SVU-International Journal of Agricultural Sciences
Volume 6 Issue (3) pp.: 90-106, 2024
Print ISSN 2636-3801 | Online ISSN 2636-381X
Doi: 10.21608/svuijas.2024.302237.1378

RESEARCH ARTICLE

Growth and yield performance of sweet corn (*Zea mays* L. var. saccharata) applied with organic and inorganic fertilizers under different methods of crop establishment

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Abstract

Crop establishment method and integrated fertilizer management are crucial in enhancing the productivity of sweet corn hybrids under unpredictable climatic conditions. A field experiment was conducted, which aimed to assess the agronomic, yield response, and profitability of sweet corn production as influenced by the combined application of inorganic and Vermicompost fertilizers under different methods of crop establishment. This study adopted a split plot arranged in an RCBD with the crop establishment method used as the main plot and fertilizer management as the subplot. Statistical analysis revealed that the transplanting method remarkably produced the highest fresh stover yield (16.60 tons ha^{-1}) and the number of marketable ear $plots^{-1}$ (44.61 ears). This method proved more cost-effective because of a higher gross margin (PhP102, 510.00) and a positive return on investment (ROI). The plants applied with 67.5-45-45 kg ha^{-1} of N, P_2O_5, and K_2O inorganic fertilizer plus 2.5 tons ha^{-1} of Vermicompost achieved the highest yield of marketable ears of 8.20 tons ha^{-1}. It attained a very high gross margin (PhP295,808.00) and an ROI of 259%. The interaction effects between the two variables were noted in the fresh stover yield, ear diameter, and the number, and yield of marketable ears. The values obtained generally increased upon applying 75% inorganic and 25% organic fertilizer (T_3), especially in the transplanting method of crop establishment. Therefore, the combined application of inorganic (75%) and organic fertilizers (25%) is the best nutrient management option for sweet corn production when established under the transplanting method amid the climate change situation.

Keywords: climate change, combined, direct seeding, response, transplanting.

1. Introduction

Sweet corn (*Zea mays* L. var. saccharata) is a widely known crop with similar morphological characteristics and cultivation methods as other corn varieties (Gavric and Omerbegovic, 2021). The crop has an upcoming potential for massive production in the rolling uplands, hilly lands, and mountainous areas since the fertile uplands in the low-lying areas have recently been converted to residential, commercial, and other uses. However, the negative experiences of sweet corn growers nowadays are mainly due to the problems of unpredictable weather and climatic conditions brought by climate change, thereby is a need to find ways to counter the negative effects of the aforesaid situation.

The ill effects of climate change nowadays coupled with ever-increasing populations may result in food self-insufficiency; thereby food production of sweet corn should be enhanced more productively to meet the demands of the growing population. One way to solve this high demand for food is to increase the production per unit area per unit time (Layuhan, 1996). This can be materialized through the adoption of suitable nutrient management practices and the best crop

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Received: July 7, 2024; Accepted: August 6, 2024; Published online: August 12, 2024.
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establishment methods to counteract the changes in climatic conditions brought by the abovementioned phenomenon.

One of the nutrient management practices that may increase sweet corn production is the proper application of fertilizer. Fertilizer application increases crop production through the application of essential nutrients to the soil which are needed by plants for their normal growth and development. These fertilizer materials can be of inorganic and organic forms. Inorganic fertilizers are readily available for crop utilization. However, this material is not only expensive but also detrimental based on its chemical components which may contribute to environmental pollution. The heavy and continuous use of inorganic fertilizers increases soil acidity which leads to the unavailability of nutrients in the soil, thereby reducing crop production (PCARRD, 1986). An alternative farming method is imperative to sustain the fertility level of the soil without ill effects on the environment. Organic fertilizers are alternative sources that are readily available, eco-friendly, and easily degraded in the environment. They are derived from either plant residues or animal manures. These have been found to make the soil easier to cultivate, provide good aeration, and improve water holding capacity. With the slow availability of this material, the supply of nutrients is gradual thus this will not be easily lost through leaching (Marsado, 2015).

The development of advanced research and improved technology relative to organic fertilizers is vital in improving the efficiency of organic fertilizers for enhancing plant growth and development (Lasco, 2017), and one of these is the production and application of Vermicompost. Vermicompost is derived from the accelerated biological degradation of organic wastes by earthworms and microorganisms. It is a solid organic fertilizer generated by composting organic materials with diverse earthworm species (Ramnarain et al., 2019). It has finely divided with peat-like material with excellent structure, porosity aeration drainage, and moisture-holding capacity (Feriol, 2015). According to Villaver (2020), sweet corn yields with a sole Vermicompost treatment were incomparable to inorganic fertilizer-treated ones. Hence, Shahid *et al.* (2015) suggested that a balanced application of inorganic and organic fertilizers is essential for producing sweet corn. The combined application of organic and inorganic fertilizers is emphasized to reduce utilization of the latter yet supply the needed nutrient elements necessary for the growth and development of the crop. The nutrients provided by the organic materials can reduce heavy dependence on inorganic fertilizer thus reducing the ill effects of its continuous use.

It has been demonstrated that various crop establishment and fertilizer application methods can significantly increase the yield of sweet corn (Tampus and Escasinas, 2019). Rattin *et al.* (2010) confirmed that transplanting method produces yields comparable to direct seeding. This method is widely employed in cultivating crops when direct seeding becomes challenging due to unfavorable environmental conditions, and also birds pose a risk to emerging seedlings (Fanadzo *et al.*, 2009). FAO (2003) stressed that maize transplanting is an intensive practice in Korea, and supported by the findings of Fanadzo *et al.* (2009), that a transplanted corn crop stand was high at 96%, while a direct seeded crop stand was only 78%. As a result of transplanting corn, the growth period in the field can be shortened and can only reach the flowering stage 11 to 15 days earlier than if planted directly.

The combined effects of crop establishment methods and application of Vermicompost supplemented with inorganic fertilizers on sweet corn hybrid production have yet to be thoroughly investigated in the Philippines, particularly in the Eastern Visayas region. Thereby, the conduct of this research undertaking.

