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Effect of Different Doses of NPK Fertilizer and Manure on N, P, K, Chlorophyll and Sweet Corn Yield in Vertisols
Efecto de Diferentes Dosis de Fertilizante NPK y Estiércol sobre N, P, K, Clorofila y Rendimiento de Maíz Dulce en Vertisol

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SUMMARY

Vertisols is one of the soils with problems in nutrient availability, necessitating nutrient input in the form of fertilizer. The continuous use of inorganic fertilizers can negatively impact soil quality and the environment. Thus, it is essential to reduce their use and balance them with manure. This study aims to evaluate the effect of combining inorganic fertilizers with manure on improving the availability of Vertisols nutrients and the growth and yield of sweet corn (*Zea mays saccharata*). The research was conducted in Sidokerto, Plupuh, Sragen, from March 2023 to August 2023, using a Randomized Complete Block Design (RCBD) with 9 treatments and 3 replications. The treatments included a control (A), NPK recommendation (B), manure (C), and combinations of manure and inorganic fertilizer at predetermined doses. The observation variables were C-Organic, CEC, Total-N, P-Available, K-Available, chlorophyll, and the growth and yield of corn. The results showed that the application of ¾ NPK + 1500 kg ha^{-1} of manure increased N-Total by 38%, P-Available by 38.68%, K-Available by 57%, chlorophyll by 29%, plant height by 28.25%, number of leaves by 20%, stem diameter by 22.89%, cob weight by 31%, cob length by 48%, and cob diameter by 29% compared to the standard NPK treatment. Application of manure and inorganic fertilizers can increase the availability of N, P, K nutrients in Vertisols, growth, and yield of sweet corn.

Index words: *total-N, P-available, K-available, photosynthetic pigment, Zea mays saccharate.*

RESUMEN

El suelo vertisol es uno de los suelos con problemas de disponibilidad de nutrientes, lo que hace necesario el aporte de nutrientes en forma de fertilizantes. El uso continuado de fertilizantes inorgánicos puede afectar negativamente a la calidad del suelo y al medio ambiente. Por ello, es esencial reducir su uso y equilibrarlos con estiércol. Este estudio pretende evaluar el efecto de la combinación de fertilizantes inorgánicos con estiércol en la mejora de la disponibilidad de nutrientes del suelo Vertisol y en el crecimiento y rendimiento del maíz dulce (*Zea mays saccharata*). La investigación se llevó a cabo en Sidokerto, Plupuh, Sragen, desde marzo de 2023 hasta agosto de 2023, utilizando un diseño de bloques completamente aleatorizados con 9 tratamientos y 3 repeticiones. Los tratamientos incluyeron un control (A), recomendación NPK (B), estiércol (C), y combinaciones de estiércol y fertilizante inorgánico a dosis predeterminadas. Las variables de observación fueron C-Orgánico, CEC, N-Total, P-Disponible, K-Disponible, clorofila, y el crecimiento y rendimiento del maíz. Los resultados mostraron que la aplicación de

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¾ NPK + 1500 kg ha^{-1} de estiércol aumentó el N-Total en un 38%, el P-disponible en un 38.68%, el K-Disponible en un 57%, la clorofila en un 29%, la altura de la planta en un 28.25%, el número de hojas en un 20%, el diámetro del tallo en un 22,89%, el peso de la mazorca en un 31%, la longitud de la mazorca en un 48% y el diámetro de la mazorca en un 29% en comparación con el tratamiento NPK estándar. La aplicación de estiércol y fertilizantes inorgánicos puede aumentar la disponibilidad de nutrientes N, P, K en el suelo vertisol, el crecimiento y el rendimiento del maíz dulce.

Palabras clave: *N-total, P-disponible, K-disponible, pigmento fotosintético, Zea mays saccharate*.

INTRODUCTION

Vertisols are widely used for agricultural activities, covering an area of approximately 2.1 million hectares in Indonesia, including 0.4 million hectares in Central Java (Masria, Lopulisa, Zubair, and Rasyid, 2014). This soil has constraints including slow permeability and poor drainage because it contains high clay, low organic matter and nutrient content because it is bound by clay particles, so its availability to plants is limited (Maydayana, Kusuma, Bakti, Sukartono, and Dewi, 2023; Suntoro *et al*., 2023)

The demand for sweet corn in Indonesia reaches 3-8 tons per day, with a demand growth rate of around 20-30% per year (Masruhing, Hasrianti, and Abdullah, 2018). This condition encourages efforts to increase sweet corn production. The yield potential of Talenta sweet corn varieties can reach 14 tonnes per hectare under conditions of high rainfall intensity in Indonesia, specifically in Purworejo district, Central Java (OFSA, 2021), while current production in Indonesia is relatively low at 8.31 tons per hectare (Rizqullah, Sitawati, and Guritno, 2017). The annual demand for sweet corn in Indonesia has not been met due to low productivity. One of the main causes of this low productivity, particularly for sweet corn, is declining soil fertility (Gribaldi, 2016). The high demand for sweet corn, coupled with the limited nutrients in Vertisols, necessitate fertilizer management.

Fertilization is needed for plants to grow, this is because the growth of corn plants is influenced by nutrients, especially macronutrients (N, P and K). These nutrients are found in inorganic and organic fertilizers. Facts in the field show that the use of inorganic fertilizers has been proven to be able to increase crop productivity (Ye *et al*., 2020) so it is widely used by farmers in Indonesia in sweet corn cultivation because it is more economical based on its nutrient content, affordable, easy to use and faster plant response (Sofyan, Sara, and Machfud 2019). However, excessive and inefficient use of inorganic fertilizers will result in a decline in soil quality and the environment, leading to land degradation (Kalasari, Syafrullah, Astuti, and Herawati, 2020). Maroeto, Suntoro, Djoko, and Rossyda (2017) explained that soil fertility degradation will impact soil productivity, ultimately leading to economic losses for agricultural businesses. Manure application is crucial for successful maize cultivation on dry land, especially considering that most agricultural land in Java is low in organic matter (Suntoro, Mujiyo, Widijanto, and Herdiansyah, 2020). Because the provision of manure can increase NPK in soil and plant growth (Suntoro *et al*., 2018). The same results were also reported by Das and Maharjan (2023) that land treated with manure had higher NO_3^- N concentrations, and lower NH_4^+ N concentrations, soil organic-C increased by more than 60% compared to land that was not treated with manure so that its fertility increased. A single application of manure resulted in increased corn yields (Kravchenko and Thelen, 2007).

Therefore, the use of inorganic fertilizers integrated with organic fertilizers is a sustainable approach for efficient nutrient use that increases chemical fertilizer efficiency while reducing nutrient losses (Schoebitz and Vidal, 2016). Previous research results show combining manure and inorganic fertilizer at the right doses can increase the growth and yield of corn plants (Sulaeman, Maswar, and Erfandi, 2016). The addition of organic fertilizers combined with inorganic ones yields the best results in soil chemical properties (organic-C, CEC, N-Total, P-Available) and can enhance corn productivity (Syamsiyah, Herdiansyah, and Hartati, 2023a).

