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Response of sweet corn (*Zea mays* L. var. saccharata) to vermicompost and inorganic fertilizer application

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Abstract
This study was conducted to determine the appropriate rate of vermicompost that would influence the agronomic performance and evaluate the effect of combining the different vermicompost rates and the specific rate of inorganic fertilizer that could effectively promote the growth and yield of sweet corn. The experiment was conducted in a Randomized Complete Block Design (RCBD) with ten (10) treatments and three (3) replications. The treatments are as follows: T_1 – 120-90-60 kg ha^{-1} inorganic fertilizer or farmers' practice, T_2 – 5 t ha^{-1} vermicompost + 102-76.5-51 kg ha^{-1} inorganic fertilizer, T_3 – 10 t ha^{-1} vermicompost + 96-72-48 kg ha^{-1} inorganic fertilizer, T_4 – 20 t ha^{-1} vermicompost + 84-63-42 kg ha^{-1} inorganic fertilizer, T_5 – 40 t ha^{-1} vermicompost + 60-45-30 kg ha^{-1} inorganic fertilizer, T_6 – no application (control group), T_7 – 5 t ha^{-1} vermicompost, T_8 – 10 t ha^{-1} vermicompost, T_9 – 20 t ha^{-1} vermicompost, and T_{10} – 40 t ha^{-1} vermicompost. Results of the study revealed that the different treatments influenced the ear yield (husked and unhusk), kernels per ear, weight per ear, percentage of marketable ears, percentage of barren plants, and percentage of double ears. The treatments 1 to 5 yielded significantly higher compared to the control treatment (T_6) which implies that the application of vermicompost with 50 - 85% of the farmers' practice had significant improvement in sweet corn production. The application of 20 t ha^{-1} vermicompost + 70% of farmers' practice achieved the highest yield at 12.50 and 15.80 t ha^{-1} husked and unhusk ears respectively. Highest percentage of double ears at 29.69% was attained on the plants applied with 40 t ha^{-1} vermicompost + half of farmers' practice. The yields of sweet corn applied with vermicompost alone were not comparable to treatments applied with inorganic fertilizers.

Keywords: inorganic fertilizer; maize; NPK fertilizer; vermicompost; yield components

Introduction

Sweet corn (*Z. mays* L. var. saccharata) is one of the most favorite foods of Filipino people on all occasions for snacks because of its sweetness, juiciness, and tenderness (Srdić et al., 2011). It is sold anywhere in the Philippines along the highways, in bus or jeepney terminals, malls, or even in the local market stalls (Salazar et al., 2009). Sweet corns are rich in nutrients and vitamins (Ghosh et al., 2013), however, criticized by some health-conscious individuals due to the toxic residues resulting from inappropriate agricultural practices and intensive pesticide application (Srdić et al., 2011) and (Cutulle et al., 2018). Since it is a favorite host of Asian corn borer (ACB), farmers used chemicals extravagantly (Ozores-Hampton et al., 2013). The presence of ACB in a sweet corn plant cannot be underestimated because it would result to crop damage or eventually failure in crop production (Rasco Jr et al., 2008). Some experienced farmers in sweet corn production used biological control like a parasitic wasp (*Trichogramma evanescens*) (Gardner et al., 2011) or cultural practice like detasseling (Belfry & Van Eerd, 2016) and (Rani et al., 2017). The use of parasitoids and detasseling are effective in controlling ACB infestation and besides, environmentally friendly (Andow, 2019). Intensive application of inorganic fertilizers is another agricultural practice that would lead to the degradation and depletion of soil fertility (Hadgu et al., 2009). Organic fertilizers can be an alternative option for inorganic fertilizers (Ayoola & Makinde, 2009). Organically grown products command higher prices in the market (Briz & Ward, 2009), (Aryal et al., 2009), (Akgüngör et al., 2010) and (Zander & Hamm, 2010). Health-conscious individuals prefer to buy organically grown sweet corn, (Basha et al., 2015), (Stolz et al., 2011), (Guilabert & Wood, 2012), and (Rana & Paul, 2017). Farmers are aiming to produce a big and damage-free ear to attract and convince more consumers. During harvest, products are sorted into big, medium, and small. Big ears are paid higher at Php10.00 to Php15.00 by the direct buyers or consumers, while small and medium are paid at Php3.00 to Php8.00. Sweet corn is a very profitable crop to grow since it can be harvested in an ideal stage at 68 to 75 days after planting or 18 to 21 days after tasseling (Singh et al., 2010). The popularity of organic agriculture is increasing due to a continuous campaign in the awareness of climate change and biodiversity (Läpple & Van Rensburg, 2011). If farmers abuse the usage of synthetic fertilizers and chemical pesticides, our health is at risk (Hati et al., 2008), and (Yan et al., 2013). This experiment was intentionally conducted to determine the appropriate rate of vermicompost alone and the effect of combining the different rates of vermicompost to inorganic fertilizers that would significantly boost the agronomic performance of sweet corn.