2. Materials and methods

This study was conducted in the experimental area of the Department of Agronomy at the Visayas State University (VSU), Visca, Baybay City, Leyte, Philippines geographically located at 10^0 45'00" N and 124^0 47'38" E. Based on the latest climate data provided by the Philippines Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), VSU was classified under Type IV corona climate classification, which implies that there is no pronounced dry season. However, the region receives almost the same rainfall throughout the year. In addition, the area's particle size distribution is 22% clay, 21% silt, and 57% sand, with a soil texture of sandy clay loam. An area of 1,331.25 m^2 was cleared of weeds before planting. Plowing was done twice in one-week intervals to allow the weed seeds to germinate and the residues to rot. Harrowing was done twice after plowing to pulverize and level the soil. The spacing between furrows was 75 cm. Before setting up the experiment, ten soil samples were collected from a depth of 20 cm throughout the experimental area (Smith and Johnson, 2010). These samples have been composited, air-dried, and sieved using a 2.0-mm wire mesh. The samples were sent to the Central Analytical Service Laboratory (CASL), Philippine Root Crops Research Center of the Visayas State University, Visca, Baybay City, Leyte, Philippines. For the determination of soil texture, pH, O.M. (%) (Modified Walkley-Black Method, PCARR 1980), total N (%) (Modified Kjeldahl Method, PCARR 1980), available P (Modified Olsen Method, Olsen and Sommer, 1982), exchangeable K content (Ammonium Acetate Method, PCARR 1980), and cation exchange capacity (CEC) (cmol kg^{-1}). For the soil electrical conductivity (E.C.), a soil sample was submitted to the Research Laboratory of the Department of Agronomy at the Visayas State University, Visca, Baybay City, Leyte.

The experiment was laid out in a split plot with three replications arranged in a Randomized Complete Block Design (RCBD). Methods of crop establishment designated as main plot namely; M_1 – direct seeding and M_2 – transplanting while the integrated fertilizer management as the subplot namely; T_0 - No fertilizer application (Control); T_1 - 90-60-60 kg ha^{-1} N, P_2O_5, K_2O (Inorganic fertilizer); T_2 - 10 tons ha^{-1} of Vermicompost; T_3 - 67.5-45-45 kg ha^{-1} N, P_2O_5, K_2O + 2.5 tons ha^{-1} of Vermicompost; T_4 - 45-30-30 kg ha^{-1} N, P_2O_5, K_2O + 5 tons ha^{-1} Vermicompost; T_5 - 22.5-15-15 kg ha^{-1} N, P_2O_5, K_2O + 7.5 tons ha^{-1} of Vermicompost. An alleyway of two meters was provided between replications and 1.5 meters between treatment plots to facilitate farm operations and data gathering.

The different rates of organic fertilizer were applied uniformly to the furrows of designated plots two weeks before planting (WBP). The complete fertilizer (14-14-14) was applied with different rates ten days after planting (DAP). Furthermore, various rates of urea (46-0-0) were also side-dressed thirty days after planting. For the transplanting method, the seeds of sweet corn were sown in a standard seedling tray 54 cm x 28 cm containing 128 cells and transplanted to the field seven days later. This study used compost and field soil in a 2:1 ratio (Dhananchezhiyan *et al.*, 2013). Planting was performed at one seedling per hill spaced at 75 cm x 25 cm. For the direct seeding method, seeds were planted in the furrow on the same day in seedling trays. Seeding was done at a rate of two seeds per hill, with a distance of 75 cm between rows and 25 cm between hills. At 15 days after planting, the plants were thinned, leaving only one plant per hill with a population of 4,320 plants in a 1,331.25 m^2 area. The missing hills were replanted one week after planting.

Relative to cultivation, off-barring was done using a carabao-drawn implement of twenty DAP. Hilling up was implemented thirty days after planting to conceal the side-dressed fertilizer. Hand weeding was performed during the seventh, twenty-first, and thirty-fifth days after planting. A drainage canal was constructed around the experimental area and between replications to prevent waterlogging during heavy precipitation. Karate (lambda-cyhalothrin) was used to control insect pests and diseases. Insect pest infestations, specifically corn stem borer, were monitored periodically during the experiment. The sweet corn was harvested when 80% of the crop population reached the R_3 stage or when the kernels turned a buttery golden color filled with a milky white fluid approximately 75 DAP. The corn silks at this stage are also beginning to dry out, as evidenced by their senesced brown color. Plant samples were obtained from the harvestable area, except for the end hills of each row and one row from each side, excluding the end hills of each row.

Data collected on the agronomic characteristics were the number of days from planting to tasselling, silking, green cob stage, plant height (cm) at 70 DAS, and fresh stover yield (ton ha^{-1}). However, the yield and yield components were ear length (cm), ear diameter (cm), number of kernel rows, the number of marketable ears $plot^{-1}$, and yield of marketable ears (tons ha^{-1}).

The meteorological data based on the total weekly rainfall (mm), average daily minimum and maximum temperatures (^{0}C), and relative humidity (%) throughout the conduct of the study were taken from the records of the Philippine Atmospheric Geophysical and Astronomical Services (PAGASA) Station, Visayas State University, Visca, Baybay City, Leyte, Philippines. The statistical analysis of the collected data and means of the data was conducted using the Statistical Tool for Agricultural Research (STAR) version 2.0.1 2014, Biometrics and Breeding Informatics, Plant Breeding Genetics and Biotechnology Division of the International Rice Research Institute, Los Baños, Laguna (IRRI, 2014). Tukey's or Honestly Significant Difference (HSD) tests were used to compare treatment means. For the cost and return analysis**,** the variable cost was determined by recording all the expenses incurred throughout the study, from land preparation to harvesting. These include fertilizers, materials, and labor used in the experiment. The total variable cost (materials and labor) was subtracted from the gross income to obtain the gross margin. The gross income was determined by multiplying the marketable ear yield of each treatment plot by the current market price of corn per kilogram.