In this study, the research objects were organic fertilizers (manure) and inorganic fertilizers namely Urea, SP and KCl (conventional). Field experiments were used to investigate the effects of different fertilization regimes on sweet corn yield and soil nutrients, In addition, the scientific and economic efficiency of the combination of chemical fertilizer reduction and manure application was also evaluated. The underlying hypotheses were that (I) chemical fertilizer reduction combined with organic fertilizer (manure) increases soil nutrient content in sweet corn fields.

MATERIALS AND METHODS

Location

This research was conducted in paddy fields with Vertisol soil type located in Sidokerto, Plupuh District, Sragen Regency. The analyses were carried out at the Laboratory of Chemistry and Soil Fertility and the Laboratory of Physics and Soil Conservation, Faculty of Agriculture, UNS. The study took place from March 2023 to August 2023.

Method

The research was conducted using a Randomized Complete Block Design (RCBD) with 9 treatments (Table 1) replicated 3 times, resulting in a total of 27 research plots (Table 1).

Planting was conducted in plots measuring 4 × 5 m² with a spacing of 25 × 75 cm², and each hole is planted with one sweet corn seed. Fertilization was performed using granulated manure and a mixture of NPK fertilizers in the form of Urea, SP-26, and KCl. Urea fertilizer contains 46% nitrogen, SP-26 fertilizer contains 26% phosphorus, and KCl fertilizer contains 60% potassium. Manure was applied 5 days before planting while Urea fertilizer was applied three times: at planting (116.5 kg ha^{-1}), 14 days after planting (116.5 kg ha^{-1}), and 28 days after planting (116.5 kg ha^{-1}). SP-26 fertilizer was applied once at planting at 75 kg ha^{-1} and KCl fertilizer was applied once at planting at 180 kg ha^{-1}. Manure is spread evenly on each plot and tillage is done to ensure the manure is mixed with the soil, while inorganic fertilizer is placed between the rows or furrows.

Maintenance was carried out in the form of watering, replanting, weeding, and eradicating pests and diseases. Soil and plant samples were taken diagonally in each plot so that each sample had 27 samples. Soil sampling was conducted before planting and during the maximum vegetative stage. Observations of plant growth (plant height, number of leaves, and stem diameter) were made on 5 samples at 56 HST. Leaf sampling to measure the nutrient content of N, P and K in leaves was done on the 5th leaf from the top at the maximum vegetative time.

Yield parameters such as cob weight, cob length, and cob diameter were measured at harvest, which occurred 56 days after planting. Soil analyses were conducted as follows: C-Organic content was determined using the Walkey and Black method (Blackmore, Searle, and Daly, 1987). Cation Exchange Capacity (CEC) was assessed using the ammonium acetate method at pH 7 (Hajek, Adams, and Cope, 1972). Total nitrogen (Total N) was analyzed via the Kjeldahl method (Nguyen and Shindo, 2011). Available phosphorus (P-Available) was determined using the Olsen method (Olsen, Cole, Watanabe, and Dean, 1954). Available potassium (K-Available) was assessed using both the Olsen method (Olsen *et al*., 1954) and the 25% HCl extraction method (Sudjadi, Widjik, and Soleh, 1971). Chlorophyll content was measured using the absorption spectroscopy method (Nilapwar, Nardell, Wasterhaff, and Verma, 2011).

Table 1. Experimental treatment design.

Code	Treatment
A	Control
B	Standard dose NPK (Mixed Fertilizer)
C	2000 kg ha^{-1} Manure
D	¼ Standard dose NPK + 2000 kg ha^{-1} Manure
E	½ Standard dose NPK + 2000 kg ha^{-1} Manure
F	¾ Standard dose NPK + 2000 kg ha^{-1} Manure
G	Standard dose NPK + 2000 kg ha^{-1} Manure
H	¾ Standard dose NPK + 1000 kg ha^{-1} Manure
I	¾ Standard dose NPK + 1500 kg ha^{-1} Manure

Control = no fertilizer; Standard dose NPK = urea 349.5 kg ha^{-1}, SP-2675 kg ha^{-1}, KCl 180 kg ha^{-1}.

Data Analysis

Kolmogorov Smirnov normality test was conducted before analyzing the data. The data were analyzed using Analysis of Variance (ANOVA) with a 95% confidence level. Subsequently, Duncan's Multiple Range Test (DMRT) was applied for mean comparison, and correlation tests were conducted to determine relationships between variables. Additionally, regression analysis was employed to ascertain the direction of these relationships.

RESULTS AND DISCUSSION

Characteristics of Vertisols

Vertisols exhibit moderate fertility, characterized by slightly acidic pH, low C-Organic content, medium N-Total, very low P-Available, and low K-Available (Table 2). According to Suntoro *et al*. (2020) the low C-Organic content in Vertisols is a limiting factor for soil fertility. The low nutrient content in Vertisol is attributed to its high clay content. Sudadi, Putri, and Suntoro (2020) further explain that Vertisols have high nutrient reserves, but these nutrients are tightly bound to clay particles, resulting in limited availability for plants.

Effect of Treatment on Soil Chemical Properties

The application of manure and inorganic fertilizer has been shown to increase C-Organic, CEC, N-Total ($P < 0.05$), P-Available ($P < 0.05$), and K-Available ($P < 0.05$) (Table 3). These findings are consistent with the research of Murnita and Taher (2021), which demonstrated that combining manure and inorganic fertilizer enhances soil C-Organic, nitrogen (N), phosphorus (P), and potassium (K) levels. The addition of manure and inorganic fertilizer had a highly significant effect on soil properties: C-Organic ($P < 0.05$) increased from 1.42% to 2.28% (Table 3), Cation Exchange Capacity (CEC) increased from 25.99 meq 100 g^{-1} to 37.24 meq 100 g^{-1} (Table 3), Total nitrogen (N-Total) increased from 0.22% to 0.55% (Table 3), Available phosphorus (P-Available) increased from 3.04 mg kg^{-1} to 7.97 mg kg^{-1} (Table 3), and Available potassium (K-Available) increased from 0.34 meq 100 g^{-1} to 1.30 meq 100 g^{-1} (Table 3).

The combination of ¾ NPK with 1500 kg ha^{-1} of manure resulted in N-Total, P-Available, and K-Available levels that were not significantly different from those with ¾ NPK + 2000 kg ha^{-1} of manure, but significantly differed from the Standard NPK treatment. This treatment increased N-Total by 38% compared to the Standard NPK treatment. According to Brar, Singh, Singh, and Kaur (2015), the combination of manure with inorganic fertilizers contributes to C-Organic content and reduces nitrogen loss. Soekamto (2015), soil fertility is highly dependent on C-organic content, higher C-Organic inputs lead to increased soil fertility.

The ¾ NPK treatment with 1500 kg ha^{-1} of manure increased P-Available by 38.68% compared to the Standard NPK treatment. (Purba, Damanik, and Lubis, 2017) explained that the application of organic and inorganic fertilizers can enhance P availability by forming complex compounds that chelate aluminum (Al) and iron (Fe) metals, making P more accessible. K-Available in this treatment also increased by 57% compared to the Standard NPK treatment.

The increase in soil K-Available is attributed to the application of organic fertilizers, which improve Cation Exchange Capacity (CEC) and thereby reduce the risk of leaching cations such as K^+. Organic materials like manure enhance soil structure and CEC, as noted in studies such as (Syamsiyah, Minardi, Khadaffi, Hartati, and Herdiansyah, 2023b). Conversely, inorganic fertilizers like KCl, which contains 38-60% K_2O, also contribute to increased soil K-Available, as highlighted by research such as (Meena, Maurya, Verma, and Meena, 2016).

