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Effect of plant spacing and NPK 16:16:16 fertilization on vegetative growth of Bonanza F1 Sweet Corn at UPMI Agricultural Field

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ABSTRACT

This study aimed to evaluate the effect of plant spacing and NPK 16:16:16 fertilization on the vegetative growth of Bonanza F1 sweet corn (Zea mays saccharata L.) at the UPMI Agricultural Experimental Field. The experiment was conducted from June to August 2025 using a factorial Randomized Block Design with two treatment factors. The first factor consisted of four plant spacing treatments, namely 40 × 40 cm, 50 × 50 cm, 60 × 60 cm, and 70 × 70 cm, while the second factor consisted of four NPK fertilizer rates, namely 0 g, 20 g, 30 g, and 40 g per plant. Growth parameters observed included plant height, number of leaves, and stem diameter. Data were analyzed using analysis of variance followed by the Least Significant Difference test at the 5% significance level. The results showed that plant spacing and NPK fertilization improved the vegetative growth of sweet corn. Wider spacing reduced interplant competition for sunlight, water, and nutrients, while NPK fertilizer increased nutrient availability required for plant growth. The best treatment combination was obtained from 70 × 70 cm spacing and 40 g NPK per plant (J4P3), which produced the highest plant height (95.50 cm), leaf number (10 leaves), and stem diameter (2.03 cm). The interaction between spacing and fertilizer treatments was generally not significant, although the combined treatment consistently showed better growth performance. Therefore, appropriate spacing and balanced fertilization are recommended to support optimal vegetative growth of Bonanza F1 sweet corn under similar cultivation conditions.

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1. INTRODUCTION

Sweet corn (Zea mays saccharata L.) is one of the important horticultural commodities widely cultivated in Indonesia because of its high economic value and increasing consumer demand. Sweet corn is preferred due to its sweet taste, soft texture, and high nutritional content compared with field corn. In addition to fresh consumption, sweet corn is also utilized in processed food industries, including frozen products, canned food, and snacks. The increasing market demand encourages efforts to improve sweet corn productivity through proper cultivation management practices (Perkasa & Noviani, 2023). However, sweet corn production in several cultivation areas remains relatively low because crop management practices are often not optimized, particularly regarding plant spacing and fertilization management (Utami et al., 2022).

Plant spacing is an important agronomic factor that determines plant population density and influences competition among plants for sunlight, nutrients, water, and growing space. Improper spacing may reduce light interception efficiency and inhibit vegetative growth due to excessive competition between plants. Narrow spacing often limits root expansion and decreases nutrient absorption efficiency, whereas wider spacing can improve canopy structure, air circulation, and photosynthetic activity (Kantikowati et al., 2022). Kartika (2019) reported that appropriate spacing treatment significantly increased sweet corn growth and supported better crop productivity. Similarly, Vera et al. (2020) explained that wider spacing improved root development and enhanced nutrient uptake efficiency in maize cultivation.

Besides spacing arrangement, balanced fertilization is also essential to support optimal plant growth. NPK 16:16:16 fertilizer contains nitrogen (N), phosphorus (P), and potassium (K), which are important macronutrients required during plant development. Nitrogen plays a major role in chlorophyll formation and vegetative growth, phosphorus supports root development and energy transfer, while potassium functions in enzyme activation, water regulation, and strengthening plant tissues (Astutik et al., 2019). Adequate nutrient availability increases photosynthetic efficiency and promotes better vegetative performance. Previous studies demonstrated that NPK fertilization significantly improved plant height, leaf formation, and biomass production in sweet corn plants (Fauziah et al., 2021; Li et al., 2020).

Several previous studies have investigated the effect of plant spacing and fertilization on sweet corn growth. However, most studies examined these factors separately, while research evaluating their combined effects on Bonanza F1 sweet corn under local cultivation conditions remains limited. Environmental conditions, including soil fertility, temperature, rainfall, and nutrient availability, may influence plant responses to agronomic treatments (Fadilla et al., 2025). Therefore, specific cultivation recommendations based on local agroecological conditions are still needed to optimize sweet corn growth and productivity at the UPMI Agricultural Experimental Field.

The novelty of this study lies in evaluating the interaction between plant spacing and NPK 16:16:16 fertilization on the vegetative growth responses of Bonanza F1 sweet corn under local cultivation conditions. This study specifically focuses on plant height, leaf number, and stem diameter as indicators of vegetative performance. The results of this research are expected to provide scientific information and practical recommendations regarding efficient cultivation management for sweet corn production.