Table 1. Amount of inorganic and organic fertilizers applied per plot

Sub-plot treatment	Vermicompost (kg $plot^{-1}$)	Complete 14-14-14 (kg $plot^{-1}$)	Urea 46-0-0 (kg $plot^{-1}$)
T_0 – No fertilizer Application (Control)	0.00	0.00	0.00
T_1 - 90-60-60 kg ha^{-1} N, P_2O_5, K_2O (Inorganic fertilizer)	0.00	0.96	0.15
T_2 - 10 t ha^{-1} of Vermicompost	22.50	0.00	0.00
T_3 - 67.7-45-45 kg ha^{-1} N, P_2O_5, K_2O + 2.5 t ha^{-1} of Vermicompost	5.63	0.72	0.11
T_4 - 45-30-30 kg ha^{-1} N, P_2O_5, K_2O + 5 t ha^{-1} Vermicompost	11.25	0.48	0.07
T_5 - 22.5-15-15 kg ha^{-1} N, P_2O_5, K_2O + 7.5 t ha^{-1} of Vermicompost	16.87	0.24	0.04

3. Results and discussion

Figure 1 depicts the total amount of rainfall, the minimum and maximum temperatures, and the relative humidity. There was a total rainfall of 791.85 mm throughout the study. Sweet corn requires a rainfall of 400-600 mm every growing season to reach its full potential. The data involving weekly rainfall depicted a direct relationship between precipitation and the production of sweet corn. Rainfall is a crucial environmental parameter in most plant growth processes, such as water uptake and nutrient assimilation. The significant rise in rainfall between weeks one and two, within the range of 26.90 and 66.40, most likely provided enough moisture for seed germination and, consequently, early crop establishment. This observation concurred with the results of Li *et al.* (2022), who highlighted the importance of adequate moisture to maize at an early stage during crop growth.

The sudden drop of precipitation in weeks 5 and 6, from 0.10 mm to 0.30 mm, may cause moisture stress conditions, leading to slow physiological processes and, ultimately, slow plant growth. Attia *et al.* (2021) have reported that a lack of sufficient water supply may adversely affect maize growth and development and thus call for a regular moisture supply during the crop's growth stage. However, the sudden rise of precipitation in week nine, which registered 70.30 mm, likely provided relief by breaking the earlier drought stress by the crop and further facilitated optimum growth. Fang *et al.* (2021) indicated a positive association between optimum moisture supply and maize yield.

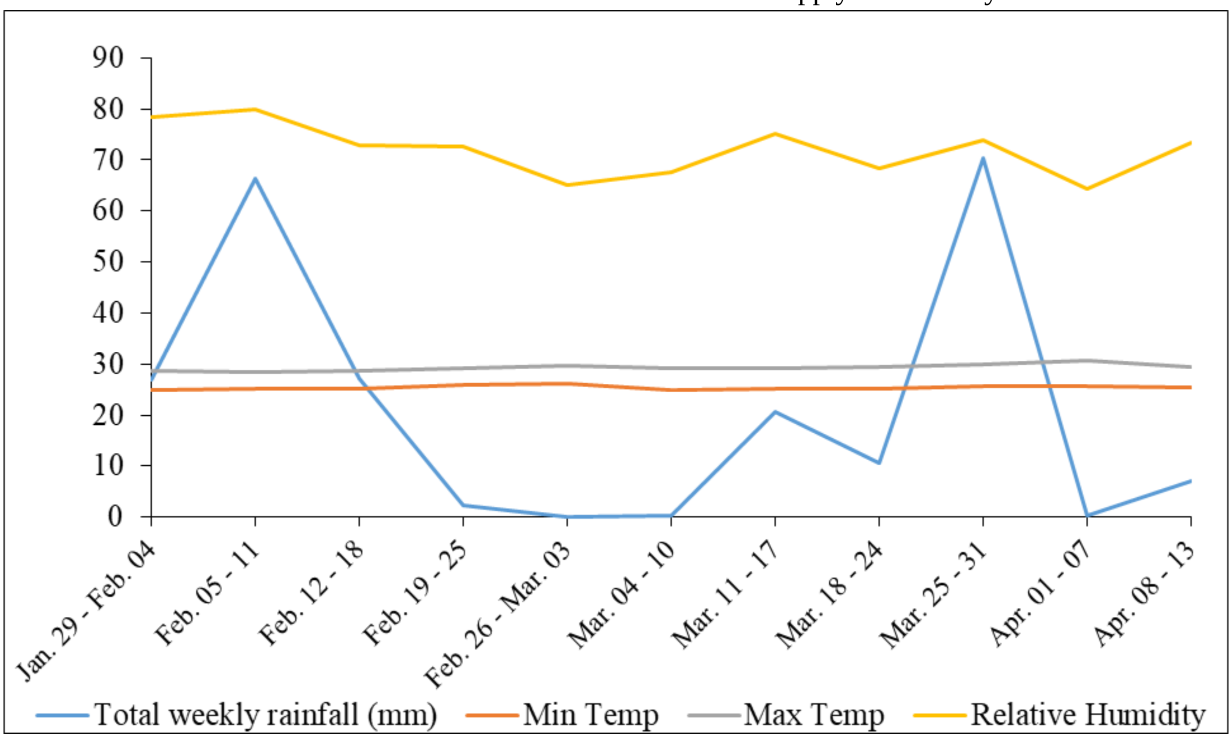

Figure 1. The total amount of weekly rainfall (mm), minimum and maximum temperatures (°C), and relative humidity (%) in the experimental area throughout the growing period

3.1. Initial soil physicochemical parameters

The initial soil physicochemical properties of the experimental site are reflected in Table 2. The results indicated that the research area has a pH of 6.22, which was slightly acidic, organic carbon of 1.06, organic matter (%) of 1.37, cation exchanged capacity (cmol kg^{-1}) of 3.49, electrical conductivity (E.C.) of 0.01, very low in total nitrogen (%) with a value of 0.052, very high in available phosphorus (mg kg^{-1}) of 50.99, and very high in exchangeable potassium with a value of 203.83 (Landon, 1991).

Table 2. Initial soil physicochemical properties of the experimental area

Soil properties	Values
Electrical Conductivity (E.C.) (d/Sm^{-1})	0.01
Soil pH (1:2.5)	6.22
Organic carbon*	1.06
Organic matter (%)	1.37
Cation Exchange Capacity (CEC) (cmol kg^{-1})	3.49
Total nitrogen (%)	0.05
Available phosphorus (mg kg^{-1})	50.99
Exchangeable potassium (mg kg^{-1})	203.83

* *To calculate the percentage of organic carbon by the Walkley and Black method, organic carbon should be multiplied by a factor 100/77 or 1.3 (77 % being the average recovery factor known as van Bemmlen factor)*

3.2. Vermicompost composition

The nutritional composition of the Vermicompost material used in the study has a pH of 7.40, total nitrogen of 0.815%, total available phosphorus content of 0.572%, total potassium of 0.101%, organic matter of 9.107%, and moisture of 20.52% (Table 3). This indicates that the Vermicompost material used is alkaline and sufficient in organic matter which is considered an organic fertilizer and the best material for applying sweet corn hybrids. Vermicompost is an excellent natural fertilizer for plants since it contains several elements that promote plant growth. It contains high amounts of nitrogen, which is a significant constituent of chlorophyll, proteins, and amino acids; phosphorous, which is a component of energy compounds such as ATP and NADP; and potassium, which serves as an activator or a cofactor for various enzymes involved in photosynthesis and carbon dioxide fixation, which may have promoted satisfactory plant growth, photosynthetic surface, and, finally, fresh stover yield.