Table 2. Initial soil characteristics

No.	Parameters	Value	Rating*
1.	pH H_2O	6.47	Slightly Acid
2.	KTK	25.05 meq 100 g^{-1}	High
3.	C-Organic	1.50%	Low
4.	Total N	0.22%	Medium
5.	P-Available	3.05 mg kg^{-1}	Very Low
6.	K-Available	0.24 meq 100 g^{-1}	Low

(*) Based on the scoring of the Soil and Fertilizer Standard Instrument Testing Center (2023).

Table 3. Effect of manure and inorganic fertilizer application on soil chemical properties.

Treatment	C-Organic (%)	CEC	N-Total	P-Available	K-Available
		meq 100 g^{-1}	%	mg kg^{-1}	meq 100 g^{-1}
Control	1.42 a	25.99 a	0.22 a	3.04 a	0.34 a
Standard dose NPK (Mixed Fertilizer)	1.82 b	28.98 b	0.36 c	4.47 bc	0.53 b
2000 kg ha^{-1} Manure	1.90 b	27.35 a	0.26 b	3.65 ab	0.52 b
¼ Standard dose NPK + 2000 kg ha^{-1} Manure	1.93 b	32.48 c	0.38 c	4.99 c	0.55 bc
½ Standard dose NPK + 2000 kg ha^{-1} Manure	2.04 c	34.52 de	0.39 c	5.89 d	0.63 c
¾ Standard dose NPK + 2000 kg ha^{-1} Manure	2.21 de	34.89 e	0.52 ef	7.62 ef	1.24 e
Standard dose NPK + 2000 kg ha^{-1} Manure	2.28 e	37.24 f	0.55 f	7.97 ef	1.30 ef
¾ Standard dose NPK + 1000 kg ha^{-1} Manure	2.11 cd	33.06 cd	0.44 d	7.00 e	0.72 d
¾ Standard dose NPK + 1500 kg ha^{-1} Manure	2.17 de	33.49 cde	0.50 e	7.29 ef	1.24 e

Control = no fertilizer; Standard dose NPK = urea 349.5 kg ha^{-1}, SP-26 75 kg ha^{-1}, KCl 180 kg ha^{-1}. Numbers followed by different letters indicate significantly different results in the DMRT test (α = 0.05).

Effect of Treatment on Chlorophyll

The analysis of variance indicated a highly significant effect of manure and inorganic fertilizer application on chlorophyll levels ($P < 0.05$), which ranged from 8.01 mg^{-1} to 25.0 mg^{-1}. This finding is consistent with research by Khrisnamurti, Yafizham, Darmawati, and Lukiwati (2021), showing that treatments combining manure with inorganic fertilizers significantly influence chlorophyll levels. Chlorophyll content in leaves is influenced by environmental conditions and nutrient availability, particularly nitrogen, a crucial component in chlorophyll synthesis. Arifiansyah, Nurjasmi, and Ruswadi (2020) also reported a significant increase in chlorophyll content with manure application, attributing it to the nitrogen content essential for chlorophyll formation. According to Suntoro *et al*. (2018), nitrogen plays a critical role in chlorophyll synthesis by forming porphyrins, essential compounds in chlorophyll metabolism.

In addition to nitrogen, phosphorus, and potassium also play crucial roles in supporting metabolic functions essential for chlorophyll synthesis. This effect is underscored by the positive and significant correlations observed between Total N (r = 0.910), P-Available (r = 0.900), K-Available (r = 0.798), and chlorophyll levels. The combination of ¾ NPK with 1500 kg ha^{-1} of manure produced a chlorophyll value of 23.6 mg g^{-1} (Figure 1), which was significantly different from the Standard NPK treatment which produced a chlorophyll value of 16.64 mg g^{-1}, showing a 29% increase compared to the Standard NPK treatment.

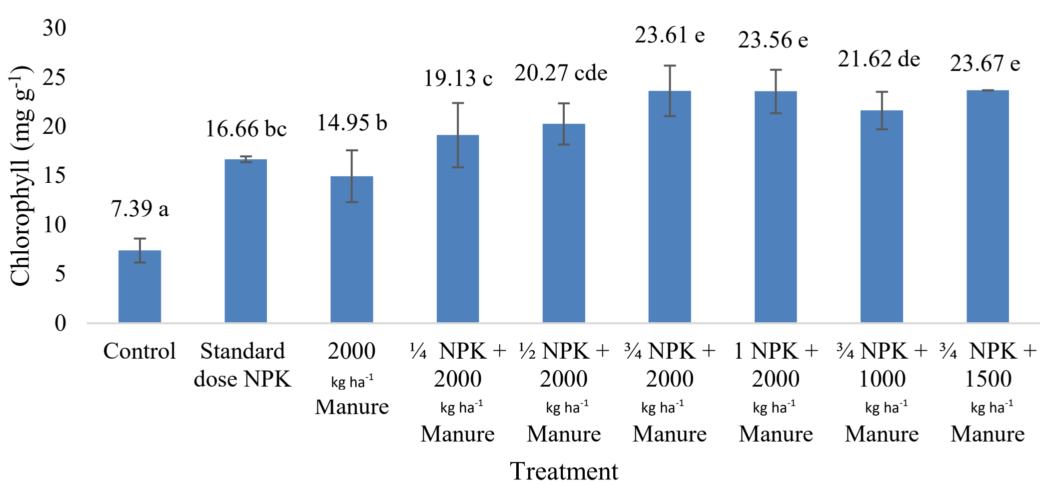

Figure 1. Effect of manure and inorganic fertilizer on chlorophyll. (Control = no fertilizer; Standard dose NPK = urea 349.5 kg ha^{-1}, SP-26 75 kg ha^{-1}, KCl 180 kg ha^{-1}). Numbers followed by different letters indicate significantly different results in the DMRT test (α = 0.05).

The regression test results indicate that N-Total has a coefficient of determination (R^2) of 0.828 (Figure 2), signifying that Total N influences chlorophyll levels by 82.80%. Similarly, P-Available has an R^2 of 0.8115 (Figure 2), indicating that P-Available influences chlorophyll levels by 81.15%. K-Available shows an R^2 of 0.6376 (Figure 2), suggesting that K-Available influences chlorophyll levels by 63.76%. The positive regression coefficients indicate a direct relationship: as Total N, P-Available, and K-Available increase, chlorophyll levels also increase.

Effect of Treatment on Growth and Yield

Statistical tests revealed significant effects of manure and inorganic fertilizers on plant height ($P < 0.05$), number of leaves ($P < 0.05$), stem diameter ($P < 0.05$), and sweet corn yield ($P < 0.05$). These findings align with studies by Sitorus and Tyasmoro (2019) and Saifulloh and Suntari (2022), indicating that sweet corn growth responds positively to increased doses of manure and NPK fertilizer. According to to Ikhwana, Ette, and Barus (2015), the application of organic and inorganic fertilizers supplies essential nutrients, including N, which plays a crucial role as a constituent of auxin, a plant growth hormone.

