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The interaction of nitrogen and potassium nutrients in increasing growth, yield, and quality of sweet corn products

Abstract. Fertilizer application is a strategy that can be used to increase sweet corn production and maintain environmental balance. This research aims (i) to determine the optimal dose of nitrogen and potassium fertilizers for sweet corn production; (ii) to study the agronomic and physiological responses of sweet corn plants at different nitrogen and potassium dose; and (iii) to determine the nitrogen (N) and potassium (K) nutrient uptake and efficiency by sweet corn at different fertilizer doses and their interactions on yield and yield quality. The research was conducted from March to November 2022 in the Faculty of Agriculture, Universitas Jenderal Soedirman. The experimental design used was a randomized block design. The treatments tried were N doses (0 kg ha^{-1} (N_0), 100 kg ha^{-1} (N_1), 200 kg ha^{-1} (N_2)) and K doses (0 kg ha^{-1} (K_0), 75 kg ha^{-1} (K_1), 150 kg ha^{-1} (K_3)). Each treatment was repeated three times. The observational data were analyzed using analysis of variance to determine the effect of treatment. If the results differed significantly, Duncan's multiple range test (α=5%) was performed. Variables observed included growth traits, yield and yield components, physiological, biochemical, nutrient uptake and efficiency, and sweetness level. The experimental results showed that nitrogen dosage had a significant influence on growth traits, yield, and yield components, physiological, biochemical, nutrient uptake and efficiency, and sweetness level. The K dosage had a significant influence on N and K nutrient uptake. The interaction between a N dose of 100 kg ha^{-1} and a K dose of 150 kg ha^{-1} shows the best values for plant growth rate and potassium uptake.

Keywords: Efficiency · Nitrogen · Nutrient uptake · Potassium · Sweet corn

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Introduction

The demand for sweet corn (*Zea mays* saccharata) continues to increase, not merely due to its sensory appeal, such as sweeter taste and tender texture, but primarily because of its distinct end-use compared to field corn. Unlike regular corn which is mainly cultivated for animal feed, industrial raw materials, or grain processing, sweet corn is specifically grown for direct human consumption due to its high sugar content, lower starch level, and shorter harvest period (Jafarikouhini et al., 2020). This makes sweet corn more suitable for fresh markets, ready-to-eat products, and culinary uses, thereby driving its rising demand. The domestic productivity of sweet corn is still relatively low compared to other producing countries due to an unsuitable cultivation system. The average productivity of sweet corn in Indonesia is only 8.31 tons/ha, while the yield potential of sweet corn can reach 14-18 tons/ha (Supriyanta et al., 2023).

Market demand for sweet corn continues to increase, but major market opportunities cannot be fully exploited by Indonesian farmers and entrepreneurs due to various constraints (Godoy et al., 2014). It is believed that the growth and yield quality of sweet corn are influenced by environmental factors, particularly soil fertility. When managed properly, soil fertility can help make sweet corn production more cost-effective and labor-efficient, while ensuring consistently high yields.

Increasing sweet corn yield and quality will not result in high actual yields in the field without proper environmental and nutritional management. Fertilizer application is one of the main strategies to improve sweet corn productivity and maintain soil health (Hou et al., 2025). Nitrogen (N) is a macronutrient essential for vegetative growth, chlorophyll synthesis, and protein formation. However, the availability of N in the soil is naturally low, making fertilization necessary. Unfortunately, excessive or imbalanced application can reduce nutrient use efficiency and cause environmental harm (Barłóg et al., 2022; Kurniadie, 2002). The efficiency of N fertilization is reported to be only around 33% of the applied dose (Hameed et al., 2019).

In addition to nitrogen, potassium (K) is another crucial macronutrient that plays a key role in improving photosynthesis, strengthening cell walls, and regulating sugar accumulation in maize (Hafsi et al., 2014; Wu et al., 2024). Importantly, N and K have interactive effects in the soil-plant system (Sedri et al., 2022). Potassium helps balance excessive nitrogen uptake by preventing luxury consumption and promoting better nutrient distribution within the plant (Kang et al., 2015). A sufficient K supply enhances nitrogen use efficiency, while a K deficiency may worsen N-related imbalances, leading to poor plant structure and lower yields (Ye et al., 2021). Therefore, a balanced application of N and K is essential to optimize nutrient uptake, growth, and yield quality in sweet corn production systems.