Table 3. Nutritional composition of Vermicompost used in the experiment

Parameters	Values
pH (1:2.5)	7.400
Total N (%)	0.815
Total P (%)	0.572
Total K (%)	0.101
OM (%)	9.107
Moisture content (%)	20.520

3.3. Agronomic characteristics of sweetcorn

Table 4 shows the agronomic characteristics of sweet corn applied with inorganic and organic fertilizers under different crop establishment methods. Analysis of variance revealed that there was a significant difference between the methods of crop establishment. Results revealed that the sweet corn plants under the direct seeding method were notably attained earlier in tasseling, earlier in silking, and emanated longer plant height at 70 DAS than those plants grown under the transplanting method of crop establishment. However, plants under the transplanting method remarkably obtained a higher fresh stover yield (16.60 tons ha^{-1}) than direct seeding (13.30 tons ha^{-1}) because transplanting seedlings provided an initial head start in a controlled environment that ensured better adaptation to field conditions when transplanted. It ensures improved overall growth and stover yield.

The application of both inorganic and Vermicompost fertilizers revealed a significant difference in the number of days from planting to tasseling, silking, green cob stage, and fresh stover yield (tons ha^{-1}). Results showed that the application of 75% based on the recommended rate of inorganic fertilizer and 2.5 tons ha^{-1} of Vermicompost (T_3) significantly attained an early tasseling, silking, green cob stage, and achieved the highest fresh stover yield of 18.92 tons ha^{-1} when compared to unfertilized control plants (T_0). However, this result was comparable to the application of 100% inorganic fertilizer (T_1). These findings agreed with the study of Hoque (1999), who found that plant height significantly increased with compost and chemical fertilizer. Vermicompost significantly affects plant growth and development because of the humic acid content (Arancon *et al.*, 2005) and macro and micronutrients (Atiyeh *et al.*, 2002). Al-Tawarah *et al.* (2024) concluded that adding Vermicompost to replace soil at 50% to 100% positively impacts common bean plant development and growth. The findings conform to the study of Bahuguna and Pal (2020), which states that applying 75% of the recommended inorganic fertilizer application rate + 25% Vermicompost significantly increased plant height. This is consistent with the findings of Kizilkaya *et al.* (2012), who discovered that using Vermicompost in conjunction with chemical fertilizer significantly increased wheat straw. Singh *et al*. (2008) found that Vermicompost increased plant growth and marketable yield relative to inorganic fertilizer.

The interaction effect between the method of crop establishment and integrated fertilizer management on fresh stover yield (tons ha^{-1}) of sweetcorn is presented in Figure 2. Data showed that both crop establishment methods responded with similar trends relative to the fertilizer management strategies adopted.

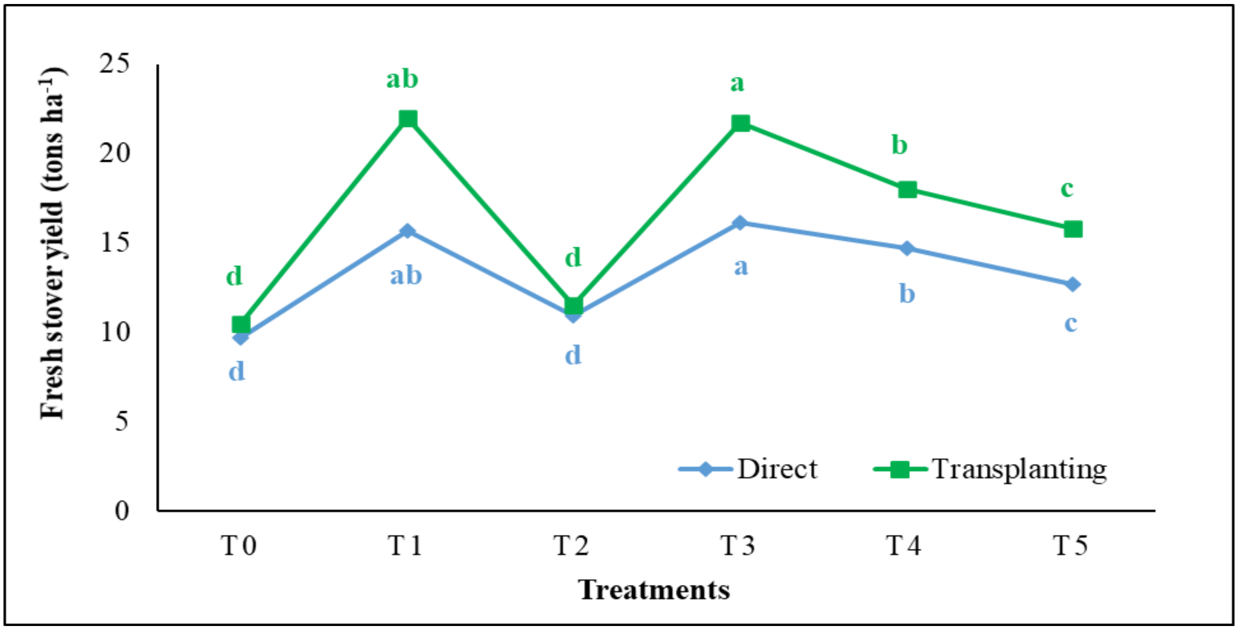

Figure 2. Interaction effect between the method of crop establishment and integrated fertilizer management on the fresh stover yield (tons ha^{-1}) of sweet corn (*Zea mays* L. var. saccharata).