Materials and Methods

Time and place of research

The study was conducted at the crop science experimental area of the Zamboanga del Sur Provincial Government College, Aurora, Zamboanga del Sur from July to September 2019.

Design

The experiment was laid out in Randomized Complete Block Design (RCBD) with ten treatments and three replications. Details of treatments with their corresponding fertilizer rates are shown in table 1. As shown in the table, T_1 has been applied with purely inorganic fertilizers while T_2 to T_5 was a combination of organic (vermicompost) and inorganic fertilizer at varying amount. T_6 on the other hand has zero application or no treatment at all while T_7 to T_{10} were applied with organic (vermicompost) fertilizer at varying degree.

Table 1. Treatments and fertilizer rates.

Treatments	Fertilizer rates
T_1	120 kg N – 90 kg P_2O_5 – 60 kg K_2O or Farmers' practice
T_2	5 t Vermicompost, 102 kg N – 76.5 kg P_2O_5 – 51 kg K_2O
T_3	10 t Vermicompost, 96 kg N – 72 kg P_2O_5 – 48 kg K_2O
T_4	20 t Vermicompost, 84 kg N – 63 kg P_2O_5 – 42 kg K_2O
T_5	40 t Vermicompost, 60 kg N – 45 kg P_2O_5 – 30 kg K_2O
T_6	Zero application or Control group
T_7	5 t Vermicompost, 0 kg N – 0 kg P_2O_5 – 0 kg K_2O
T_8	10 t Vermicompost, 0 kg N – 0 kg P_2O_5 – 0 kg K_2O
T_9	20 t Vermicompost, 0 kg N – 0 kg P_2O_5 – 0 kg K_2O
T_{10}	40 t Vermicompost, 0 kg N – 0 kg P_2O_5 – 0 kg K_2O

Land preparation and crop establishment

The area was plowed using a tractor for two times at one-week interval to destroy all weeds and insect pests. Furrowing was done three days after the second plowing. Vermicomposts were applied 0 DAP (basal application) while synthetic fertilizers were applied in three application times – 0 DAP, 15 DAP, and 30 DAP. Furrows were spaced at 75 cm apart. Two seeds were sown in each row at a depth of one cm and a distance of 25 cm between hills. Thinning was done at 12-15 DAP. Pests and diseases were monitored regularly.

Harvesting

Harvesting was done at 75 DAP. All ears were harvested in the 4 inner rows of each plot. Husked ears were sorted into small, medium, large, and non-marketable or damaged ears.

Data gathered

The plant height was measured from the ground level up to the base of the panicle at 10 days before harvesting. Ear height was measured from the ground level up the base of the primary ear. Plant height and ear height were based on the 10 randomly selected plants per plot. The weight of ears in each plot was determined using the weighing scale (50 kg. cap.). Weight of 10 sample ears was determined using a digital weighing scale. The diameter was obtained using a vernier caliper. The length was determined using a ruler. The number of kernels per ear was determined by counting the number of rows and multiplied by the number of kernels per row. Leaf area index was calculated using the formula below:

$$LAI = \frac{L \times W \times \text{number of leaves} \times CF}{PD}$$

Where: LAI = leaf area index, L = length, W= width, CF = correction factor of 0.75, and PD = planting distance.

The yield of husked and unhusk ears in tons per hectare was calculated using the formula:

$$\text{Yield } (t\ ha^{-1}) = \frac{\text{plot weight (kg)}}{\text{Plot size (sq. m.)}} \times \frac{10{,}000 \text{ (sq. m/ha)}}{1{,}000 \text{ (kg/t)}}$$

Statistical Tools

The study used descriptive statistics specifically percentage in determining the marketable ears, barren plants, and double ears. An F-test or Analysis of Variance (ANOVA) was used to determine the response or influence of organic (vermicompost) and inorganic fertilizer to the sweet corn plant. Tukey's test or honestly significant difference (HSD) test was used to compare the treatment differences. Moreover, the principal component analysis was used to determine the relationships of yield to other yield components.