The observed increases in plant height and number of leaves can be attributed to the higher levels of Total N in the soil, supported by significant positive correlations between Total N and plant height (r = 0.960) and number of leaves (r = 0.952). Nitrogen is a primary macronutrient essential for the growth and development of vegetative parts such as leaves, stems, and roots (Indra and Nursalam, 2023). The relationship between total nitrogen (Total N) and available nitrogen, primarily in the form of nitrate (NO_3^--N), indicates that high nitrogen application increases both N-total and NO_3^--N concentrations in plants, which subsequently decline as the plants age and accumulate dry matter. N-total is more predominant in the leaves, while NO_3^--N concentrations are higher in the stems (Chen *et al*., 2015). NO_3^--N begins to accumulate significantly only after N-total reaches a certain threshold, which varies between 1.5% and 4.5%, depending on the plant part, species, and nitrogen source. Below this threshold, NO_3-N concentrations remain very low, approaching near-zero levels (Terman, Noggle, and Hunt, 1976).

The highest yield of sweet corn was observed in the 1 NPK treatment with 2000 kg ha^{-1} of manure (Figures 3,4,5), although it was not significantly different from the yield of the ¾ NPK treatment with 1500 kg ha^{-1} of manure. The ¾ NPK treatment with 1500 kg ha^{-1} of manure increased plant height by 28.25%, the number of leaves by 20%, and stem diameter by 22.89% compared to the Standard NPK treatment. According to (Mujiyo, Naaifah, Suntoro, and Maro'ah, 2023), organic fertilizers such as manure increase nutrient availability, promoting optimal vegetative growth through the addition of organic matter to the soil.

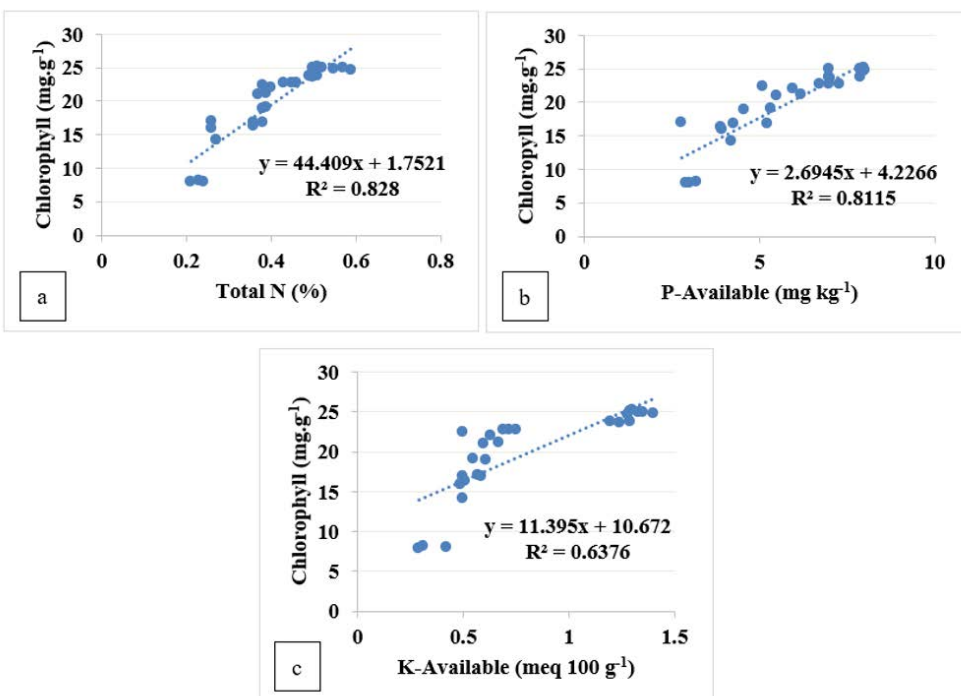

Figure 2. a) Relationship between Soil N-Total and Chlorophyll, b) Relationship between soil P-available and chlorophyll and c) Relationship between Soil K-Available and Chlorophyll.

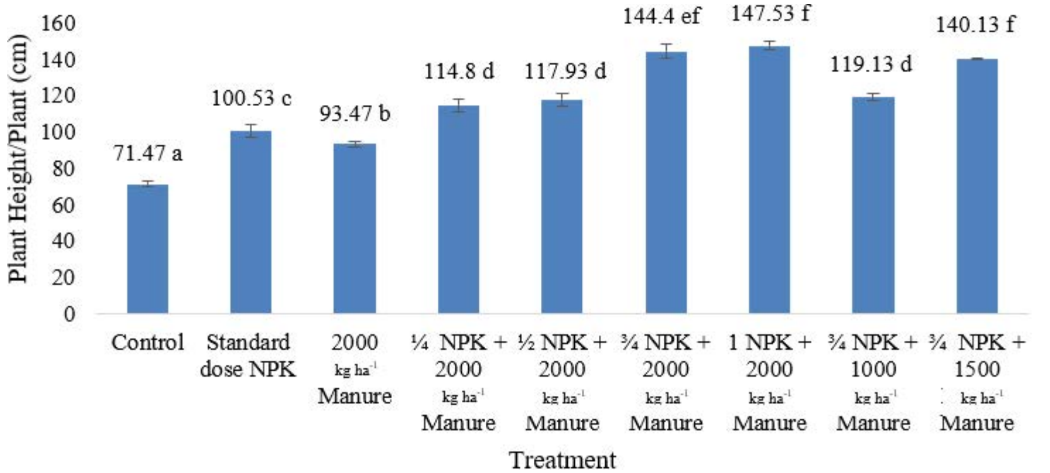

Figure 3. Effect of manure and inorganic fertilizer on plant height. (Control = no fertilizer; Standard dose NPK = urea 349.5 kg ha^{-1}, SP-26 75 kg ha^{-1}, KCl 180 kg ha^{-1}). Numbers followed by different letters indicate significantly different results in the DMRT test (α = 0.05).

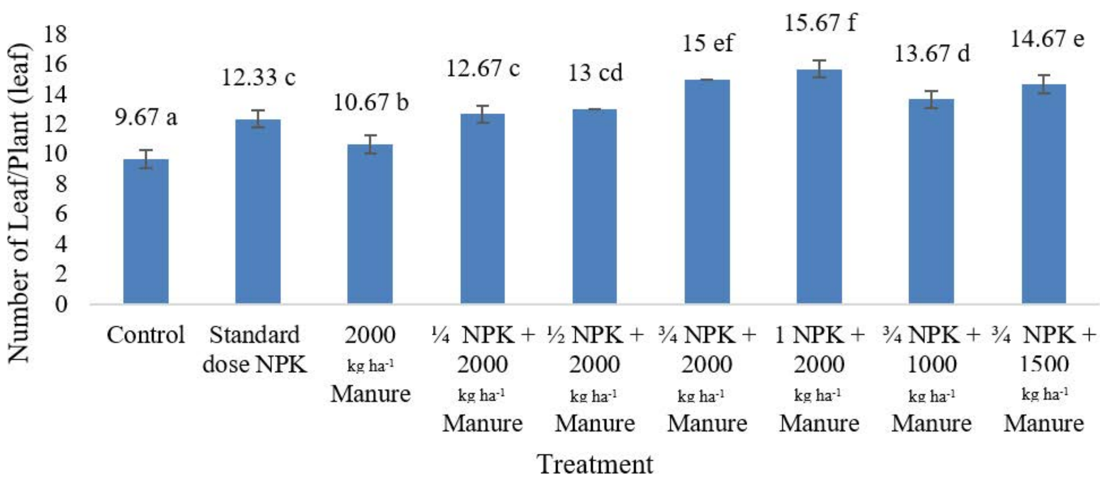

Figure 4. Effect of manure and inorganic fertilizer on number of leaves. (Control = no fertilizer; Standard dose NPK = urea 349.5 kg ha^{-1}, SP-26 75 kg ha^{-1}, KCl 180 kg ha-1). Numbers followed by different letters indicate significantly different results in the DMRT test (α = 0.05).

