root area of plants. Its presence can provide benefits for plant growth by facilitating the absorption and mobilization of various nutrients in the soil. (Nafiah, 2016) state that PGPR comprises several types of rhizobacteria, some of which function as plant growth stimulants or biological agents for controlling disease, thereby increasing plant productivity.

PGPR will function optimally as supplemented with organic fertilizers. Providing adequate organic resources will enable bacteria to proliferate, thereby ensuring their survival in the rhizosphere area and allowing them to perform their tasks and roles effectively (Lehar, Salli, et al., 2018). (Lehar, Arifin, et al., 2018) posited that the direct use of PGPR into the soil is believed to facilitate the degradation of organic matter in the soil, which subsequently transforms into nutrients for microbial proliferation. This study aims to improve the growth and yield of sweet corn plants through the use of organic PGPR and goat manure, thereby minimizing the ongoing reliance on inorganic fertilizers, which can severely degrade agricultural land. It is harmful not only to the land and vegetation but also to the farmers. This study seeks to determine the growth and yield of sweet corn (*Zea mays saccharata* Sturt) plants using organic PGPR tests and several doses of goat manure. It produces morphological characters of sweet corn using the PGPR test and varying doses of goat manure.

2. METHOD

This study was conducted on the land owned by the Faculty of Agriculture, Universitas Muhammadiyah Sumatera Utara, at Jl. Sampali, Percut Sei Tuan Subdistrict, Deli Serdang Regency, North Sumatera, situated at a height of ± 27 meters above sea level. This research was conducted from April to June 2023.

The materials used in this study included Paragon variety sweet corn seeds, water, goat manure, and organic *Plant Growth Promoting Rhizobacteria* (PGPR) containing microorganisms (*Rhizobium* sp., *Lactobacillus* sp., *Acetobacter* sp., *Aspergillus* sp., *Penicillium* sp., and *Trichoderma* sp.). The tools used were hoes, machetes, measuring devices, rulers, plastic ropes, scissors, sample signs, watering cans, scales, measuring cups, refractometers, vernier calipers, cameras, and stationery.

This study employed a Factorial Randomized Block Design (RBD) with two factors. A randomized block design is a restricted randomized design, wherein experimental units are initially organized into homogeneous blocks, followed by the random assigned treatments to these units within the blocks. The primary benefit of this design is that, once executed properly, it provides more precise results (Palaniswamy, 2020). The first factor was the concentration of organic *Plant Growth Promoting Rhizobacteria* (PGPR) consisting of four levels, viz. P0 = no PGPR (control), P1 = 20 ml/liter of water, P2 = 30 ml/liter of water, and P3 = 40 ml/liter of water. The second factor was goat manure (K) comprising four levels, viz. K0 = no goat manure (control), K1 = 1 kg/plot, K2 = 1.5 kg/plot, and K3 = 2 kg/plot. The findings were further analyzed using the Analysis of Variance (ANOVA) followed by Duncan's Mean Difference Test (DMRT), with a linear model of Factorial Randomized Block Design (RBD) as follows:

$$Y_{ijk} = \mu + \gamma_i + \alpha_j + \beta_k + (\alpha\beta)_{jk} + \epsilon_{ijk} \dots\dots (1)$$

Notes:

Y_{ijk} : observational results of factor P at level j and factor K at level k in repetition i

μ : erroneous

γ_i : the impact of the i-level block

P_j : the impact of the factor of giving P level j
 K_k : the impact of the K level assignment factor to k
 $(PK)_{jk}$: the impact of the combination of giving P level j and giving K level k
 E_{ijk} : the impact of errors from the factors of giving P level j, K level k, and block i
 Linear model of Factorial Randomized Block Design (RBD) as shown in Eq. 1.

The parameters observed were plant height, stem diameter, and flowering age. Plant height was measured from the base of the stem to the growing point using a meter. Plant height was measured starting from 2 weeks after planting to 8 WAP. Stem diameter was measured using a caliper at the base of the stem. Stem diameter was measured at the ages of 2, 4 and 6 WAP. Flowering age was calculated from the appearance of the first flower on each sample plant.

3. RESULTS AND DISCUSSION

3.1 Plant Height (cm)

Based on the analysis of variance, PGPR treatment and the interaction of the two treatments had no significant effect on plant height metrics. However, goat manure treatment had a significant effect on plant height at 6 and 8 WAP. Table 1 presents the average plant height.