Corn growth is affected by several environmental factors such as growing season, climatic conditions, water availability, and soil conditions, which can also affect sweet corn yield and quality. Soil moisture can significantly influence sugar content in sweet corn (Motazedian et al., 2019; Zarei et al., 2019). The presence of plant debris on the soil surface can also affect sweet corn plant growth and macronutrient mobilization (Mehta et al., 2020).

Sweet corn development in Indonesia is gaining traction among researchers, but adoption among farmers remains limited. To support optimal yield and quality, effective cultivation strategies—especially proper N and K management—are essential. Efficient nutrient uptake and tailored environmental practices are also critical components in improving productivity. This study aimed to: a) determine the optimal N and K fertilizer rates for sweet corn production; b) evaluate the agronomic and physiological responses of sweet corn to varying N and K levels; and c) assess the efficiency of N and K uptake and their potential interaction effects on yield and quality.

Materials and Methods

The research was conducted at the Experimental Farming area, Faculty of Agriculture, Universitas Jenderal Soedirman, Indonesia, situated at an altitude of 110 meters above sea level. The soil at the study site is classified as Inceptisol, with a dusty clay loam texture, a slightly acidic pH of 6.5, and a cation exchange capacity (CEC) of 19.96 cmol kg^{-1}. The soil has a C/N ratio of 12 and contains 2.47% organic carbon. In terms of nutrient availability, the soil contains 12 ppm nitrogen (N), 70 ppm phosphorus (P_2O_5), and 484 ppm potassium (K_2O), indicating moderate nitrogen content and high potassium availability. These baseline conditions provide critical context for evaluating the plant response to added N and K fertilizers in this study. The research was conducted from March to November 2022.

Materials used in this study were Bonanza sweet corn seed, aquadest, acetone, sulfuric acid, urea fertilizer, KCl fertilizer, chemicals for ANR analysis, nitrogen analysis, and potassium analysis, filter paper, tissue, and pesticides. Tools used include test tubes, graduated pipettes, measuring cups, erlenmeyer, beaker's glass, spectrophotometers, micrometers, microscopes, Kjedahl, flame photometers, SPAD chlorophyll meters, polybags, ovens, analytical scales, seed counters, scales, analytical scales, seed counters, porcelain cups, materials, and stationery.

The design used in this study was a factorial randomized block design. The factors tested were N and K fertilizer doses. The N fertilizer factor consisted of 0 kg ha^{-1} (N_0), 100 kg ha^{-1} (N_1), and 200 kg ha^{-1} (N_2). The K fertilizer factor consisted of 0 kg ha^{-1} (K_0), 75 kg ha^{-1} (K_1), and 150 kg ha^{-1} (K_3). Nine combination treatments were repeated three times to obtain 27 experimental units. The plants were maintained with optimal irrigation (field capacity) and phosphate fertilization at a dose of 150 kg ha^{-1} in the form of SP-36 fertilizer.

The observed variables consist of growth variables (plant height (2, 4, 6, 8 weeks after planting/WAP), leaf area (3, 5, 7 WAP), leaf dry weight (75 days after planting/DAP), stomatal opening width (40 DAP), stomatal density (40 DAP), root length (3, 5, 7 WAP), shoot/root ratio (3, 5, 7 WAP) and plant dry weight (75 DAP)), yield variables and yield components (cob length, cob diameter, cob weight with husk and cob weight without husk), physiological characteristics (3, 5, 7 WAP), biochemical characteristics (7 WAP), nutrient uptake and nutrient use efficiency (7 WAP), yield and yield quality (harvest time).

1. Physiological characteristics consisting net assimilation rate (NAR) (Rajput, 2017) and relative growth rate (RGR).

   $$NAR = \frac{(W2-W1)(\ln(L2)-\ln(L1))}{(t2-t1)(L2-L1)}\, g\ cm^{-2}\ week^{-1}$$

   Where: W2 and W1 are the dry weight of the plants at the first and second destruction, L1 and L2 are the areas of the rice plants at the first and second destruction, t1 and t2 are the first and second destruction times of the plants.