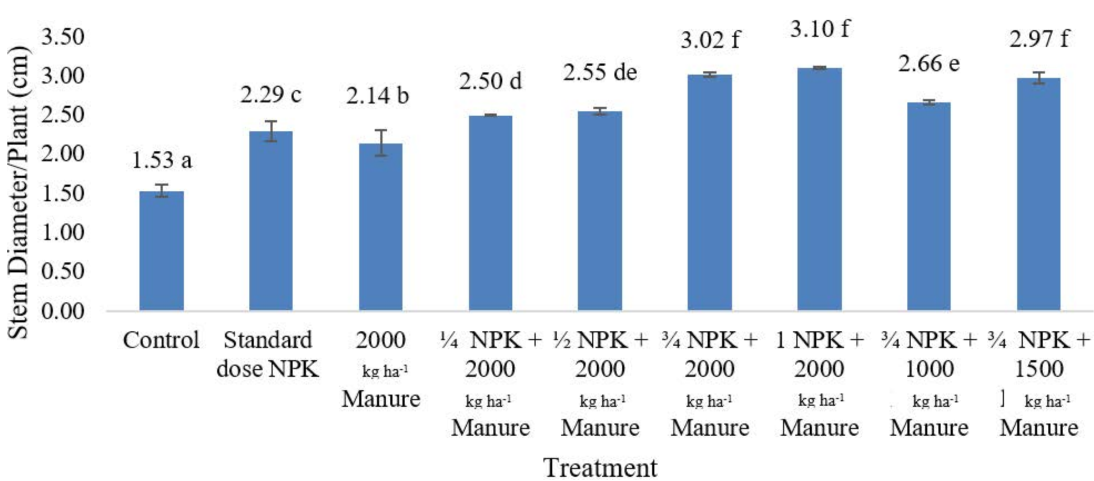

Figure 5. Effect of manure and inorganic fertilizer on stem diameter. (Control = no fertilizer; Standard dose NPK = urea 349.5 kg ha^{-1}, SP-26 75 kg ha^{-1}, KCl 180 kg ha^{-1}). Numbers followed by different letters indicate significantly different results in the DMRT test (α=0.05).

Total N affects plant height and number of leaves, this can be n from the equations in Figure 6 a,b which show that the more upright the graph, the better the relationship between the two variables. Available P has a positive significant relationship with stem diameter (Figure 6c). According to Setiono and Azwarta (2020), P plays a crucial role in carbohydrate formation, promoting sufficient carbohydrate levels that stimulate cell expansion and consequently increase stem diameter. This finding aligns with research by Syamsiyah *et al*. (2023b), which suggests that increased soil available phosphorus levels influence plant height, including stem diameter size.

The combination of the ¾ NPK treatment with 1500 kg ha^{-1} of manure significantly influenced sweet corn yield, as evidenced by cob weight, cob length, and cob diameter. Statistical tests indicated that the application of inorganic and organic fertilizers had a significant effect on corn yield ($P < 0.05$), cob weight ($P < 0.05$), cob length ($P < 0.05$), and cob diameter ($P < 0.05$). This effect can be attributed to the increased soil P-availability, as supported by significant correlations between P-availability and cob weight (r = 0.916), cob length (r = 0.952), and cob diameter (r = 0.942). Phosphorus plays a critical role in maximizing corn cob formation (Syamsiyah *et al*., 2023a), thereby affecting cob weight, cob length, and cob diameter. According to Lingga and Marsono (2002), nutrient P enhances assimilate formation in the form of carbohydrates and proteins, which are crucial for d development and consequently influence cob formation (Figures 7, 8, 9).

The application of ¾ NPK combined with 1500 kg ha^{-1} of manure increased cob weight by 31%, cob length by 48%, and cob diameter by 29% compared to the Standard NPK treatment. Regression test results indicate a coefficient of determination (R^2) of 0.8398 between P-Available and cob weight (Figure 10), indicating that P-Available influences cob weight by 83.98%. Similarly, P-Available influences cob length by 90.66% and cob diameter by 88.81% (Figure 10). According to Noviarini, Subadiyasa, and Dibia (2017), cob development and sweet corn d size are significantly influenced by phosphorus availability. Insufficient P-Available can lead to smaller cob sizes and reduced sweet corn production.

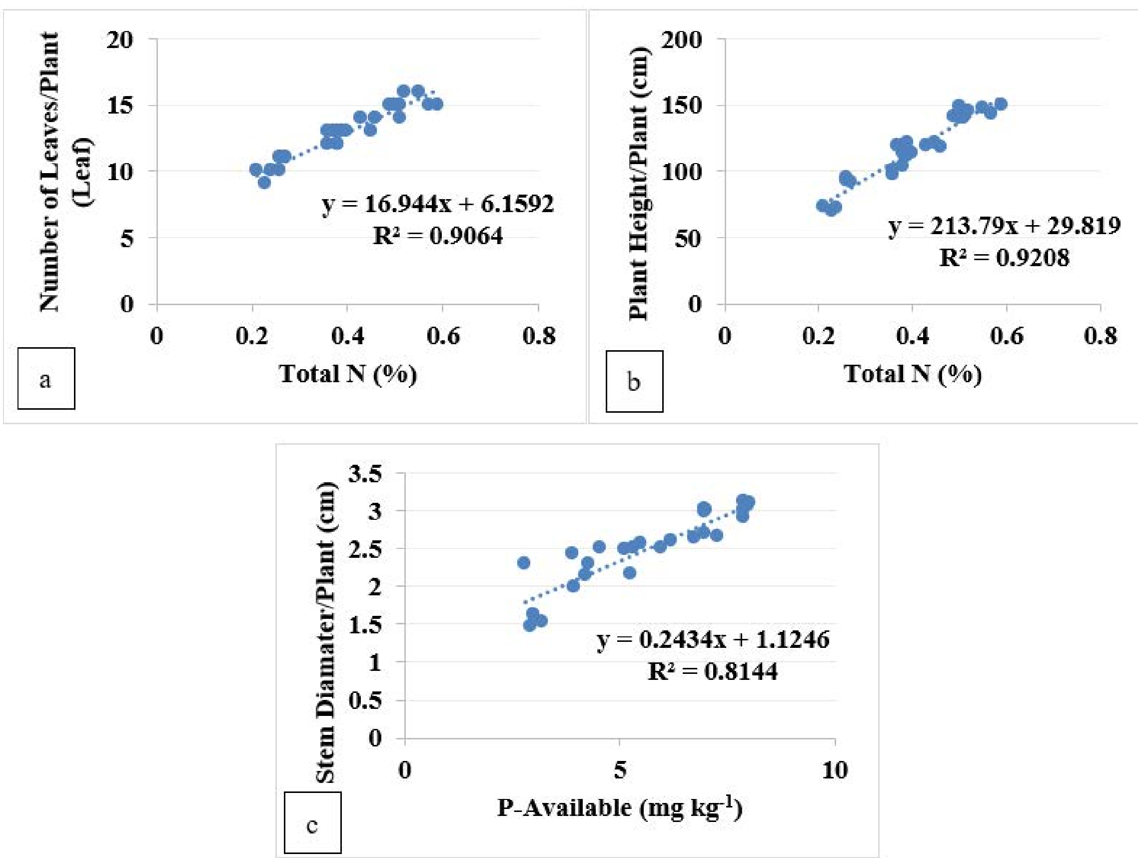

Figure 6. a) Relationship between Soil N-Total and Plant Height, b) Relationship between Soil N-Total and Number of Leaves and c) Relationship between Soil P-Available and Stem Diameter.

