

Response of nitrogen source and plant spacing to the physiology and yield of sweet corn (*Zea mays saccharata* Sturt)

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Abstract

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Sweet corn (*Zea mays saccharata* Sturt) has high public interest, as it encourages farmers to cultivate it. The nitrogen source is related to the plant's physiological response. In addition to nitrogen fertilizer, plant spacing in sweet corn cultivation also needs to be considered. Plant spacing refers to the distance between individual plants or a plant population. Therefore, it is essential to investigate these efforts to enhance the physiological response of plants. This research is a factorial experiment arranged according to a randomized complete block design (RCBD) with two factors. The first factor is the type of nitrogen source, specifically urea, at a rate of 350 kg.ha⁻¹ (Control), Urea 200 kg.ha⁻¹, ZA 200 kg.ha⁻¹, and KNO₃ 200 kg.ha⁻¹. The plant spacing is 70 cm x 20 cm, 70 cm x 30 cm, and 70 cm x 40 cm. Nitrogen source and plant spacing treatments did not show any significant interaction. The most effective combination is 200 kg of KNO₃ per hectare with a planting distance of 70 cm x 40 cm.

Keywords: Nitrogen sources, plant spacing, sweet corn.

Introduction

Sweet corn (*Zea mays saccharata* Sturt) is a horticultural commodity also known as sweet corn. The high public interest in sweet corn encourages farmers to cultivate it. Sweet corn is composed of the following nutrients per 100 g: 3.5 g of protein, 1.0 g of fat, 96 calories of energy, 22.8 g of carbohydrates, 0.7 mg of iron, 111 mg of phosphorus, and 72.7 g of water (Zulfahmi et al., 2025). Additionally, sweet corn can be harvested faster than field corn. Sweet corn can be used as an ingredient in the food and beverage industry, specifically for making corn sugar, corn syrup, and sweet corn yoghurt. Additionally, sweet corn can also be used to control insulin hormones for people with diabetes. Sweet corn production in Indonesia from 2020 to 2023 has fluctuated. This data indicates that national sweet corn production decreased by 12.5% from 2020 to 2023. Efforts to increase sweet corn production can be made by analyzing the physiological response of plants to the cultivation treatments applied.

The nitrogen source is related to the physiological response of the plant. Nitrogen plays a role in chlorophyll formation in corn plants. Sweet corn plants that receive nitrogen nutrients according to their needs will have leaves rich in chlorophyll. With an abundance of chlorophyll, the plants will find it easier to perform photosynthesis (Yunaning et al., 2022). Corn plants absorb nitrogen throughout their growth period until seed maturation, so they require a continuous supply of nitrogen from the growth phase until seed formation. Sources of nitrogen fertilizer in sweet corn cultivation can be obtained from the application of Urea, ZA, and KNO₃ fertilizers. In addition to nitrogen fertilizer, plant density in sweet corn cultivation also needs to be considered.

Plant spacing is the living space of a plant or plant population. The ideal planting distance can be determined by knowing the characteristics of the crop to be planted. Applying the ideal planting distance can reduce competition for water and nutrients between plants. To optimize nutrient absorption between plants, the planting spacing needs to be adjusted. The closer the spacing between plants, the greater the competition, resulting in lower production per unit area. Therefore, distance regulation is necessary to achieve optimal results (Kholid et al., 2023). Efforts to optimize the growth and development of sweet corn as a means of obtaining optimal yields. Many studies separate nitrogen factors or planting distance, but few

specifically integrate both for sweet corn. Therefore, this study focuses on the interaction of both in improving the physiological response and yield of sweet corn plants.

Materials and Methods

Study Area

The study was conducted in the Tahulu Village, located within the Merakurak District of Tuban Regency. The research was carried out between February 2025 and May 2025. This area is situated at an elevation of approximately 500 meters above sea level, with an average temperature range of 24°C to 33°C. Chlorophyll analysis was performed at the Biotechnology Laboratory, Faculty of Agriculture, Universitas Pembangunan Nasional Veteran Jawa Timur.

Equipment and Materials

The study utilized several pieces of equipment, including a hand tractor, shovel, hoe, Leaf Color Chart, measuring tape, rope, labels, and signboards. The materials employed in this research comprised sweet corn seeds of the NB SUPER F1 variety, as well as various fertilizers, including urea, ZA, KNO₃, SP-36, and KCl, in addition to cattle manure, Previcur N 722 SL, and Racumin 0.75 TP.