Therefore, this study aimed to determine the effect of plant spacing, NPK 16:16:16 fertilization, and their interaction on the vegetative growth of Bonanza F1 sweet corn at the UPMI Agricultural Experimental Field.

2. METHOD

2.1 Research Site and Duration

The research was conducted at the UPMI Agricultural Experimental Field, Faculty of Agriculture, Universitas Pembinaan Masyarakat Indonesia, located in Marindal II Village, Deli Serdang Regency, North Sumatra, Indonesia. The study was carried out from June to August 2025 under tropical environmental conditions suitable for sweet corn cultivation.

2.2 Materials and Equipment

The materials used in this study consisted of Bonanza F1 sweet corn seeds, NPK 16:16:16 fertilizer containing 16% nitrogen (N), 16% phosphorus (P_2O_5), and 16% potassium (K_2O), chicken manure, pesticides, herbicides, and water. The equipment used included hoes, machetes, measuring tape, hand sprayers, weighing scales, planting sticks, stationery, cameras, bamboo markers, and observation sheets.

2.3 Experimental Design

The experiment applied a factorial Randomized Block Design (RBD) consisting of two treatment factors. The first factor was plant spacing, while the second factor was NPK fertilizer dosage. The spacing treatments were: J1 = 40 cm × 40 cm; J2 = 50 cm × 50 cm; J3 = 60 cm × 60 cm; J4 = 70 cm × 70 cm. The NPK fertilizer dosages were: P0 = 0 g per plant; P1 = 20 g per plant; P2 = 30 g per plant; P3 = 40 g per plant

A total of 16 treatment combinations were obtained and each treatment was repeated three times, resulting in 48 experimental plots. Each plot measured 1 m × 1 m and contained four plants, with two plants selected as observation samples.

2.4 Land Preparation

The experimental field was cleaned from weeds, plant residues, and stones before soil tillage. The soil was cultivated until loose and suitable for planting. Experimental plots were then prepared according to the treatment layout. Chicken manure was applied as basal fertilizer before planting to improve soil fertility and support early plant growth (Fauziah et al., 2021).

2.5 Planting Procedure

Planting was conducted manually using direct seeding techniques. Planting holes were made at a depth of approximately 3–5 cm according to the spacing treatment. Each planting hole was filled with one or two seeds depending on the treatment arrangement. The holes were then covered lightly with soil to maintain seed moisture and support germination.

2.6 Fertilizer Application and Crop Maintenance

NPK 16:16:16 fertilizer was applied in two stages. The first application was conducted at planting time using 50% of the treatment dosage, while the remaining fertilizer was applied at 30 days after planting. Fertilizer was applied approximately 5–10 cm from the plant base to minimize nutrient loss and improve nutrient absorption efficiency (Astutik et al., 2019). Nitrogen in the fertilizer supported vegetative growth and chlorophyll formation, phosphorus promoted root development, while potassium contributed to stem strengthening and regulation of plant physiological processes.

2.7 Observation Variables

Several growth parameters were observed during the study, namely: Plant height (cm), measured from soil surface to the highest growing point. Number of leaves (strands), counted from fully opened leaves. Stem diameter (cm), measured at the lower stem section above soil level using a measuring tool. Observations were conducted periodically at 1, 2, and 3 weeks after planting.

2.8 Data Collection and Statistical Analysis

Data obtained from field observations were tabulated and analyzed statistically using analysis of variance (ANOVA) to determine the significance of treatment effects. When significant differences among treatments were detected, further analysis was performed using the Least Significant Difference (LSD) test at the 5% significance level. Statistical analysis was conducted to evaluate the influence of spacing, NPK fertilizer dosage, and their interaction on sweet corn growth performance (Gomez & Gomez, 1984).

3. RESULTS AND DISCUSSION

3.1 Effect of Plant Spacing on Plant Height

The results showed that plant spacing significantly affected the height growth of Bonanza F1 sweet corn. Plants grown under wider spacing treatments generally exhibited better vegetative growth compared with plants cultivated under narrower spacing conditions. Reduced competition among plants for sunlight, water, nutrients, and growing space enabled more efficient physiological activity during plant development. Similar findings were reported by Kantikowati et al. (2022), who explained that wider spacing improves light interception and enhances photosynthetic activity in sweet corn cultivation.