   RGR was calculated using the method (Sridevi & Chellamuthu, 2015)

   $$RGR = \frac{W2-W1}{G\ (t2-t1)}\, g\ cm^{-2}\ week^{-1}$$

   Where: W1 and W2 are the dry weight of the plants at the destruction times t1 and t2. G is the land area occupied by plants.
2. Biochemical characteristics (content of chlorophyll a and b of the leaves using the colorimetric method with a spectrophotometer, as well as analysis of nitrate reductase (ANR) was determined with the Yoshida et al. (1976) method:

   Chlorophyll content was reported in Yoshida et al. (1976) measured using the Holden method (1965) by extraction with the organic solvent acetone. Rice leaf samples were collected at eight weeks after planting, with each sample weighed precisely at 0.1 g. The leaf samples were ground with a mortar and pestle, and 10 ml of 80% acetone was added. The leaf extract was filtered with Whatman No. 1 filter paper, and the solution was collected in a test tube. The absorbance of the chlorophyll extract solution was measured with a spectrophotometer at λ 645 nm and 663 nm. The chlorophyll content of the leaves was calculated using the following formula:

   Chlorophyll a = 0.0127 (OD 663) – 0.00269 (OD 645)

   Chlorophyll b = 0.0229 (OD 645) – 0.00468 (OD 663)

   Total Chlorophyll = 0.0202 (OD 645)– 0.00802(OD 663)

   Nitrate reductase (ANR) activity was reported in Yoshida et al. (1976) . Rice plant leaves were removed, cleaned with blotting paper and cut into small pieces. A total of 300 mg of leaf pieces was placed in a dark test tube, 5 ml of phosphate buffer pH 7.5 was added, and the leaves were soaked for 24 hours. After 24 hours, the buffer was discarded and replaced with 4.9 ml of fresh phosphate buffer, then 0.1 ml of 5 M NaNO3 solution was added as a substrate for nitrate reductase enzyme and incubated for 3 hours. The test tube was filled with 0.2 ml of 1% sulfanilamide solution and 0.2 ml of 0.02% naphthyl ethylene diamine solution in 3N HCl. A total of 0.1 ml of the solution was

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placed in a test tube filled with nitrite dye and allowed to wait for 10 to 15 minutes until it turned pink. 9.5 ml of distilled water was added to the solution. The solution in the test tube was shaken and transferred to a cuvette. Their absorbance was then measured at a wavelength of 540 nm using a spectrophotometer. ANR is expressed as the number of moles of nitrite formed per gram of fresh weight of the sample per hour.

ANR =AsA0x1000Bx17xx5001000 μmol NO_2^- *jam*$^{-1}$

Where: As: absorbance value of sample solution, Ao: standard absorbance value (0,0106 or 0,0142), B: Fresh weight of sample leaves (= 300 mg), T: incubation time.

3. Nitrogen analysis in plant tissue according to the Kjeldahl method (Yoshida et al., 1976). The nitrogen content in the tissue is then used to determine the nitrogen uptake of the sweet corn plants using the following formula:

   Nitrogen uptake = %N in plant tissue x dry weight

   The N use efficiency was measured using the method of Good et al. (2004), where the efficiency of agronomist was calculated using the following formula:

   NUE (g g^{-1}*) = Shoot weight/N*

   Where: NUE: Nitrogen Use Efficiency, N: % N in plant tissue.
4. Measurement of sweetness/sugar content with a digital refractometer.

The data obtained were analyzed using ANOVA, and if they differed significantly, they were further analyzed with the Duncan's multiple range test with a confidence level of 95%. A regression analysis was performed to obtain the optimal dose.

Results and Discussion

Observations on sweet corn plants included various parameters encompassing growth characteristics, physiology, biochemistry, yield and yield quality, and nutrient uptake and efficiency. Based on the analysis of variance in Table 1, nitrogen fertilizer application significantly influenced the growth characteristics of sweet corn. The dose of 200 kg ha^{-1} showed the most pronounced effect, particularly on plant height, leaf area, plant dry weight, and stomatal width. These findings are consistent with previous studies showing that nitrogen doses of 100 and 200 kg ha^{-1} result in optimal plant height (Zangani et al., 2021), leaf expansion, and stomatal development. The improved growth is attributed to nitrogen's role in promoting cell division and enlargement, especially in the apical meristems (Asfaw, 2022), as well as its essential function in chlorophyll and protein synthesis (Zayed et al., 2023).