Experimental Design

This research is a factorial experiment arranged according to a randomized complete block design (RCBD). The factors are the type of nitrogen fertilizer, which consists of four treatment levels, and the plant spacing, which consists of three treatment levels. The nitrogen sources, specifically Urea 350 kg.ha⁻¹ (Control), Urea 200 kg.ha⁻¹, ZA 200 kg.ha⁻¹, and KNO₃ 200 kg.ha⁻¹. The planting spacing is specifically 70 cm x 20 cm, 70 cm x 30 cm, and 70 cm x 40 cm. The two treatment factors, each of which has been determined, result in 12 treatment combinations that were repeated three times, for a total of 36 experimental units. The population in each experimental unit was determined by the planting distance applied, resulting in differences in plant population among the three planting distances used in the treatment. Sampling for each experimental unit was conducted using the same method, with three uniform plants selected as samples.

Chlorophyll analysis (mg.L⁻¹)

Chlorophyll content was analyzed at 49 days after planting (DAP) by collecting leaf samples from each replicate and placing them in labeled zip-lock bags. In the laboratory, 5 g of leaf tissue was weighed, cut into small pieces, and ground in a mortar with 25 mL of 80% acetone. The extract was filtered through filter paper, and the filtrate was transferred into a 25 mL volumetric flask. Absorbance was measured at 663 nm and 645 nm using a spectrophotometer, and chlorophyll a, chlorophyll b, and total chlorophyll contents were calculated according to Harborne (1987):

$$\text{Chlorophyll a (mg.L}^{-1}\text{)} = (12,7 \times \text{OD } 663) - (2,69 \times \text{OD } 645)$$

$$\text{Chlorophyll b (mg.L}^{-1}\text{)} = (22,9 \times \text{OD } 645) - (4,68 \times \text{OD } 663)$$

$$\text{Total Chlorophyll (mg.L}^{-1}\text{)} = (20,2 \times \text{OD } 645) + (8,02 \times \text{OD } 663)$$

Leaf color

Leaf color was measured at 13 and 49 days after planting (DAP) using a Leaf Color Chart with scales ranging from 2 (yellowish green), 3 (light green), 4 (medium or deep green) and 5 (dark green), as shown in Figure 1. Observations were conducted in the morning on fully expanded upper leaves. The middle part of the leaf was compared against leaf color chart and intermediate values were recorded when leaf color chart fell between two scales (e.g., 3.5 between scales 3 and 4) (Erythrina, 1999).



Figure 1. Leaf Color Chart
(Witt et al., 2005)

Data analysis

The data were analyzed using analysis of variance (ANOVA) based on a randomized complete block design (RCBD). When treatment effects were significant, mean comparisons were performed using the honestly significant difference (HSD) test at the 5% level. The analysis was conducted using SPSS 9.4.

Result and Discussion

Leaf Color

Table 1. The Effect of Nitrogen Sources and Plant Spacing Treatments on Leaf Color

Treatments		Leaf Color	
		13	49
Nitrogen Souces			
Urea	350 kg.ha ⁻¹	2.06	3.98 b
Urea	200 kg.ha ⁻¹	2.02	3.94 a
ZA	200 kg.ha ⁻¹	2.02	3.82 a
KNO ₃	200 kg.ha ⁻¹	2.02	3.92 a
HSD 5%		ns	0.15
Plant Spacing			
	70 x 20 cm	2.06	3.82 a
	70 x 30 cm	2.00	3.92 a
	70 x 40 cm	2.03	4.00 b
HSD 5%		ns	0.10

Note: The numbers accompanied by the same letter in the same column show no significant difference in the HSD test at the 5% level. ns = not significant

Table 1 shows that the urea treatment at a dose of 350 kg.ha⁻¹ had the best effect on leaf color, measured using a leaf color chart at 49 DAP. Urea fertilizer had the best value compared to other treatment levels because the nitrogen content in urea at 350 kg.ha⁻¹ was the highest, at 161 kg N ha⁻¹. Additionally, nitrogen in urea is easily absorbed by plants. Consistent with the research by Fayaz et al. (2022), the accumulation of nitrogen that plants can absorb affects leaf color. The research results show that the urea treatment at a dose of 350 kg.ha⁻¹ yielded a value of 3.98. This value falls into the medium green category, indicating that the processes of nitrogen assimilation and chlorophyll synthesis are active. This statement is supported by the research of Muchhadiya et al. (2024). The greenness observed in the leaf color is related to the nitrogen assimilation process.