Legend:

T_0 – No fertilizer application (Control)

T_1 – 90-60-60 kg ha^{-1} N, P_2O_5, K_2O (Inorganic fertilizer)

T_2 – 10 t ha^{-1} of Vermicompost

T_3 – 67.5-45-45 kg ha^{-1} N, P_2O_5, K_2O + 2.5 t ha^{-1} of Vermicompost

T_4 – 45-30-30 kg ha^{-1} N, P_2O_5, K_2O + 5 t ha^{-1} Vermicompost

T_5 – 22.5-15-15 kg ha^{-1} N, P_2O_5, K_2O + 7.5 t ha^{-1} of Vermicompost

However, the application of 75% inorganic along with 2.5 tons ha^{-1} of Vermicompost provided a higher fresh stover yield (tons ha^{-1}) in plants under the transplanting method than those plants under the direct-seeding method of crop establishment. This investigation elucidated that the synergistic interaction between inorganic fertilizers and Vermicompost was more pronounced in transplanting methods compared to direct seeding. The present findings corroborate those of Tufa (2023) on maize, which demonstrated that the concomitant application of Vermicompost and mineral fertilizers can enhance the release of plant nutrients and expedite the mineralization of nitrogen from the fertilizers. This accelerated nutrient availability likely contributes to more vigorous plant growth than other fertilization treatments.

Table 4. Agronomic characteristics of sweet corn *(Zea mays* L. var. saccharata) applied with inorganic and organic fertilizers under different methods of crop establishment

Treatment	Number of days from sowing to			Plant height (cm) 70 DAS	Fresh stover yield (t/ha)
	Tasseling	Silking	Green cob		
Methods of crop establishment					
M_1 – Direct seeding	53.94^b	56.39^b	72.11	193.46^a	13.30^b
M_2 – Transplanting	56.50^a	58.89^a	72.94	177.13^b	16.60^a
Mean	55.22	57.64	72.53	185.29	14.95
Integrated fertilizer management					
T_0 – No fertilizer application (Control)	57.67^a	61.50^a	74.33^a	168.85^b	10.10^d
T_1 – 90-60-60 kg ha^{-1} of N, P_2O_5, K_2O (Inorganic fertilizer)	55.00^b	57.33^b	71.50^{cd}	194.87^a	18.83^{ab}
T_2 – 10 t ha^{-1} of Vermicompost	55.50^b	57.33^b	73.67^a	177.43^{ab}	11.23^d
T_3 – 67.5-45-45 kg ha^{-1} of N, P_2O_5, K_2O + 2.5 tons ha $^{-1}$ of Vermicompost	54.00^b	56.17^b	71.00^d	196.18^a	18.92^a
T_4 – 45-30-30 kg ha^{-1} of N, P_2O_5, K_2O + 5 t ha^{-1} Vermicompost	55.00^b	56.67^b	71.83^c	185.70^{ab}	16.37^b
T_5 – 22.5-15-15 kg ha^{-1} of N, P_2O_5, K_2O + 7.5 tons ha $^{-1}$ of Vermicompost	54.17^b	56.83^b	72.83^b	188.74^{ab}	14.24^c
Mean	55.22	57.64	72.53	185.29	14.95
CE x IFM	ns	ns	ns	ns	**
C.V. (a)%	2.68	2.60	1.05	5.71	3.82
C.V. (b)%	1.56	2.18	0.54	6.56	3.31

Means within a column with the same letter and those without letter designations are not significantly different at the 5% level, based on HSD.

3.4. Yield and yield components of sweet corn

Table 5 shows sweet corn's yield and components applied with inorganic and organic fertilizers under different crop establishment methods. Statistical analysis revealed no significant difference in the ear length, ear diameter, and kernel rows of sweet corn under different crop establishment methods. However, the number of marketable ears/plot and yield of marketable ears (ton/ha) showed significant differences under the different crop establishment methods. These findings suggest that the transplanting method combined with integrated fertilizer management using inorganic and organic fertilizers has substantial synergistic effects, ensuring a balanced and sustained nutrient supply that enhances plant growth and yield. The transplanting method of sweet corn and applying both inorganic and organic fertilizers can substantially increase the yield of marketable ears. Kandil (2013) reported that transplanting, combined with balanced fertilization, significantly improved the yield and quality of sweet corn ears.

The sweet corn plants applied with 75% inorganic fertilizer + 2.5 tons ha^{-1} of Vermicompost (T_3) obtained remarkably the highest ear length, ear diameter, number of marketable ears $plot^{-1}$, and yield of marketable ears (tons ha^{-1}) when compared to other treatments, especially unfertilized control plants. The results of the aforementioned data were generally comparable to the sole application of inorganic fertilizer (T_1) and other integrated fertilizer management options except for the yield of marketable ears for T_5 plants. This finding conforms to the study of Ojeniyi (2002), who further observed that applying inorganic and organic fertilizers immensely increased crop production in corn. The combination shows that inorganic fertilizer plus Vermicompost produced the highest ear length, ear diameter, number of kernel rows, number of marketable ears $plot^{-1}$, and yield (tons ha^{-1}) of marketable ears (Lina *et al.*, 2014; Muktamar *et al.*, 2017; Tahir *et al.*, 2012). Adediran *et al.* (2005) found that integrating organic manure with inorganic fertilizers significantly boosted maize yields, highlighting the importance of nutrient synergy in crop production. Integrated fertilizer management provides immediate nutrient availability through inorganic fertilizers and improves soil structure and microbial activity through organic amendments. This combination is particularly effective in meeting the high nutrient demands of sweet corn. The organic component enhances soil health and nutrient retention. In contrast, the inorganic component ensures that nutrients are readily available during critical growth stages, leading to increased yield and better-quality ears.

The interaction effect between the methods of crop establishment and integrated fertilizer management on the ear diameter (cm) of sweet corn is reflected in Figure 3. Results showed that the two methods of crop establishment responded differently when compared with the different fertilizer management options tested. This was observed in unfertilized plants and sweetcorn plants applied with a minimal amount of inorganic (25%) but fertilized abundantly with organic at 75% (T_5). In effect, an opposite trend was noted for the unfertilized plants (T_0) and T_5 plants relative to the different crop establishment methods adopted. The control plants under the direct seeding method remarkably emanated longer ear diameters than the transplanting method. On the other hand, a reverse result was observed in T_5 plants wherein the transplanting method notably achieved a longer ear diameter than those plants under the direct method of crop establishment. However, all fertilized sweet corn plants regardless of the crop establishment responded similarly except those plants applied with a lower amount of inorganic (25%) and supplied with Vermicompost at 75% (T_5). This finding conformed to the study of Sofyan and Sara (2019) on maize diameter, which found that applying organic fertilizer in combination with NPK fertilizers showed better results than applying organic fertilizer alone and the control treatment.