According to Table 1, the provision of PGPR had no significant effect on plant height metrics at 2, 4, 6, and 8 WAP. Despite the lack of statistical response, there was an observable increase; the highest average data was recorded at the P3 level (203.50 cm), while the lowest was at the P1 level (203.06 cm). This aligns with the assertion of (Fitri et al., 2020) that the ultisol soil used in this study had a pH of 5.50 (acidic) and had not undergone liming, resulting in its continued acidity. Table 1 indicates that the provision of PGPR (Plant Growth Promoting Rhizobacteria) to corn plants results in variable plant height growth; in general, there was no significant difference in the vegetative growth of corn plants treated with PGPR (Plant Growth Promoting Rhizobacteria) due to the acidic soil pH, which hinders the development of N-fixing bacteria.

Table 1. Plant Height with PGPR Test Treatment and Goat Manure at 2, 4, 6 and 8 WAP

Treatment	Week After Planting (WAP)			
	2	4	6	8
PGPR				
			(cm).....	
P ₀	34.81	84.44	166.48	203.06
P ₁	34.42	84.47	162.72	202.25
P ₂	32.67	83.56	165.00	202.75
P ₃	31.86	83.62	168.24	203.50
Goat Manure				
K ₀	32.00	83.39	162.61 d	200.69 d
K ₁	33.25	83.42	163.25 c	202.78 c
K ₂	33.92	84.23	166.99 b	203.50 b
K ₃	34.58	85.06	169.60 a	204.58 a
Interaction (PxK)				
P ₀ K ₀	33.33	82.78	162.78	201.00
P ₀ K ₁	32.89	83.56	166.67	204.78
P ₀ K ₂	36.67	86.22	163.67	202.78
P ₀ K ₃	36.33	85.22	172.83	203.67
P ₁ K ₀	32.33	82.33	162.22	201.22
P ₁ K ₁	32.56	82.56	158.33	198.33
P ₁ K ₂	36.56	86.00	163.67	205.00
P ₁ K ₃	36.22	87.00	166.67	204.44
P ₂ K ₀	31.89	81.89	160.67	200.67
P ₂ K ₁	33.44	83.44	163.67	203.00
P ₂ K ₂	31.78	81.78	166.22	203.22
P ₂ K ₃	33.56	87.11	169.44	204.11
P ₃ K ₀	30.44	86.56	164.78	199.89
P ₃ K ₁	34.11	84.11	164.33	205.00
P ₃ K ₂	30.67	82.93	174.41	203.00
P ₃ K ₃	32.22	80.89	169.44	206.11

Description: Numbers followed by distinct letters within the same column exhibit substantial differences as per the 5% DMRT test.

Goat manure treatment on corn plants significantly affected plant height metrics at 6 and 8 WAP. The optimal outcomes in goat manure administration occurred at the K3 level with a dose of 2 kg/plot (204.58 cm), which was substantially different from the K2 level (203.50 cm), K1 (202.78 cm), and the K0 level, which exhibited the lowest plant height growth (200.69 cm). Figure 1 illustrates the correlation between corn plant height and goat manure treatment at 6 and 8 WAP.

The height of plants at 6 and 8 WAP with goat manure treatment showed a positive linear correlation, represented by the following equations: for 6 WAP, $\hat{y} = 162.06 + 2.1714x$ with r value = 0.85, and for 8 WAP, $\hat{y} = 200.73 + 1.9175x$ with r value of 0.96. The K3 level had the highest tendency with a dose of 2 kg/plot, measuring 204.58 cm at 8 WAP. The application of goat manure significantly influenced plant height growth due to its nutritional content. This is in accordance with the statement of (Washaya & Washaya, 2023) that goat manure possesses properties that do not damage the soil, provide macro and micronutrients, increase water retention, promote soil microbiological activity, boost cation exchange capacity, and improve soil structure. The nutritional content of goat manure comprises 64% water, organic matter N (31%), P₂O₅ (0.7%), K₂O (0.4%), CaO (0.4%), and C/N (20-25%). The presence of nutrients in the soil and their efficient uptake by plants affected the growth of plant height.