Additionally, the greenness level of the leaf color also indicates the nitrogen content within the plant. This aligns with the research by Shio et al. (2022), the darker the green color of the leaves, the higher the nitrogen content that the plant can absorb. Plant density at the 70 x 40 cm treatment had the most significant

effect on leaf color. The leaf color value at 49 days after planting (DAP) was 4.00. This value falls into the moderate green category. The green color indicates that the chlorophyll content in the leaves is sufficient for vegetative growth but less than optimal for generative growth. Chlorophyll affects the efficiency of photosynthesis. This aligns with the research by Zhang et al. (2021), which found that chlorophyll efficiency is closely related to the regulation of stomatal opening and leaf chlorophyll content in the 70 x 50 cm low-density treatment. Therefore, the intensity of sunlight received by the leaves increases. Conversely, if the high density of plants, the intensity of light received by the leaves will be low. The low intensity of light received by plant leaves is due to the overlapping leaf canopy. In that case, overlapping must be arranged by spacing. According to Du et al. (2021), a broad and dense leaf canopy causes leaves to overlap, resulting in lower leaves not photosynthesizing optimally.

Chlorophyll Content (mg.L⁻¹)

Table 2. Combination of Nitrogen Sources and Plant Spacing on Chlorophyll Content

Nitrogen Sources		Chlorophyll Content (mg.L ⁻¹)		
		Plant Spacing		
		70 x 40 cm		
		Chlorophyll a	Chlorophyll b	Total Chlorophyll
Urea	350 kg.ha ⁻¹	6,60	13,08	21,70
Urea	200 kg.ha ⁻¹	6,47	12,73	20,94
ZA	200 kg.ha ⁻¹	6,57	12,67	20,10
KNO ₃	200 kg.ha ⁻¹	7,17	11,19	20,76

Note: Calculation using Harbone's Method (1987)

Leaf sampling for chlorophyll content analysis was conducted using a planting spacing of 70 x 40 cm. Wider planting spacing generally provides more optimal growing space for plants, thus reducing competition among plants for light, water, and nitrogen nutrients, which are the main components of chlorophyll structure. Additionally, lower plant spacing, such as 70 x 40 cm, also allows plant leaves to receive more even and maximum light intensity. Good lighting conditions support increased chlorophyll production because photosynthesis occurs optimally. According to Jovanić et al. (2022), sunlight plays an important role in the activation of photosynthetic enzymes and chlorophyll biosynthesis. Physiologically, sufficient inter-plant spacing also contributes to the development of a wider root system, making nitrogen absorption more efficient. In line with the research by Syarifah et al. (2025), this can increase chlorophyll synthesis, as nitrogen is a building block of chlorophyll molecules.

The combination of 70 x 40 cm spacing and KNO₃ nitrogen sources yielded the highest average chlorophyll a analysis compared to all other treatment combinations. KNO₃ contains nitrogen in the form of nitrate (NO₃⁻) and potassium (K⁺). Research by Khudhair & Hamza (2024) found that nitrate, a form of nitrogen directly available to plants, is highly efficient for chlorophyll and enzymatic protein synthesis, while potassium plays a role in osmotic regulation, enzyme activity, and the photosynthetic process. The combination with a plant spacing of 70 x 40 cm creates a metabolic balance and supports the formation of green tissue because the roots can optimally absorb potassium. Thus, the combination of nitrate and potassium in a single-compound results in more stable physiological conditions, maximizes photosynthesis, and leads to higher chlorophyll accumulation compared to other nitrogen fertilizers that only provide one central element or have an antagonistic effect on metabolic processes.

The combination of a planting spacing of 70 x 40 cm and the nitrogen source urea at a dose of 350 kg.ha⁻¹ yielded the highest average values for chlorophyll b and total chlorophyll analysis compared to all treatment combinations. High levels of chlorophyll b and total chlorophyll are associated with high doses of urea. High doses of urea can stimulate reductase enzyme activity and the synthesis of photosynthetic pigments, including chlorophyll b, which plays a role in absorbing additional light and facilitating energy transfer to other pigments. According to Feng et al. (2024), this results in an increase in total chlorophyll accumulation. On the other hand, under wide spacing conditions, a high dose of nitrogen can increase leaf greenness. Research by Cassim et al. (2024) indicates that a high nitrogen dose can increase the photosynthetic surface area, maintain metabolic capacity, and enable plants to absorb light more efficiently.