There was an interaction between the crop establishment method and integrated fertilizer management on the number of marketable ears $plot^{-1}$ (Figure 4). Results indicated that the two crop establishment methods differed significantly when compared to all fertilizer management options tested except those unfertilized sweetcorn plants (T_0), plants applied with 75% inorganic +

25% organic fertilizers (T_3), and also those plants purely applied with organic (Vermicompost) fertilizer (T_2). The interaction effect between these two variables clearly showed that the transplanting method significantly produced an abundant number of marketable ears per plot when applied purely with inorganic fertilizer (T_2),

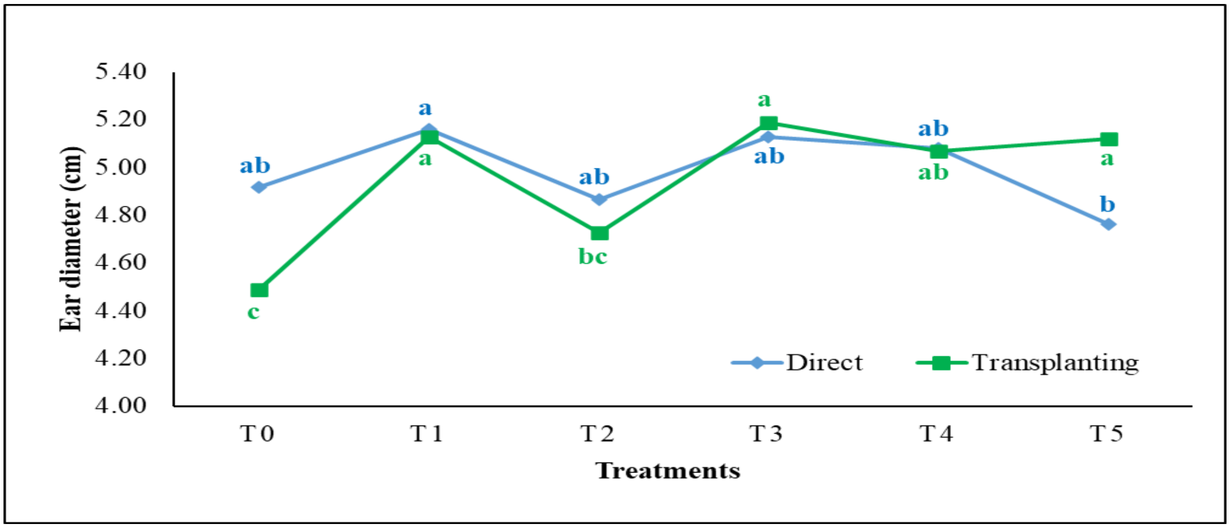

Figure 3. Interaction effect between the methods of crop establishment and integrated fertilizer management on the ear diameter (cm) of sweet corn (*Zea mays* L. var. saccharata).

Legend:
T_0 – No fertilizer application (Control)
T_1 – 90-60-60 kg ha^{-1} N, P_2O_5, K_2O (Inorganic fertilizer)
T_2 – 10 t ha^{-1} of Vermicompost
T_3 – 67.5-45-45 kg ha^{-1} N, P_2O_5, K_2O + 2.5 t ha^{-1} of Vermicompost
T_4 – 45-30-30 kg ha^{-1} N, P_2O_5, K_2O + 5 t ha^{-1} Vermicompost
T_5 – 22.5-15-15 kg ha^{-1} N, P_2O_5, K_2O + 7.5 t ha^{-1} of Vermicompost

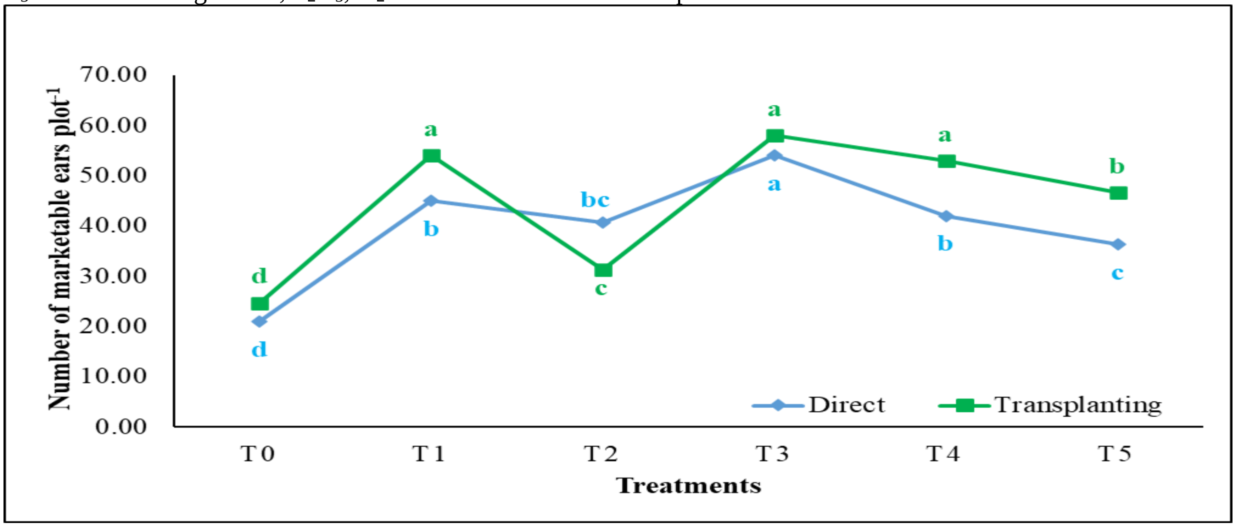

Figure 4. Interaction effect between the methods of crop establishment and integrated fertilizer management on the number of marketable ears $plot^{-1}$ of sweet corn (*Zea mays* L. var. saccharata)

Legends:
T_0 – No fertilizer application (Control)
T_1 – 90-60-60 kg ha^{-1} of N, P2O5, K2O (Inorganic fertilizer)
T_2 – 10 tons ha^{-1} of Vermicompost
T_3 – 67.5-45-45 kg ha^{-1} of N, P_2O_5, K_2O + 2.5 tons ha^{-1} of Vermicompost
T_4 – 45-30-30 kg ha^{-1} of N, P_2O_5, K_2O + 5 tons ha^{-1} Vermicompost
T_5 – 22.5-15-15 kg ha^{-1} of N, P_2O_5, K_2O + 7.5 tons ha^{-1} of Vermicompost

and in sweet corn plants applied with the combination of inorganic fertilizers ranging from 25 to 50% + organic fertilizers ranges from 50% to 75% (T_4 and T_5) than the direct seeding method of crop establishment. Therefore, transplanted sweet corn plants generally produced a remarkable number of marketable ears per plot than those plants raised under the direct seeding method of crop establishment.