However, the analysis did not reveal any significant interaction effects between nitrogen and potassium on all observed growth parameters. This absence of interaction might be due to the already sufficient availability of potassium in the soil (484 ppm K_2O), as indicated in the site's physicochemical characteristics. Under such high baseline potassium levels, additional K fertilization may not further enhance growth, thereby minimizing its interactive effect with nitrogen (Pandey, 2024). Moreover, potassium's primary physiological role tends to be more pronounced in later developmental stages such as carbohydrate translocation and stress resilience, rather than early vegetative growth, which is dominantly driven by nitrogen availability (Sustr et al., 2019).

Table 1. Effect of Nitrogen dan Potassium doses on the sweet corn growth characteristics

Treatment	Plant Heigh (cm)	Leaf Area (cm^2)	Shoot-Root Ratio	Plant Dry Weight (g)	Stomatal Width Opening (μm)	Stomatal Density (unit mm^{-2})
Nitrogen dose						
0 kg ha^{-1}	66.77 b	102.05 b	3.34 c	29.00 c	0.25 b	0.12 a
100 kg ha^{-1}	83.80 a	155.58 a	7.05 b	89.78 b	0.33 a	0.11 ab
200 kg ha^{-1}	85.58 a	162.33 a	8.86 a	108.45 a	0.34 a	0.10 b
Potassium dose						
0 kg ha^{-1}	76.42 b	142.51 a	6.49 a	76.26 a	0.32 a	0.11 a
75 kg ha^{-1}	78.36 ab	139.65 a	6.48 a	79.65 a	0.32 a	0.11 a
150 kg ha^{-1}	82.38 a	137.80 a	6.39 a	71.32 a	0.28 a	0.11 a

Note: Means followed by the same lowercase alphabet in the same column are not significantly different based on Duncan's multiple range test at 5 %.

Statistically, the dose of 200 kg ha^{-1} nitrogen fertilizer showed higher values than the control value compared to the control and the dose of 100 kg ha^{-1} in terms of the parameters of shoot-root ratio and plant dry weight. Nitrogen utilization in plants can result in faster vegetative growth, elongated stems, larger leaves, and greener leaf color (Gardner et al., 1991). Higher dry weight indicates a more efficient and productive photosynthesis process, tissue cells develop larger and faster, and plant growth is better (Sembada et al., 2024). Table 1 shows that growth is manifested by an increase in size, reflects an increase in protoplasm, and is characterized by an increase in the dry weight of the plant (Utomo et al., 2016). The major components of plant dry matter are biomass, which consists of cell wall polysaccharides and lignin, as well as cytoplasmic components such as proteins, lipids, amino acids, and organic acids (Shivakumar et al., 2024).

Table 1 also shows that the parameters stomatal aperture width and stomatal density can be used to express the amount of leaf area that performs the photosynthesis process (Q. Yin et al., 2020). Stomatal closure is a plant response to limited water availability, minimizing water loss but also restricting CO_2 uptake, thereby reducing photosynthesis and inhibiting seedling growth. The amount of transpiration is also determined by the width of the stomatal aperture, which is caused by differences in turgor pressure in the guard cells. Increased stomatal resistance under stress indicates the efficiency of water conservation in the species (Widodo et al., 2016).

The results of the study also showed that the provision of potassium fertilizers had an effect on the variables of plant height, but had no effect on leaf area, shoot-root ratio, plant dry weight, stomatal width, and stomatal density. The provision of potassium fertilizer is not directly visible because the potassium element acts as an enzyme activator and can open and close stomata in the metabolism of plants, thus increasing photosynthesis and shifting photosynthesis from the leaves, which will later be used for the actively growing part, namely the apical meristem (Xu et al., 2020). K is a nutrient that is very sensitive to leaching, especially in tropical areas with high rainfall, which is why potassium in the soil is often considered a limiting factor (Bender et al., 2013). Potassium is taken up by plants in very large quantities and sometimes exceeds nitrogen, especially in tuber crops, but potassium availability is limited (Jan & Hussan, 2022).