Sweetness Index (°Bx)

Tabel 3. Combination Nitrogen Sources and Plant Spacing Treatments on Sweetness Index

Nitrogen Sources	Sweetness Index (°Bx)		
	Plant Spacing		
	70 x 20 cm	70 x 30 cm	70 x 40 cm
Urea 350 kg.ha ⁻¹	12,56 a	12,89 a	12,66 a
Urea 200 kg.ha ⁻¹	13,11 a	12,66 a	13,78 a
ZA 200 kg.ha ⁻¹	13,56 a	13,67 a	13,55 a
KNO ₃ 200 kg.ha ⁻¹	12,57 a	13,33 a	14,33 b
HSD 5%	1,43		

Note: The numbers accompanied by the same letter in the same column show no significant difference in the HSD test at the 5% level.

The combination of 70 x 40 cm spacing and nitrogen fertilizer type KNO₃ at a dose of 200 kg.ha⁻¹ provided the best significant interaction on the sweet corn sweetness index parameter, with value of 14.33 °Bx. Proper nutrient availability and optimal spacing can increase sugar accumulation in sweet corn ears. KNO₃ fertilizer contains nitrate nitrogen and potassium that are quickly available and easily absorbed by plants. According to Fitriyah et al. (2024), potassium plays a crucial role in the process of translocating the products of photosynthesis, which ultimately affects the formation of simple sugars and, consequently, sweetness levels. Appropriate planting distances can support optimizing potassium element absorption. The combination with a planting distance of 70 x 40 cm can reduce competition between plants in absorbing potassium for sugar formation, which affects the sweetness level at that planting distance due to the low plant population. This aligns with the research by Desta et al. (2025), which found that the combination of KNO₃ fertilization and wider planting distances can support the optimization of the photosynthetic process and the distribution of photosynthates, thereby increasing the sugar content in the cobs.

Weight per ear without husk

Table 4. Nitrogen Sources and Plant Spacing Treatments on Weight per ear without husk

Weight per ear without husk (g)	
Nitrogen Sources	
Urea 350 kg.ha ⁻¹	285,52 a
Urea 200 kg.ha ⁻¹	290,59 b
ZA 200 kg.ha ⁻¹	261,93 a
KNO ₃ 200 kg.ha ⁻¹	260,52 a
HSD 5%	28,80
Plant Spacing	
70 x 20 cm	260,94 a
70 x 30 cm	268,50 a
70 x 40 cm	294,47 b
HSD 5%	20,63

Note: The numbers accompanied by the same letter in the same column show no significant difference in the HSD test at the 5% level.

Applying urea at a rate of 200 kg.ha⁻¹ resulted in the highest husk-free cob weight. This indicates that the nitrogen availability at that level is sufficient to support chlorophyll synthesis and photosynthetic activity, ensuring that the assimilates produced are adequate for seed filling. According to Nazirah (2025) a moderate nitrogen dose can enhance ear development by maintaining a good source-sink balance, where photosynthates are more efficiently allocated to ear growth compared to vegetative biomass accumulation. Conversely, applying nitrogen at lower doses leads to nutrient deficiency, reducing leaf area and photosynthetic capacity, and limiting assimilate allocation to the cob. Meanwhile, higher doses tend to promote excessive vegetative growth, decrease nitrogen use efficiency, and restrict the distribution of assimilates to the grain. Therefore, the optimal dose of 200 kg.ha⁻¹ can increase the agronomic efficiency of nitrogen and maximize grain filling, resulting in the highest cob weight without husks.

The 70 x 40 cm spacing treatment provided the best significant effect on the weight of an ear without husks, at 294.47 g. This is because at wider spacing, competition between plants for light, water, and nutrients is reduced, allowing each plant to obtain more optimal resources for generative growth. A wider growing environment can enhance carbon assimilation and photosynthetic efficiency, which in turn improves ear filling and increases diameter. This finding is consistent with the research of Krizsán et al. (2024), which states that increasing planting distance improves the development of reproductive organs and increases the size of individual yields due to better assimilate distribution.

Conclusion

The most effective combination is 200 kg of KNO_3 per hectare with a planting distance of 70 cm x 40 cm. The nitrogen source KNO_3 has the best effect on leaf color parameters at 49 DAP and the highest chlorophyll a analysis value. The best single-factor treatment for plant spacing is 70 x 40 cm, as it has the most significant effect on leaf color parameters at 49 DAP, weight per ear without husk, and the highest values for chlorophyll b and total chlorophyll analysis parameters.

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