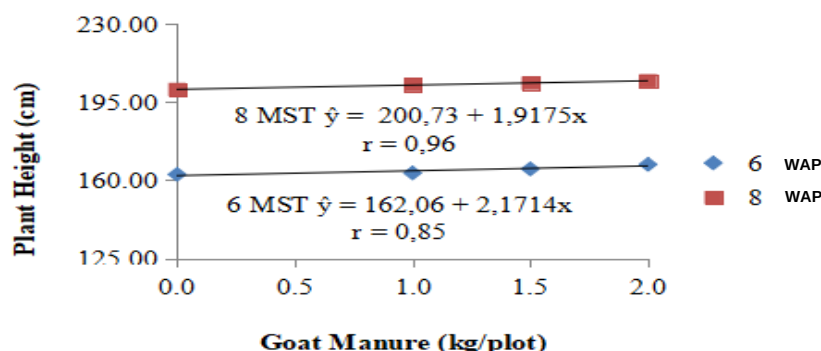


Figure 1. Correlation between Plant Height and Goat Manure Treatment at 6 and 8 WAP

3.2 Stem Diameter (mm)

The analysis of variance indicated that PGPR treatment and the interaction of the two treatments had no significant effect on stem diameter. Nonetheless, goat manure treatment exerted a substantial impact at 6 WAP.

Table 2. Displays the statistics on the average stem diameter.

Treatment Goat Manure	PGPR				Average
	P ₀	P ₁	P ₂	P ₃	
K ₀	3.00	3.17	3.22	3.22	3.15 c
K ₁	3.22	3.17	3.33	3.50	3.31 bc
K ₂	3.67	3.56	3.61	3.11	3.49 b
K ₃	3.78	3.78	3.94	3.67	3.79 a
Average	3.42	3.42	3.53	3.38	

Description: Numbers followed by distinct letters within the same column exhibit substantial differences as per the 5% DMRT test.

According to Table 2, the provision of PGPR had no significant effect on stem diameter at 4, 6, and 8 WAP. Despite the lack of statistical response, there was an observable increase in stem diameter measures. The highest average measurement was at the P₂ level (3.53 cm), while the lowest was at the P₃ level (3.38 cm). The use of goat manure significantly influenced stem diameter metrics at 6 WAP. The optimal outcomes occurred at the K₃ level with a dose of 2 kg/plot (3.79 cm), which was considerably distinct from the K₂ level (3.49 cm). However, the K₂ level did not exhibit a significant difference from the K₁ level (3.31 cm) and K₀ (3.15 cm), which had the lowest stem diameter growth. Figure 2 illustrates the correlation between stem diameter and goat manure treatment.

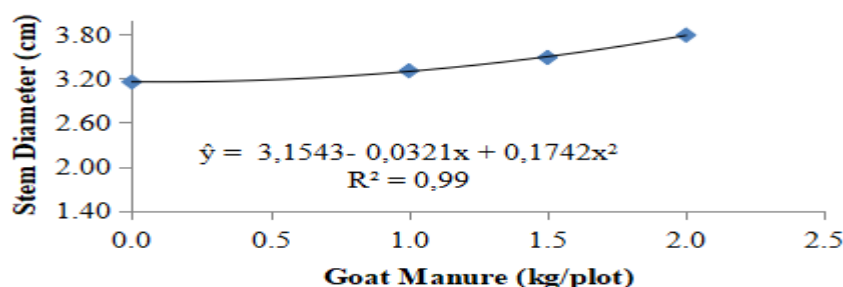


Figure 2. Correlation between Stem Diameter and Goat Manure Treatment at 6 WAP

According to Figure 2, the stem diameter in response to goat manure treatment exhibited a positive quadratic correlation, represented by the equation $\hat{y} = 3.1543 - 0.0321x + 0.1742x^2$, with r value of 0.99. The highest tendency was observed at the K3 level with a dose of 2 kg/plot (3.79 cm).

Goat manure influences the growth of stem diameter in corn plants, likely due to its composition of macro and micronutrients. Nutrients available in the soil in quantities suitable for plant needs provide optimal plant growth outcomes. This aligns with the assertion of (Hidayati et al., 2021) that the use of organic fertilizer can establish a nutritional balance in the soil and improve its physical quality by augmenting the soil texture, porosity, and structure. The increase in stem diameter is attributed to the availability of nitrogen nutrients, optimizing nutrition absorption. Elevated N content improves plants greenness, facilitating efficient photosynthetic processes, which in turn affects plant diameter. An increase in N content accelerates plant growth, resulting in a large stem diameter.

3.3 Flowering Age (day)

The analysis of variance indicated that the PGPR treatment and the interaction of the two treatments had no significant effect on flowering age. Nonetheless, the goat manure treatment had a significant effect. Table 3 presents the statistics on the average flowering age.