The application of nitrogen fertilizer influenced several physiological and biochemical characteristics of sweet corn plants, as shown in Table 2. Although the nitrogen dose of 200 kg ha^{-1} numerically showed the highest values for relative growth rate (RGR), chlorophyll b content, and nitrate reductase activity (ANR), statistical analysis indicated no significant difference compared to the 100 kg ha^{-1} dose for RGR and chlorophyll-a content. Similarly, net assimilation rate (NAR) also did not differ significantly between the 100 and 200 kg ha^{-1} nitrogen treatments. However, both 100 and 200 kg ha^{-1} nitrogen doses significantly improved plant physiological and biochemical parameters compared to the control (0 kg ha^{-1}), particularly in terms of nitrate reductase activity and chlorophyll b content. Chlorophyll is a biochemical component and a key ingredient in the photosynthesis process, as well as a component of a plant's health indicator. Its interaction with water, temperature, nutrient availability, CO2, and sunlight can affect the rate of photosynthesis (Muñoz-Ortuño et al., 2017; Olivera Viciedo et al., 2021). Providing nitrogen at the right dose not only promotes the growth of maize plant weight, but also affects the increase in biomass productivity through photosynthesis and net assimilation (Pérez-Álvarez et al., 2024). This increase can also be caused by stopping the transfer of assimilates to male flowers. Since male flowers are absent, the assimilates are only directed to the producing parts that need them, namely the seeds (Kumar et al., 2023). Providing synergistic nitrogen will certainly also increase the seed yield and quality of maize seeds, and the interaction between leaf cuttings and male flower cuttings can also affect the distribution of assimilates between reproductive and vegetative organs (Heidari, 2013).

Nitrogen is a very important nutrient for plant growth (Leghari et al., 2016), as it functions as a part of amino acids, proteins, and chlorophyll pigment components that are important in the photosynthesis process (Fathi, 2022). When plants are supplied with the N element, they have a content of green leaf substance, which is very important for the process of photosynthesis (Bassi et al., 2018). Providing this element can also accelerate growth and increase plant height, which is influenced by the availability of nutrients such as nitrogen, phosphorus, and potassium (Razaq

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et al., 2017; Xu et al., 2020). Maize plants require high N content of nutrients, where N nutrients can be taken up by maize plants by 55-60%, P by 20%, and K by 50-70%. Lack of availability inhibits the growth and production of maize plants (Syafruddin et al., 2021).

Table 2 shows that potassium fertilization significantly affected the Net Assimilation Rate (NAR), but had no significant effect on Relative Growth Rate (RGR), chlorophyll a and b content, and nitrate reductase activity. Interestingly, among all the physiological and biochemical parameters, only RGR showed a statistically significant interaction between nitrogen and potassium applications (Table 3). The highest RGR value was observed in the 200 kg N ha^{-1} + 0 kg K ha^{-1} treatment (1.22 g dm^{-2} week^{-1}); however, this value was not significantly different from several other combinations, including 200 kg N ha^{-1} + 75 kg K ha^{-1} and 200 kg N ha^{-1} + 150 kg K ha^{-1}, which all shared the same statistical grouping. This indicates that while interaction exists, it does not show a clear superiority of one N–K combination over another within the tested levels. For other physiological variables, no significant interaction between N and K was found, suggesting that nitrogen plays a more dominant role in influencing sweet corn physiological traits, while potassium's effect might be more nuanced or masked under certain environmental conditions. Although potassium is crucial for photosynthetic efficiency and enzymatic activities (Hasanuzzaman et al., 2018; Xu et al., 2020), its independent effect may be limited under sufficient nitrogen conditions and specific environmental settings (Jalilian & Delkhoshi, 2014).

Table 3 shows that a significant interaction was observed between nitrogen and potassium doses on the relative growth rate (RGR). The highest RGR (1.07 g g^{-1} week^{-1}) was achieved under the combined application of 200 kg ha^{-1} nitrogen and 150 kg ha^{-1} potassium. This suggests that optimal N-K synergy enhances biomass accumulation, with nitrogen supporting vegetative growth and potassium facilitating physiological efficiency. Nitrogen fertilizer helps to increase the growth rate of plant tissue, for example, by stimulating the growth of young leaves (Rutkowski & Łysiak, 2023; Singh et al., 2014). The more leaves a plant produces, the more chlorophyll is absorbed by the leaves, which increases the yield of maize plants(S. Huang et al., 2017). Nitrogen is one of the nutrients that can directly and indirectly affect plant growth (Anas et al., 2020; Jaiswal et al., 2021) and plays a role in increasing the energy of plant cells by increasing the ion exchange capacity (Bloom, 2015). Potassium has a balancing effect on excess nitrogen in plants (Li et al., 2022). The requirement of potassium in maize plants varies depending on the needs of ongoing processes (Oosterhuis et al., 2014), such as photosynthesis and CO2 fixation, photosynthetic transfer to different users, and its relationship with water in plants (Yang et al., 2021).