Figure 5 depicts the interaction effect between crop establishment methods and integrated fertilizer management on the marketable ear yield (tons ha^{-1}) of sweet corn. Results indicated that the two crop establishment methods responded to similar trends to the fertilizer management options adopted. Regardless of crop establishment method, the yield of marketable ears has of similar response with the application of the different fertilizer management options tested. This was pronounced in sweetcorn plants applied with pure inorganic fertilizer (T_1) and in those plants applied with 75% inorganic plus 25% organic fertilizer (T_3). This synergistic effect of crop establishment methods and integrated fertilizer management underscores the importance of adopting a holistic approach to cultivation, ultimately enhancing the productivity and marketability of sweet corn (Bhattacharyya *et al.*, 2012). The findings suggest that the choice of crop establishment method and the integration of organic and inorganic fertilizers can profoundly impact the marketable ears of sweet corn.

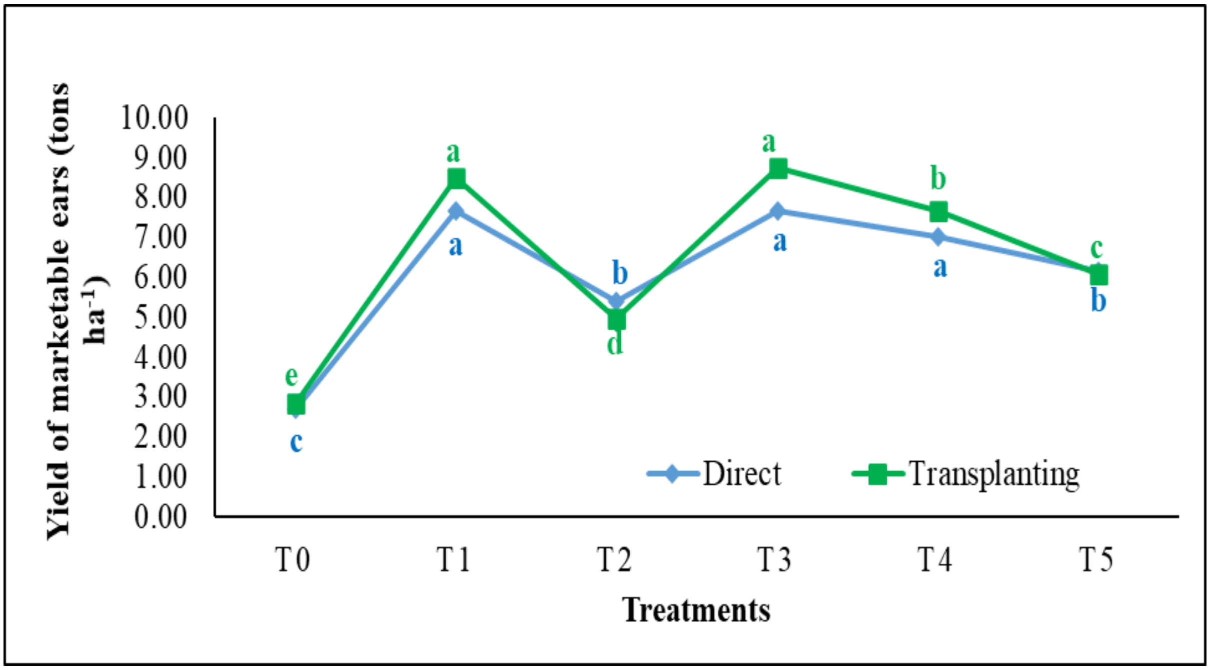

Figure 5. Interaction effect between the methods of crop establishment and integrated fertilizer management on the marketable ear yield (tons ha^{-1}) of sweet corn (*Zea mays* L. var. saccharata)

Table 5. Yield and yield components of sweet corn (*Zea mays* L. var. saccharata) applied with inorganic and organic fertilizers under different methods of crop establishment

Treatment	Ear length (cm)	Ear diameter (cm)	Number of kernel rows	Number of marketable ears $plot^{-1}$	Yield of marketable ears (tons ha^{-1})
Methods of crop establishment					
M_1 – Direct seeding	19.40	4.99	15.93	39.83^{b}	6.11^{b}
M_2 – Transplanting	19.76	4.95	15.66	44.61^{a}	6.49^{a}
Mean	19.58	4.97	15.80	42.22	6.29
Integrated fertilizer management					
T_0 – No fertilizer application (Control)	18.21^{b}	4.70^{bc}	15.52	22.83^{d}	2.77^{ce}
T_1 – 90-60-60 kg ha^{-1} of N, P_2O_5, K_2O (Inorganic fertilizer)	20.53^{a}	5.15^{a}	15.47	49.50^{ab}	8.10^{a}
T_2 – 10 tons ha^{-1} of Vermicompost	18.35^{b}	4.79^{abc}	15.58	$36.00b^{c}$	5.21^{bd}
T_3 – 67.5-45-45 kg ha^{-1} of N, P_2O_5, K_2O + 2.5 tons ha^{-1} of Vermicompost	20.48^{a}	5.15^{a}	16.25	56.00^{a}	8.20^{a}
T_4 – 45-30-30 kg ha^{-1} of N, P_2O_5, K_2O + 5 tons ha^{-1} Vermicompost	20.32^{a}	5.07^{ab}	15.88	47.50^{ab}	7.36^{ab}
T_5 – 22.5-15-15 kg ha^{-1} of N, P_2O_5, K_2O + 7.5 tons ha^{-1} of Vermicompost	19.59^{ab}	4.94^{ab}	16.08	41.50^{bc}	6.13^{bc}
Mean	19.58	4.97	15.80	42.22	6.29
CE x IFM	ns	**	ns	**	**
C.V. (a)%	11.96	4.47	4.82	1.58	3.23
C.V. (b)%	3.98	2.96	3.32	4.86	4.84

Means within a column with the same letter and those without letter designations are not significantly different at the 5% level, based on HSD.