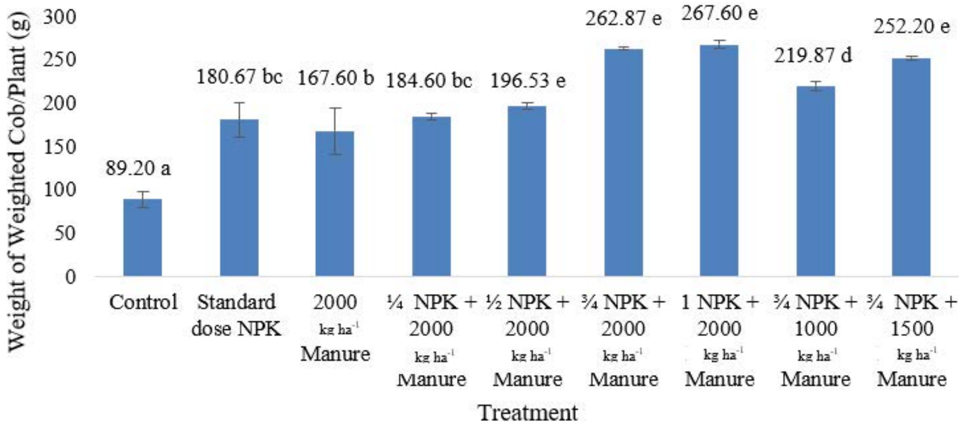

Figure 7. Effect of manure and inorganic fertilizer on weight of weighted cobs. (Control = no fertilizer; Standard dose NPK = urea 349.5 kg ha^{-1}, SP-26 75 kg ha^{-1}, KCl 180 kg ha^{-1}). Numbers followed by different letters indicate significantly different results in the DMRT test (α = 0.05).

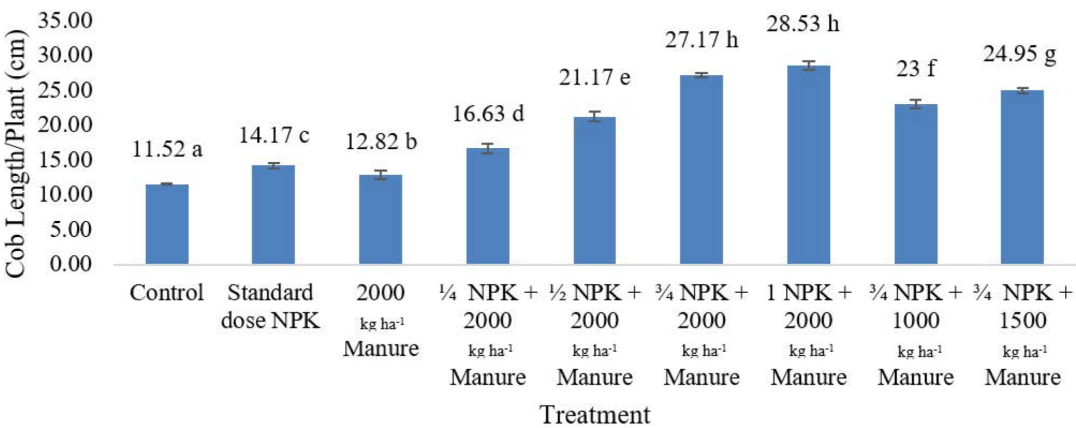

Figure 8. Effect of manure and inorganic fertilizer on cob length. (Control = no fertilizer; Standard dose NPK = urea 349.5 kg ha^{-1}, SP-26 75 kg ha^{-1}, KCl 180 kg ha-1). Numbers followed by different letters indicate significantly different results in the DMRT test (α = 0.05).

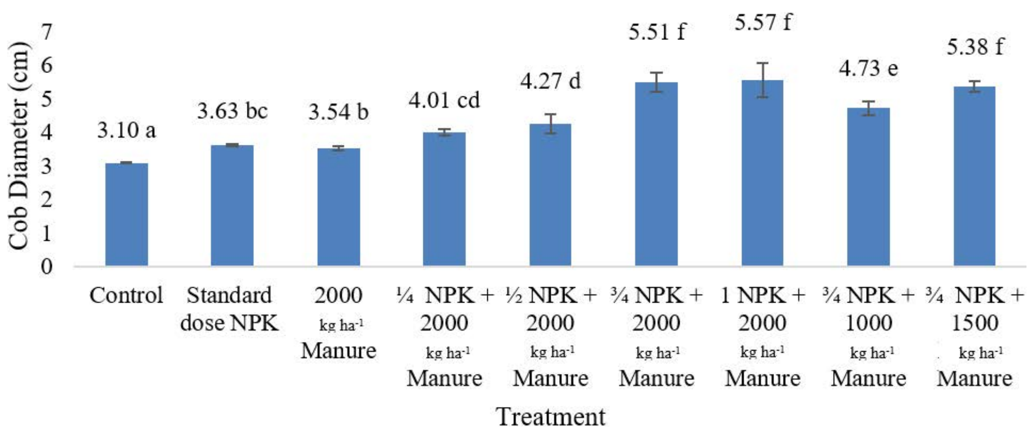

Figure 9. Effect of manure and inorganic fertilizer on cob diameter. (Control = no fertilizer; Standard dose NPK = urea 349.5 kg ha^{-1}, SP-26 75 kg ha^{-1}, KCl 180 kg ha^{-1}). Numbers followed by different letters indicate significantly different results in the DMRT test (α = 0.05).