Table 2. Effect of Nitrogen and Potassium doses on the sweet corn physiology and biochemical characteristics

Treatment	Net Assimilation Rate (g dm^{-2} week^{-1})	Relative Growth Rate (g dm^{-2} week^{-1})	Chlorophyll a Content (mg g^{-1})	Chlorophyll b Content (mg g^{-1})	Analysis of Nitrate Reductase (μmol NO_2 g^{-1} h^{-1})
Nitrogen dose					
0 kg ha^{-1}	2.16 b	0.41 b	0.017 b	0.006 c	2.881 c
100 kg ha^{-1}a	7.95 a	0.53 ab	0.026 a	0.012 b	5.121 b
200 kg ha^{-1}	7.85 a	0.56 a	0.028 a	0.016 a	6.537 a
Potassium dose					
0 kg ha^{-1}	6.25 ab	0.55 a	0.024 a	0.012 a	6.116 a
75 kg ha^{-1}	4.96 b	0.44 a	0.023 a	0.011 a	3.612 a
150 kg ha^{-1}	6.74 a	0.51 a	0.024 a	0.011 a	4.810 a

Note: Means followed by the same lowercase alphabet in the same column are not significantly different based on Duncan's multiple range test at 5 %.

Table 3. Interaction between Nitrogen dan Potassium doses on the sweet corn relative growth rate

	Potassium		
Nitrogen	0 kg ha^{-1}	75 kg ha^{-1}	150 kg ha^{-1}
0 kg ha^{-1}	0.53 Bc	0.81 Ab	0.58 Bb
100 kg ha^{-1}a	0.90 Ab	0.91 Aab	1.07 Aa
200 kg ha^{-1}	1.22 Aa	1.06 Aa	1.07 Aa

Note: Means followed by the same uppercase alphabet in the same row and lowercase alphabet in the same column are not significantly different based on Duncan's multiple range test at 5 %.

Table 4. Effect of Nitrogen dan Potassium doses on the sweet corn yield and yield quality

Treatment	Cob Length (cm)	Cob Diameter (mm)	Cob Weight with Husk (g)	Cob Weight without Husk (g)	Sweetness Level (°brix)
Nitrogen dose					
0 kg/ha	17.81 b	37.50 c	111.39 c	75.25 c	9.00 b
100 kg/ha	**25.70 a**	51.86 b	296.99 b	195.95 b	14.00 a
200 kg/ha	26.41 a	**57.47 a**	**370.89 a**	**256.97 a**	14.89 a
Potassium dose					
0 kg/ha	23.37 a	48.51 a	242.38 a	170.85 a	12.44 a
75 kg/ha	22.56 a	48.50 a	264.06 a	171.75 a	12.33 a
150 kg/ha	24.00 a	49.81 a	272.84 a	185.57 a	13.11 a

Note: Means followed by the same lowercase alphabet in the same column are not significantly different based on Duncan's multiple range test at 5 %.

Table 5. Effect of Nitrogen dan Potassium doses on the nutrient uptake and nutrient use efficiency

Treatment	Nitrogen uptake (%)	Potassium uptake (%)	Nitrogen use efficiency (%)	Potassium use efficiency (%)	Nitrogen agronomic efficiency (%)	Potassium agronomic efficiency (%)
Nitrogen dose						
0 kg/ha	10.38 c	28.45 c	24.77 b	9.47 b	-	-
100 kg/ha	78.81 b	184.04 b	62.91 a	26.10 a	85.53 a	-
200 kg/ha	116.62 a	241.57 a	62.10 a	29.95 a	55.87 b	-
Potassium dose						
0 kg/ha	65.42 b	141.97 b	50.84 a	23.17 a	-	-
75 kg/ha	63.75 b	143.58 b	54.72 a	23.46 a	-	17.34 a
150 kg/ha	76.64 a	168.51 a	44.27 a	19.78 a	-	12.95 a

Note: Means followed by the same lowercase alphabet in the same column are not significantly different based on Duncan's multiple range test at 5 %.