The highest average plant height at 3 weeks after planting was observed in treatment J4 (70 × 70 cm), while the lowest value was recorded in treatment J1 (40 × 40 cm). Wider spacing allowed better canopy arrangement and increased sunlight penetration into plant leaves, thereby improving photosynthetic efficiency and carbohydrate production. According to Taiz et al. (2015), increased photosynthetic activity promotes assimilate accumulation required for cell elongation and stem growth.

In addition, wider spacing supported better root expansion and nutrient absorption efficiency because root competition among plants was reduced. Improved uptake of nitrogen, phosphorus, and potassium contributed positively to metabolic processes, chlorophyll formation, and vegetative tissue development. Nitrogen availability particularly stimulated leaf chlorophyll synthesis, which increased the source capacity of leaves in producing photosynthates for plant growth.

The source-sink relationship also played an important role in determining plant height response. Leaves function as the source organs that produce assimilates through photosynthesis, while actively growing tissues such as stems and roots act as sink organs. Under wider spacing conditions, assimilate translocation from leaves to growing tissues occurred more efficiently due to reduced competition and improved environmental conditions. Consequently, stem elongation and plant growth increased significantly under wider spacing treatments.

Table 1. Average Plant Height of Sweet Corn

Treatment	1 WAP	2 WAP	3 WAP
J1P0	19.07	44.23	75.57
J1P1	21.57	46.37	76.50
J1P2	23.67	49.97	80.23
J1P3	23.93	50.43	82.93
J2P0	22.77	49.50	79.17
J2P1	24.77	49.20	81.67
J2P2	24.60	51.57	84.53
J2P3	26.47	56.60	85.77
J3P0	24.53	50.63	83.33
J3P1	24.50	54.00	85.17
J3P2	27.60	55.00	89.10
J3P3	28.37	57.03	91.43
J4P0	27.23	53.30	87.00
J4P1	28.93	55.73	88.77
J4P2	29.53	58.03	90.53
J4P3	30.20	57.57	95.50

Table 1 shows that plant height increased continuously from 1 to 3 weeks after planting in all treatment combinations. The highest plant height was observed in treatment J4P3 with a value of 95.50 cm at 3 WAP, while the lowest value was found in treatment J1P0 at 75.57 cm. These findings indicate that wider spacing combined with higher NPK 16:16:16 fertilizer application supported better vegetative growth through improved photosynthetic efficiency and nutrient utilization.

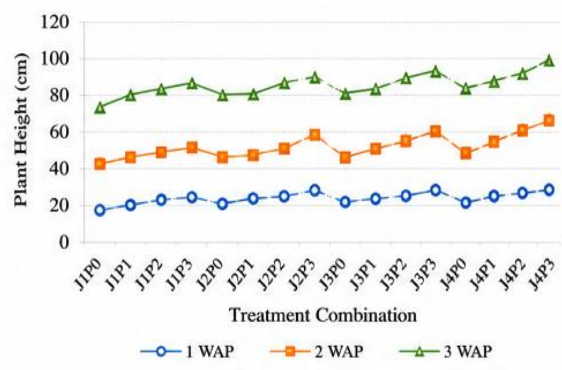

Figure 1. Plant Height Response under Different Treatments

Figure 1 illustrates that plant height increased progressively under wider spacing and higher NPK fertilizer application. The J4P3 treatment consistently produced superior growth compared with other treatment combinations. This result indicates that balanced nutrient supply together with optimal plant population density enhanced physiological performance and promoted better vegetative growth.

3.2 Effect of NPK Fertilizer on Leaf Formation

Application of NPK 16:16:16 fertilizer positively affected leaf development in sweet corn plants. Treatments receiving higher fertilizer rates generally produced more leaves compared with unfertilized plants. Adequate nutrient availability increased chlorophyll formation and enhanced physiological processes associated with vegetative growth (Astutik et al., 2019).

Nitrogen contained in NPK fertilizer plays an important role in chlorophyll synthesis, protein formation, and enzymatic activity related to photosynthesis. Increased chlorophyll concentration improved the efficiency of light absorption by leaves and enhanced photosynthetic activity. As a result, plants were able to produce more assimilates required for leaf expansion and biomass accumulation. Marschner (2012) explained that nitrogen availability strongly influences leaf area development and photosynthetic capacity in crop plants.