3.5. Correlation analysis

Table 6 shows the linear correlation between plant height, fresh stover yield, leaf area index, ear length, ear diameter, and total ear yield of sweet corn applied with inorganic and organic fertilizers under different crop establishment methods. Results showed a positive correlation between plant height and fresh stover yield ($r = 0.947$). It was noted that the fresh stover yield increases as the plant height increases. Moreover, the length of the ears and the overall yield showed a strong correlation with the plant height. The results of this study align with the research conducted by Tan and Yap (1973), which demonstrated a positive correlation between plant height and grain yield in sweet corn. The results of this study support the findings of Hansen (1975) who discovered a positive correlation between ear length, plant height, and ear height.

3.6. Cost and return analysis

Table 7 shows the cost and return analysis of sweet corn production applied with inorganic and organic fertilizers under various crop establishment methods. Based on the analysis, results showed that the sweet corn plants under the transplanting method of crop establishment obtained a higher gross income of PhP324,500.00 than direct seeding with only PhP 305,500.00.

Relative to the fertilizer management options adopted, the subplot treatment with the highest gross income (PhP410,000.00) was obtained by the application of 75% inorganic fertilizer and 2.5 t ha^{-1} of Vermicompost (T_3) with a corresponding gross margin of PhP295,808.00 and ROI of 259%. This result showed that the combined application of inorganic fertilizer and Vermicompost was economically favorable due mainly to a higher gross income. Besides, this option can sustain crop productivity and improve soil fertility in the forthcoming cropping periods. Therefore, the most vital strategy during the upcoming unpredictable climatic conditions is the adoption of an integrated fertilizer management option not only to enhance sweet corn productivity but also for the main reasons of crop sustainability, improving soil fertility, and an adaptation strategy amid the climate change situation.

Table 6. Coefficients of linear correlation between plant height, fresh stover yield, leaf area index, ear length, ear diameter, and total ear yield of sweet corn to the combined application of inorganic and organic fertilizers under different methods of crop establishment

	Plant height	Fresh stover	Leaf area index	Ear length	Ear diameter	Total ear yield
Plant height	1					
Fresh stover	0.947**	1				
Leaf Area index	0.961**	0.982**	1			
Ear length	0.919**	0.977**	0.966**	1		
Ear diameter	0.946**	0.994**	0.987**	0.987**	1	
Total ear yield	0.937**	0.997**	0.981**	0.970**	0.994**	1

Correlation is significant at the 0.01 level.

Table 7. Cost and return analysis of sweet corn (*Zea mays* L.) var saccharata to the combined application of inorganic and organic fertilizers under different methods of crop establishment

Treatment	Marketable yield (t ha^{-1})	Gross income (PhP)	Cost of investment (PhP)	Gross margin (PhP)	Return on investment (ROI)
Methods of crop establishment					
M_1 – Direct seeding	6.11	305,500.00	216,532.00	88,968.00	41
M_2 – Transplanting	6.49	324,500.00	221,990.00	102,510.00	46
Mean	6.29	314,500.00			
Integrated fertilizer management					
T_0 – No fertilizer application (Control)	2.77	138,500.00	72,127.00	111,373.00	154
T_1 – 90-60-60 kg ha^{-1} N, P_2O_5, K_2O (Inorganic fertilizer)	8.10	405,000.00	93,227.00	311,773.00	334
T_2 – 10 t ha^{-1} of Vermicompost	5.21	260,500.00	183,560.00	76,940.00	42
T_3 – 67.5-45-45 kg ha^{-1} N, P_2O_5, K_2O + 2.5 t ha^{-1} of Vermicompost	8.20	410,000.00	114,192.00	295,808.00	259
T_4 – 45-30-30 kg ha^{-1} N, P_2O_5, K_2O + 5 t ha^{-1} Vermicompost	7.36	368,000.00	137,296.00	230,704.00	168
T_5 – 22.5-15-15 kg ha^{-1} N, P_2O_5, K_2O + 7.5 t ha^{-1} of Vermicompost	6.13	306,500.00	161,864.00	144,636.00	89
Mean	6.29	314,500.00			

Current Market price: PhP50.00/kg
As of the conduct of this study April 2024

4. Conclusion

The agronomic parameters, yield, and yield components are substantially affected by the different crop establishment methods, aside from ear length, ear diameter, and number of kernel rows. The number of days from sowing to tasseling, silking, green cob, fresh stover yield (tons ha^{-1}), ear length, ear diameter, number of marketable ears plot^{-1}, and marketable ear yield (tons ha^{-1}) were remarkably affected by the integrated fertilizer management strategy.

An interaction effect was observed between the method of crop establishment and integrated fertilizer management on fresh stover yield (tons ha^{-1}), ear diameter, number of marketable ears plot^{-1}, and yield of marketable ears (tons ha^{-1}). The application of 75% inorganic fertilizer and 25% Vermicompost based on their recommended rate obtained the highest marketable ear yield of 8.20 (tons ha^{-1}), most especially when planted under the transplanting method of crop establishment.

Recommendations

Further study and verification of the correlation analysis of sweet corn under different agronomic parameters are recommended. Conduct a similar study under different agro-climatic conditions to further verify the effect of the applied treatments.

Acknowledgment

The primary author would like to thank, first and foremost, the HEAVENLY FATHER, who allowed him to experience a joyous yet challenging life. To the DOST-ASTHRDP for funding this research. To his graduate advisory committee, Dr. D.M. Bañoc, Dr. B.C. Ratilla, and Dr. S.B. Lina. Blessed be GOD Forever.

Authors' Contributions

All authors are contributed in this research

Funding

There is no funding for this research.

Institutional Review Board Statement

All Institutional Review Board Statements are confirmed and approved.

Data Availability Statement

Data presented in this study are available on fair request from the respective author.

Ethics Approval and Consent to Participate

Not applicable

Consent for Publication

Not applicable.

Conflicts of Interest

The authors disclosed no conflict of interest.

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