The application of nitrogen fertilizer affected the yield and yield quality of sweet corn plants, as shown in Table 4. A nitrogen dose of 200 kg ha^{-1} significantly increased cob diameter, cob weight with husk, and cob weight without husk compared to the other treatments. Although cob length and sweetness level appeared higher in plants treated with 100 kg ha^{-1} nitrogen, statistical analysis showed no significant difference between the 100 and 200 kg ha^{-1} nitrogen doses for these two variables. Nitrogen fertilization improved cob weight significantly, with increases of 33.87%, 56.02%, and 77.97% observed at doses of 50, 100, and 200 kg ha^{-1}, respectively, demonstrating the positive role of nitrogen in enhancing yield components (Afrida et al., 2024). Proper fertilization during the maize growth period increases maize yield if applied properly (gradually) to prevent leaching or evaporation (N. Wang et al., 2023). Nitrogen is important for the production and storage of carbohydrates. Therefore, plants that produce large amounts of carbohydrates have a high nitrogen requirement (Gardner et al., 1991). One of the functions of nitrogen is to improve the quality of fruits during the reproductive period (Novizan, 2002). Nutrients taken up by plants are used to form proteins, carbohydrates and fats (Švarc et al., 2022), which are then stored in the seeds and increase the weight of the cobs (Govender et al., 2008).

Table 4 shows that there was no significant interaction between nitrogen and potassium treatments on any of the yield and yield quality parameters, including cob length, cob diameter, cob weight with husk, cob weight without husk, and sweetness level. Additionally, the application of potassium fertilizer alone did not result in any significant improvements in these traits. One possible explanation is the limited availability of potassium in the soil due to its chemical form. Only 1–2% of total soil potassium exists in an exchangeable and plant-available form, while the majority—approximately 18–20%—is fixed in mineral structures and not readily accessible to plants (Buckman & Brady, 1982). This slow-release nature of potassium may have reduced its effectiveness within the crop cycle, especially if the timing of availability did not align with the critical growth phases of sweet corn.

The availability of nutrients required by plants can be ensured by adding suitable nitrogen fertilizers to accelerate the uptake of nutrients (Plett et al., 2020). This can certainly lead to the optimum production of plants. Nitrogen is the most important supporting element for the growth process, development, and determining the quality of plant yields (Hameed et al., 2019). Plants require large amounts of nitrogen to grow. Nitrogen is also the most important macronutrient that makes up proteins and is the main constituent of protoplasm, chloroplasts, and enzymes (Kumar et al., 2023). The role of nitrogen is related to photosynthetic activity and is therefore required for metabolism and respiration (Noor et al., 2023).

The application of nitrogen fertilizer significantly influenced nutrient uptake and nutrient use efficiency in sweet corn (Table 5). Nitrogen doses of 100 kg ha^{-1} and 200 kg ha^{-1} both led to significantly higher nitrogen uptake, potassium uptake, and nitrogen agronomic efficiency compared to the control. Among these, the 200 kg ha^{-1} dose showed the highest values. However, for nitrogen use efficiency and potassium use efficiency, there was no statistically significant difference between the 100 kg ha^{-1} and 200 kg ha^{-1} treatments, indicating that increasing nitrogen beyond 100 kg ha^{-1} did not further improve the efficiency of nutrient utilization. This suggests that while higher nitrogen input boosts nutrient uptake, it does not necessarily translate into more efficient nutrient use (Table 5). Plants absorb about 33% of the total nitrogen supplied, the rest is lost through chemical and biological processes (Fageria & Baligar, 2005). To achieve optimal results, a correct and appropriate dosage is required when applying nitrogen to sweet corn plants, as increasing the nitrogen dosage to sweet corn does not necessarily result in an increase in yield under the same cropping system (Wang et al., 2023).

Optimal nitrogen supply can support optimal plant growth and production. Sufficient nitrogen supply is characterized by high photosynthetic rates, good vegetative growth, and dark green plant color (M. Huang et al., 2019; Munawar, 2011). Increasing nitrogen use efficiency in sweet corn shows that providing nitrogen at the right dose can increase its use efficiency, so that it can support plant growth, physiological, and production processes (Tamagno et al., 2024). Nitrogen uptake by plants increases with the addition of nitrogen fertilizer, and increased nitrogen uptake is associated with increased nitrogen availability in the soil (Govindasamy et al., 2023; Liu et al., 2017). Nitrogen functions as a component of amino acids, proteins, chlorophyll, nucleic acids, and coenzymes (Munawar, 2011; X. M. Yin et al., 2014). Higher N doses lead to stronger plant growth (Qiao et al., 2013).