At 3 weeks after planting, treatment P3 (40 g per plant) consistently produced a higher number of leaves compared with lower fertilizer dosages. This condition indicates that balanced nutrient availability enhanced source organ development, particularly leaf formation. Wider spacing treatments also supported better leaf expansion because improved air circulation and reduced shading increased light distribution among plants.

The source-sink mechanism contributed to leaf formation response in this study. Leaves act as the primary source organs producing carbohydrates through photosynthesis, while developing tissues function as sinks requiring assimilates for growth. Increased nutrient availability promoted assimilate production and improved translocation efficiency toward developing leaves and stems. Consequently, treatments combining wider spacing and higher NPK application produced superior vegetative performance.

Table 2. Average Number of Leaves of Sweet Corn

Treatment	1 WAP	2 WAP	3 WAP
J1P0	2.33	4.33	6.33
J1P1	3.00	5.33	7.33
J1P2	3.67	6.00	8.00
J1P3	4.00	6.33	8.67
J2P0	2.33	4.67	6.67
J2P1	3.00	5.33	7.67
J2P2	3.67	6.00	8.67
J2P3	4.33	6.67	9.33
J3P0	2.33	4.33	6.67
J3P1	3.00	5.67	8.00
J3P2	3.67	6.33	9.00
J3P3	4.33	7.00	9.67
J4P0	2.33	4.33	6.67
J4P1	3.00	5.67	8.67
J4P2	3.67	6.67	9.33
J4P3	4.67	7.33	10.00

Table 2 demonstrates that the number of leaves increased progressively during the observation period. The highest leaf number was obtained in treatment J4P3 with an average of 10 leaves at 3 WAP, whereas the lowest value was recorded in treatment J1P0. These results indicate that wider spacing and balanced fertilization improved physiological activity and supported optimal vegetative growth.

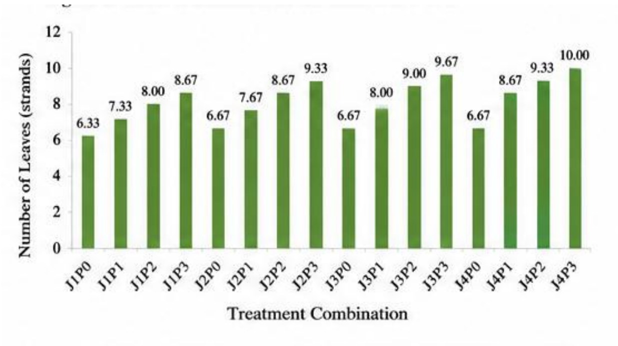

Figure 2. Effect of Treatments on Leaf Number

Figure 2 shows that plants receiving higher NPK fertilizer rates produced more leaves compared with lower fertilizer treatments. Improved nutrient availability increased photosynthetic efficiency and supported leaf expansion. Wider spacing also contributed to better light interception and reduced interplant competition, resulting in more efficient assimilate production.

3.3 Stem Diameter Response

The observation results demonstrated that stem diameter was influenced by plant spacing and NPK 16:16:16 fertilizer application. Plants grown under wider spacing generally developed thicker stems compared with plants planted at higher population density. Reduced plant competition allowed more efficient utilization of sunlight, water, and soil nutrients, thereby supporting better structural growth.

Potassium contained in NPK fertilizer contributed significantly to stem development by regulating carbohydrate translocation and strengthening vascular tissues. Adequate potassium availability improved water regulation, enzyme activation, and cell turgor maintenance, which are essential for stem thickening and plant rigidity (Shamita et al., 2022). Improved stem diameter reflects enhanced assimilate distribution and stronger vegetative development.

In addition, better photosynthetic efficiency under wider spacing increased carbohydrate production in leaves. The assimilates produced by source organs were subsequently translocated to sink organs such as stems, where they were utilized for tissue enlargement and strengthening. This efficient source-sink relationship contributed to thicker stem formation in treatments receiving wider spacing and higher fertilizer rates.

The highest stem diameter value was obtained from treatment combination J4P3, whereas the lowest value occurred in J1P0. These findings indicate that reduced interplant competition together with balanced nutrient supply improved physiological performance and enhanced stem structural development in sweet corn plants.