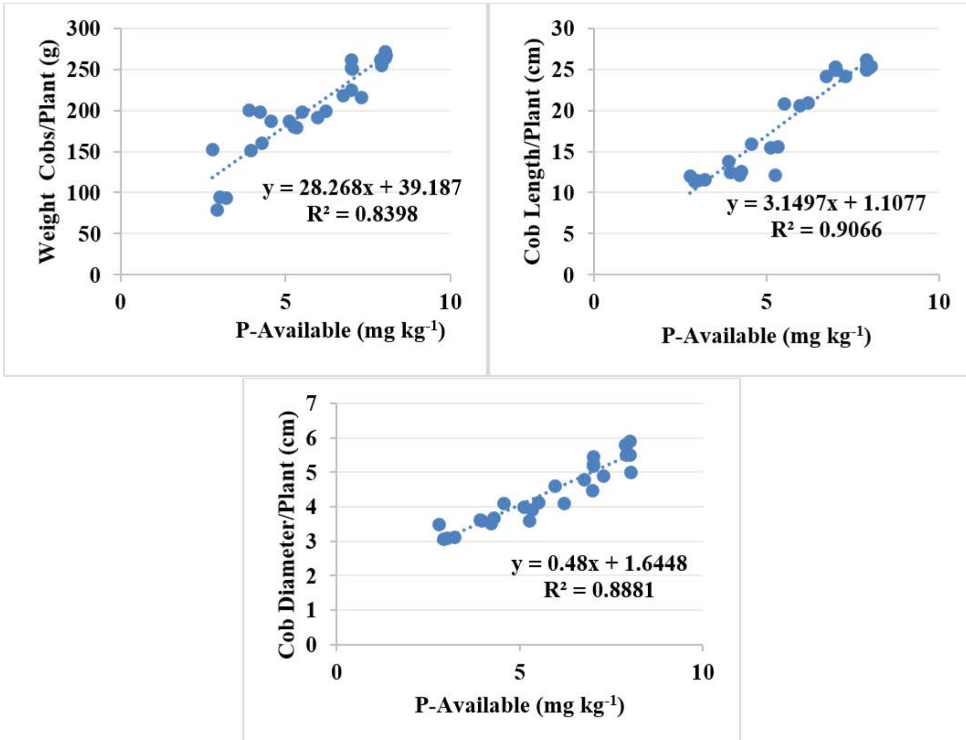

Figure 10. Relationship of soil P-available on cob weight, cob length and cob diameter.

CONCLUSIONS

The application of manure and inorganic fertilizers at the right dose can increase the content of N-Total, P-Available, and K-Available in the soil which can increase chlorophyll, growth, and yield of sweet corn. The authors recommend applying a dose of ¾ inorganic fertilizer (NPK mixed) with 1500 kg ha^{-1} of manure because the results are not significantly different and the results are close together. The ¾ inorganic fertilizer dose (NPK mixed) can reduce 25% of the use of inorganic fertilizers and in terms of farming, it will facilitate the economy of farmers because the dose of fertilizer used is not too large compared to the use of a fertilizer dose of 2000 kg ha^{-1} of manure with 1 inorganic fertilizer (NPK Mixed).

ETHICS STATEMENT

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF SUPPORTING DATA

The datasets used or analyzed during this study were obtained from field experiments and laboratory analysis.

COMPETING INTERESTS

The authors declare that they have no competing interests.

FINANCING

Not applicable.

AUTHORS' CONTRIBUTIONS

Research concept and design: J.S., S.S. Data analysis: W.I.N., I.A.S.A. Project administration: J.S. Data collection, statistical analysis: I.A.S.A, W.I.N. Writing: W.I.N., I.A.S.A. Literature review, critical revision: J.S., S.S., S.H., S.M. Technical Supervision, final manuscript editing: G.H.

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REFERENCES

Arifiansyah, S., Nurjasmi, R., & Ruswadi, R. (2020). Effect of organic fertilizer on growth and chlorophyll content of wheatgrass (*Triticum Aestivum* L.). *Respati Scientific Journal, 11*(2), 82-92.

Blackmore, L. C., Searle, P. L., & Daly, B. K. (1987). *Methods for Chemicals Analysis of Soils*. New Zealand: Department of Scientific and Industrial Research. https://doi.org/10.7931/DL1-SBSR-80

Brar, B. S., Singh, J., Singh, G., & Kaur, G. (2015). Effects of long term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize–wheat rotation. *Agronomy, 5*(2), 220-238. https://doi.org/10.3390/agronomy5020220

Chen, F. S., Niklas, K. J., Liu, Y., Fang, X. M., Wan, S. Z., & Wang, H. (2015). Nitrogen and phosphorus additions alter nutrient dynamics but not resorption efficiencies of Chinese fir leaves and twigs differing in age. *Tree Physiology, 35*(10), 1106-1117.

Das, S., & Maharjan, B. (2023). Manure improves soil health and provides yield stability and reliability. Consulted on august 22, 2024, retrieve from https://water.unl.edu/article/animal-manure-management/manure-improves-soil-health-and-provides-yield-stability-and

Gribaldi, G. (2016). A increasing of growth and sweet corn production through implementation of tillage system and mulching on the dry land. *Journal of Suboptimal Land, 5*(2), 119-126.

Hajek, B. F., Adams, F., & Cope, J. T. (1972). Rapid determination of exchangeable bases, acidity and cation exchange capacity. *Soil Science Society of America Journal, 36*, 436-438.

Ikhwana, P., Ette, A., & Barus, H. N. (2015). Growth and yield responses of sweet corn (*Zea mays* l. saccharata) plants to the application of various organic fertilizers. *Agrotekbis, 3*(2), 168-177.

Indra, I. W., & Nursalam, N. (2023). Growth and result of sweet corn with liquid organic fertilizer. *Agrotekbis Journal, 11*(2), 352-360.

Kalasari, R., Syafrullah, S., Astuti, D.T., & Herawati, K. (2020). Effect of fertilizer type on growth and production of several watermelon plant varieties (*Citrullus vulgaris* Schard). *Chlorophyll Journal, 15*(1), 30-36.

Khrisnamurti, S., Yafizham, Y., Darmawati, A., & Lukiwati, D. R. (2021). Effect of inorganic fertilizers and np-organic enriched manure on the growth and production of pulut maize (*Zea mays ceratina* L.). *Buana Science Journal, 21*(1), 99-108.

Kravchenko, A. G., & Thelen, K. D. (2007). Effect of winter wheat crop residue on no-till corn growth and development. *Agronomy Journal, 99*(2), 549-555. https://doi.org/10.2134/agronj2006.0192

Lingga, P., & Marsono, M. (2007). *Fertilizer Instructions for Use*. Jakarta: Penebar Swadaya.

Masria, M., Lopulisa, C., Zubair, H., & Rasyid, B. (2014). Mineral types and chemical properties of vertisol soils resulting from weathering of limestone in jeneponto regency. *Partner Journal, 24*(1), 879-887.

Masruhing, B., Hasrianti, H., & Abdullah, A. A. (2018). Growth and production response of sweet corn (*zea mays saccharata* sturt) plants at various doses of manure and liquid organic fertilizer. *Agrominansia Journal, 3*(2), 141-149.

Maydayana, A., Kusumo, B. H., Bakti, L. A. A., & Dewi, R. A. S. (2023). Pengaruh pemberian biochar terhadap perubahan sifat kimia tanah Vertisol dan pertumbuhan kacang hijau (*Vigna radiata* L.): The ımpact of biochar application on alterations in chemical properties of Vertisol soil and the growth of mung bean (*Vigna radiata* L.). *Jurnal Sains Teknologi & Lingkungan, 9*(4), 663-674.

Maroeto, M., Suntoro, W. A., Djoko, S., & Rossyda, P. (2017). Net farm ıncome as a reflection of critical land evaluation in welang watershed, Indonesia. *Bulgarian Journal of Agricultural Science, 23*(5), 826-833.

Meena, V. S., Maurya, B. R., Verma, J. P., & Meena, R. S. (2016). Potassium solubilizing microorganisms for sustainable agriculture. In V. S. Meena, B. R. Maurya, J. Prakash Verma, & Meena, R. S. (Eds.). *Potassium Solubilizing Microorganisms for Sustainable Agriculture* (pp. 1-20). New Delhi, India: Springer.