Table 5 indicates that there was no significant interaction between nitrogen and potassium doses on nutrient uptake and efficiency variables, including nitrogen use efficiency (NUE), potassium use efficiency (KUE), and nitrogen agronomic efficiency (NAE). Table 5 also showed that the provision of potassium fertilizers had an effect on the variables of nitrogen uptake and potassium uptake. Plants with a potassium application rate of 150 kg ha^{-1} showed the best potassium application rate for the variables nitrogen uptake and potassium uptake. This is probably because the total potassium content in the soil is high enough for plants to take up potassium well. The amount of potassium that plants take up is determined by several factors, including the potassium concentration in the soil (Sardans & Peñuelas, 2021; Torabian et al., 2021). Potassium is an element that moves in plant cells, plant tissues, both xylem and phloem. Potassium in the cytoplasm and chloroplasts is needed to neutralize the solution to a pH of 7-8. This pH environment provides an optimal reaction process for almost all plant enzymes. When plants are deficient in potassium, many processes such as carbohydrate accumulation, reduced starch content, and accumulation of nitrogen compounds in plants do not function properly (Hasanuzzaman et al., 2018).

Potassium uptake is strongly influenced by the presence of macronutrients in the soil. These nutrients can help improve the photosynthesis process, increase water use efficiency, form stronger stems and strengthen roots to keep plants healthy, and increase plant resistance to disease (Medrano et al., 2015). N nutrients act as building blocks for proteins, chlorophyll, amino acids, and many other organic compounds (Gardner et al., 1991). When plants have an excess of nitrogen, potassium plays a role in restoring the balance (Xu et al., 2024).

Meanwhile, there is no effect on nitrogen use efficiency, potassium use efficiency, and potassium agronomic efficiency with the provision of potassium fertilizers. Each element has a solubility within a certain pH range. If the pH is too high, the solubility of the element is reduced, which can reduce the plant's ability to absorb it or make elements such as potassium inaccessible to plants. As a result, the roots show symptoms of potassium deficiency, such as stunted growth and reduced production (Geng et al., 2023).

The nitrogen dose of 100 kg ha-1 showed the best effect on the nitrogen agronomic efficiency, compared to the dose of 200 kg ha-1, but did not show an effect on the potassium agronomic efficiency (Table 5). Agronomic efficiency (AE) is the efficiency of applied nutrients in increasing grain or biomass yield. It is calculated as the increase in yield per unit of nutrient applied (Brouder & Volenec, 2017; Vaneeckhaute et al., 2014). Agronomic efficiency is useful in assessing how much production increase is achieved by the specific amount of fertilizer added (Davies et al., 2020). Agronomic N-use efficiency is the basis for economic and environmental efficiency, and an effective agro-ecosystem management practice, improving nutrient use efficiency, is a crucial challenge for a more sustainable production of horticultural, industrial, and cereal crops (Montemurro & Diacono, 2016).

Conclusion

Based on the results of this study, a nitrogen fertilizer dose of 200 kg ha^{-1} significantly increased cob diameter, cob weight (with and without husk), nitrogen uptake, potassium uptake, and nitrogen agronomic efficiency, indicating its effectiveness in enhancing sweet corn yield components and nutrient absorption. However, no significant difference was observed between the 200 kg ha^{-1} and 100 kg ha^{-1} doses for cob length, sweetness level, nitrogen use efficiency, and potassium use efficiency. Therefore, while 200 kg ha^{-1} supports optimal performance in several key parameters, a dose of 100 kg ha^{-1} may be more efficient for certain physiological traits. Regarding the applied potassium dose, it has not been shown which dose is best for the growth, physiology, and yield of sweet corn. Moreover, the 200 kg ha^{-1} dose results in higher nitrogen and potassium absorption values compared to other doses. On the other hand, applying a nitrogen fertilizer dose of 100 kg ha^{-1} gives better results in terms of nitrogen efficiency, potassium efficiency, and nitrogen agronomic efficiency. A potassium fertilizer dose of up to 150 kg ha^{-1} can increase the uptake of nitrogen and potassium. There is no interaction between nitrogen and potassium doses and nutrient uptake or nutrient use efficiency, and agronomic efficiency.

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