Table 3. Average Stem Diameter of Sweet Corn

Treatment	Stem Diameter (cm)
J1P0	1.43
J1P1	1.53
J1P2	1.63
J1P3	1.77
J2P0	1.47
J2P1	1.60
J2P2	1.73
J2P3	1.87
J3P0	1.47
J3P1	1.63
J3P2	1.77
J3P3	1.93
J4P0	1.43
J4P1	1.63
J4P2	1.87
J4P3	2.03

Table 3 demonstrates that stem diameter tended to increase under wider spacing and higher fertilizer application. The largest stem diameter was recorded in treatment J4P3 with a value of 2.03 cm, while the smallest value was observed in treatment J1P0. This condition indicates that improved nutrient uptake efficiency and assimilate translocation supported stronger stem formation.

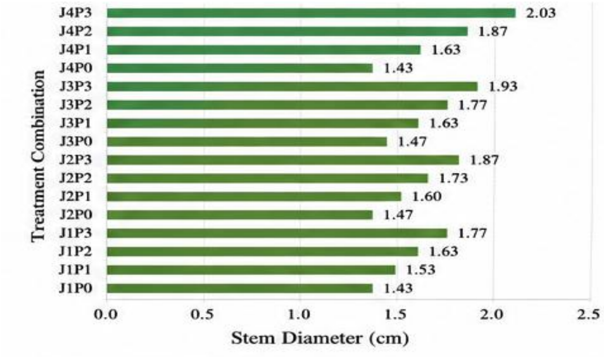

Figure 3. Stem Diameter under Different Treatment Combinations

Figure 3 clearly illustrates that stem diameter increased progressively with wider spacing and higher NPK fertilizer dosage. Better environmental conditions reduced plant stress and enhanced physiological processes associated with stem growth and tissue strengthening.

3.4 Interaction Between Plant Spacing and NPK Fertilizer

Statistical analysis indicated that the interaction between plant spacing and NPK 16:16:16 fertilizer application was generally not significant for several observed variables. However, treatment combinations involving wider spacing and higher fertilizer rates consistently produced superior vegetative growth compared with other treatments.

The combination of 70 × 70 cm spacing and 40 g NPK fertilizer per plant (J4P3) resulted in the highest plant height, leaf number, and stem diameter. This condition suggests that reduced interplant competition improved nutrient uptake efficiency and enhanced physiological activity in sweet corn plants. Rokhayati and Pateda (2024) explained that proper crop population management combined with balanced fertilization creates favorable environmental conditions for plant growth.

The interaction between spacing and fertilization influenced photosynthetic efficiency through improved canopy arrangement and nutrient availability. Wider spacing increased light penetration and reduced shading among plants, thereby enhancing photosynthetic activity. Meanwhile, balanced NPK fertilization supplied essential nutrients required for chlorophyll formation, enzyme activity, and carbohydrate metabolism.

The source-sink relationship also contributed to the interaction response observed in this study. Leaves as source organs produced assimilates through photosynthesis, while stems, roots, and developing tissues acted as sink organs requiring assimilates for growth. Under wider spacing and adequate nutrient supply, assimilate translocation from source to sink organs occurred more efficiently, resulting in improved vegetative development.

Overall, the findings demonstrate that proper spacing and balanced fertilization management are important agronomic practices for improving vegetative growth of Bonanza F1 sweet corn. Improved photosynthetic efficiency, nutrient uptake, and assimilate distribution contributed positively to plant growth performance under optimal cultivation conditions.

Figure 4. Experimental Field and Observation Activities

Figure 4 presents field documentation and observation activities conducted during the experiment. The figure supports the validity of the research implementation and provides visual evidence of field management practices during sweet corn cultivation.

4. CONCLUSION

Plant spacing and NPK 16:16:16 fertilization improved the vegetative growth of Bonanza F1 sweet corn at the UPMI Agricultural Experimental Field. The best treatment was obtained from the combination of 70 × 70 cm spacing and 40 g NPK per plant (J4P3), which produced the highest plant height (95.50 cm), leaf number (10 leaves), and stem diameter (2.03 cm). Wider spacing reduced interplant competition and improved photosynthetic efficiency, while balanced fertilization enhanced nutrient uptake and vegetative development. Therefore, the combination of wider spacing and appropriate NPK fertilization is recommended to support optimal sweet corn growth under similar cultivation conditions.

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