Mujiyo, M., Naaifah, M. I., Suntoro, S., & Maro'ah, S. (2023). A Comparative study of soil fertility in organic, semi-organic, and conventional rice field farming systems (Case Study: Nguntoronadi District, Wonogiri, Indonesia). *Yuzuncu Yıl University Journal of Agricultural Sciences, 34*(1), 44-61. https://doi.org/10.29133/yyutbd.1357044

Murnita, M., & Taher, Y. A. (2021). Dampak pupuk organik dan anorganik terhadap perubahan sifat kimia tanah dan produksi tanaman padi (*Oriza sativa* L.). *Menara Ilmu: Jurnal Penelitian dan Kajian Ilmiah, 15*(2), 1-10.

Nguyen, T. H., & Shindo, H. (2011). Effects of different levels of compost application on amounts and distribution of organic nitrogen forms in soil particle size fractions subjected mainly to double cropping. *Agricultural Sciences, 2*(3), 213.

Nilapwar, S. M., Nardell, M., Wasterhaff, H.V., & Verma, M. (2011). Absorption Spectroscopy. In *Methods in Enzymology* (pp. 59-75). Cambridge, MA, USA: Academic Press.

Noviarini, M., Subadiyasa, N. N., & Dibia, I, N. (2017). Production and quality of sweet corn (*Zea mays saccharata* Sturt.) due to chemical, organic, mineral fertilization, and their combination in ınceptisol soil of experimental garden of faculty of agriculture, Udayana University. *Journal of Tropical Agroecotechnology, 6*(4), 469-480.

OFSA (Office of Food Security and Agriculture of Purworejo Regency). (2021). Talenta sweet corn, tantalizing price. Consulted on August 15, 2024, retrieve from https://dkpp.purworejokab.go.id/jagung-manis-talenta-harga-yang-menggiurkan.

Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean, L. A. (1954). Estimation of available P in soils by extraction with sodium bicarbonate. Washington, D.C., USA: USDA.

Purba, S. T., Damanik, M. M. B., & Lubis, K. S. (2017). The effect of Fertilizer TSP and chicken manure on availability and phosphorus uptake and growth of maize on soil ınceptisol Kwala Bekala. *Jurnal Online Agroekoteknologi, 5*(3), 638-643.

Rizqullah, H., Sitawati, S., & Guritno, B. (2017). Pengaruh macam dan cara aplikasi pupuk organik terhadap pertumbuhan dan produksi tanaman jagung manis (Sturt.). *Journal of Crop Production, 5*(3), 383-389.

Saifulloh, A. A., & Suntari, R. (2022). Growth enhancement, uptake of N, P, K nutrients and production of maize in an entisol of kalidawir, tulungagung due to application of cow manure fertilizer and NPK fertilizer. *Jurnal Tanah dan Sumberdaya Lahan, 9*(1), 193-200.

Schoebitz, M., & Vidal, G. (2016) Microbial consortium and pig slurry to improve chemical properties of degraded soil and nutrient plant uptake. *Journal of Soil Science and Plant Nutrition, 16*, 226-236. http://dx.doi.org/10.4067/S0718-95162016005000018

Setiono, S., & Azwarta, A. (2020). Effect of cow manure on growth and yield of sweet corn plants (*Zea mays* L). *Journal of Agro Sciences, 5*(2), 1-8. https://doi.org/10.36355/jsa.v5i2.463

Sitorus, M. P., & Tyasmoro, S. Y. (2019). Effect of NPK fertilizer and cow manure on growth and yield of sweet corn plants (*Zea mays saccharata* Sturt). *Jurnal Produksi Tanaman, 7*(10), 1912-1919.

Soekamto, M. H. (2015). Assessment of soil fertility status in cocoa fields of klain village, Mayamuk District, Sorong Regency. *Agroforestry Journal, 10*(3), 201-208.

Sofyan, E. T., Sara, D. S., & Machfud, Y. (2019). The effect of organic and ınorganic fertilizer applications on N, P-uptake, K-uptake and yield of sweet corn (*Zea mays saccharata* Sturt). *IOP Conference Series: Earth and Environmental Science, 3939*(1), 111-116. https://doi.org/10.1088/1755-1315/393/1/012021

Soil and Fertilizer Standard Instrument Testing Center (2023). *Chemical Analysis of Soil, Plant, Water, and Fertilizer*. Bogor, Indonesia: Kementrian Pertanian Republik.

Sudadi, S., Putri, E. Y., & Suntoro, S. (2020). The use of biofilmed biofertilizer to improve soil chemical fertility and yield of upland kangkung (Ipomoea reptans) on Vertisol. *Planta Tropika, 8*(2), 83-92.

Sudjadi, M., Widjik, S., & Soleh, M. (1971). *Soil analysis manual. publication* No.10/71. Bogor, Indonesia: Soil Research Institute.

Sulaeman, Y., Maswar., & Erfandi, D. (2016). Effect of organic and inorganic fertilizer combinations on soil chemical properties, and maize yields in acidic drylands. *Jurnal Pengkajian Dan Pengembangan Teknologi Pertanian,20*(1), 1-12

Suntoro, S., Widijanto, H., Syamsiyah, J., Afinda, D. W., Dimasyuri, N. R., & Triyas, V. (2018). Effect of cow manure and dolomite on nutrient uptake and growth of corn (*Zea mays* L.). *Bulgarian Journal of Agricultural Science, 24*(6), 1020-1026.

Suntoro, S., Dewi, W. S., Syamsiyah, J., Mujiyo., Herdiansyah, G., Widijanto, H., & Herawati, A. (2023). Evaluation of land suitability as the basis for sustainable crop development. *Earth An Enviromental Science. 1228*(1), 1-13.

Suntoro, S., Mujiyo, M., Widijanto, H., & Herdiansyah, G. (2020). Cultivation of rice (*Oryza sativa*), corn (*Zea mays*) and soybean (Glycine max) based on land suitability. *Journal of Settlements and Spatial Planning, 11*(1), 9-16.

Syamsiyah, J., Herdiansyah, G., & Hartati, S. (2023a). Use of trichoderma as an effort to increase growth and productivity of maize plants. *IOP Conference Series: Earth and Environmental Science, 1165*(1), 1-6. https://doi.org/10.1088/1755-1315/1165/1/012020

Syamsiyah, J., Minardi, S., Khadaffi, J, Hartati, S., & Herdiansyah, G. (2023b). Partial substitution of inorganic fertilizers with organic materials on the availability of N, P, K and yield of maize in inceptisol soil. *Jurnal Agro, 10*(2), 242-251. https://doi.org/10.15575/27875

Terman, G. L., Noggle, J. C., & Hunt, C. M. (1976). Nitrate-N and Total N concentration relationships in several plant species 1. *Agronomy Journal, 68*(4), 556-560.

Ye, L., Zhao, X., Bao, E., Li, J., Zou, Z., & Cao, K. (2020). Bio-organic fertilizer with reduced rates of chemical fertilization improves soil fertility and enhances tomato yield and quality. *Scientific Report, 10*(177), 1-11. https://doi.org/10.1038/s41598-019-56954-2