Table 3. Flowering Age with PGPR and Goat Manure Treatment

Treatment Goat Manure	PGPR				Average
	P ₀	P ₁	P ₂	P ₃	
K ₀	48.89	49.44	49.78	48.44	49.14 a
K ₁	47.22	46.89	49.22	46.78	47.53 b
K ₂	48.89	47.22	46.44	45.11	46.92 c
K ₃	46.67	45.33	47.00	46.56	46.39 d
Average	47.92	47.22	48.11	46.72	

Notes: Numbers followed by distinct letters within the same column exhibit substantial differences as per the 5% DMRT test.

According to Table 3, the provision of PGPR had no significant effect on flowering age. Despite the lack of statistical response, there was an observable increase in each treatment. The average duration for the fastest flower emergence was at the P3 level (46.72 days), while the slowest was at the P2 level (48.11 days). The provision of goat manure significantly affected the flowering age metrics. The optimal outcomes were at the K3 level with a dose of 2 kg/plot (46.39 days), which was significantly different from the K2 level (46.92 days), K1 (47.53 days), and K0 (49.14 days), the latter exhibiting the longest flowering age. Figure 3 illustrates the correlation between flowering age and goat manure treatment.

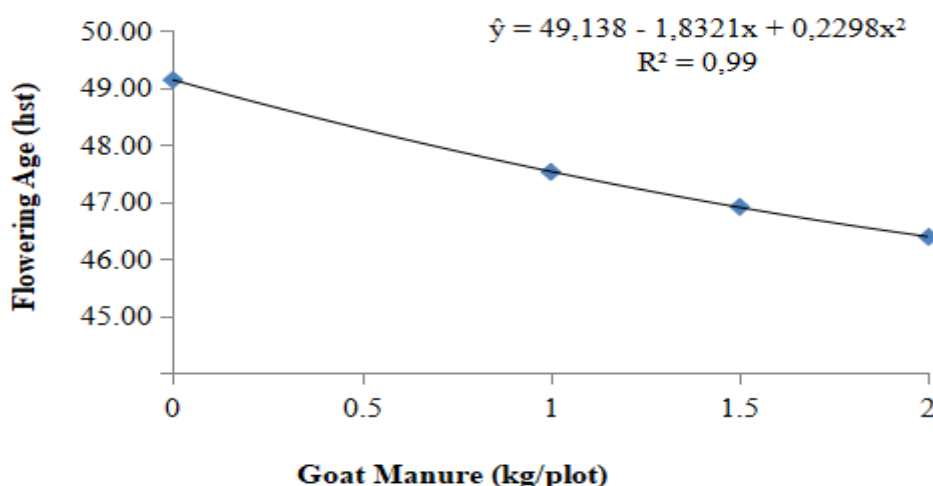


Figure 3. Correlation between Flowering Age and Goat Manure Treatment

According to Figure 3, the flowering age in response to the goat manure treatment exhibited a negative quadratic correlation, represented by the equation $\hat{y} = 49.138 - 1.8321x + 0.2298x^2$, with r value of 0.99. The K3 level, with a dose of 2 kg/plot, had the most rapid floral emerging propensity, occurring in 46.39 days.

Goat manure enhances the flowering process in corn plants by enriching the soil with nutrients, e.g., nitrogen, phosphorus, and potassium. Additionally, goat manure contains hormones that promote the growth of plant parts, including leaves and stems, and accelerate flowering age. It can also improve soil fertility, hence optimizing plant growth. This aligns with (Rukudzo, 2017; Sitepu, 2019) statement that goat manure fertilizer possesses benefits due to its elevated nutritional content, including organic matter N (31%), P₂O₅ (0.7%), and K₂O (0.4%), CaO (0.4%), and C/N (20-25%). The macronutrients contained in goat manure are available to plants, facilitating healthy vegetative growth. Goat manure is one of the organic fertilizers readily available in ample amounts, particularly in environments that breed numerous goats, and it possesses a high nutritional content. Organic fertilization can be done by adding goat manure, which possesses a higher potassium concentration and lower moisture content relative to other manures (Ilham et al., 2023).

4. CONCLUSION

The provision of PGPR had no significant effect on the growth and yield of corn plants. The provision of goat manure at a dose of 2 kg/plot had a significant effect on plant height, stem diameter, and flowering age. There was no significant interaction between the combination of PGPR and goat manure on the growth and yield of corn plants.

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