Results and Discussion

Plant height and ear height (cm)

The plant height and ear height is presented in table 2. The tallest plant height and ear height were obtained in T_5 (40 t ha^{-1} VC, 60–45–30 NPK kg ha^{-1}) at 198 and 67.06 cm respectively. Statistical analysis did not reveal any significant difference in the plant height and ear height of sweet corn as influenced by vermicompost and inorganic fertilizer application. The study of (Joshi et al., 2015) revealed that vermicompost improved the plants' height due to humic acid and growth promoting bacteria. Khan Mohammadi et al.(2017) found out that vermicompost with the combination of inorganic fertilizers at various levels enhanced the plant height and ear height of sweet corn. Thus, in this study, it is obvious that the highest rate of vermicompost at 40 t ha^{-1} with inorganic fertilizer produced the highest plant height and ear height, although statistically insignificant.

Table 2. Plant height and ear height of sweet corn.

Treatments	Plant height (cm) ±SE	Ear height (cm) ±SE
T_1 –120-90-60 NPK (kg ha^{-1}) or Farmers' Practice	177.67±10.3	58.00±6.53
T_2 – 5 t ha^{-1} VC; 102-76.5-51 NPK (kg ha^{-1})	172.00±2.78	53.83±6.39
T_3 – 10 t ha^{-1} VC; 96-72-48 NPK (kg ha^{-1})	180.77±3.62	66.17±1.20
T_4 – 20 t ha^{-1} VC; 84-63-42 NPK (kg ha^{-1})	177.33±3.44	67.00±0.29
T_5 – 40 t ha^{-1} VC; 60-45-30 NPK (kg ha^{-1})	198.00±10.2	67.06±3.22
T_6 – Zero Application (Control)	161.50±2.57	53.00±3.04
T_7 – 5 t ha^{-1} VC; 0-0-0 NPK (kg ha^{-1})	168.50±5.77	55.50±3.33
T_8 – 10 t ha^{-1} VC0-0-0 NPK (kg ha^{-1})	161.50±10.5	62.83±1.64
T_9 – 20 t ha^{-1} VC; 0-0-0 NPK (kg ha^{-1})	168.67±2.89	59.17±4.48
T_{10} – 40 t ha^{-1} VC; 0-0-0 NPK (kg ha^{-1})	172.17±8.12	48.17±9.06
F-test	ns	ns
C.V. (%)	8.75	14.01

ns – non-significant

Leaf area index (LAI)

Table 3 shows the LAI of sweet corn at 65 DAP. Treatment 3 obtained the highest LAI at 3.66 followed by T_4 at 3.64. Results revealed no significant difference in the LAI of sweet corn at 65 DAP as affected by vermicompost and inorganic fertilizers. The experiment conducted by (Bekele et al., 2018) proved the efficacy of combining vermicompost with the inorganic fertilizer to improve the leaf area index in corn. The study of (Rasool et al., 2015)about combining inorganic and organic fertilizer improved the leaf area index of sweet corn. The result confirmed the findings of (Fahrurrozi et al., 2017) where, they found out that the organic foliar fertilizer did not reveal significant result on the leaf area of sweet corn. The leaf area index data are not significant; however, it clearly shows the pattern of increase when applied with the combination of vermicompost and inorganic fertilizer compared to the control group.

Table 3. Leaf area index of sweet corn as influenced by vermicompost and inorganic fertilizer application in Aurora, Zamboanga del Sur.

Treatments	Leaf area index
T_1 –120-90-60 NPK (kg ha^{-1}) or Farmers' Practice	3.07
T_2 – 5 t ha^{-1} VC; 102-76.5-51 NPK (kg ha^{-1})	3.18
T_3 – 10 t ha^{-1} VC; 96-72-48 NPK (kg ha^{-1})	3.66
T_4 – 20 t ha^{-1} VC; 84-63-42 NPK (kg ha^{-1})	3.64
T_5 – 40 t ha^{-1} VC; 60-45-30 NPK (kg ha^{-1})	3.51
T_6 – Zero Application (Control)	2.72
T_7 – 5 t ha^{-1} VC; 0-0-0 NPK (kg ha^{-1})	2.46
T_8 – 10 t ha^{-1} VC0-0-0 NPK (kg ha^{-1})	3.16
T_9 – 20 t ha^{-1} VC; 0-0-0 NPK (kg ha^{-1})	3.05
T_{10} – 40 t ha^{-1} VC; 0-0-0 NPK (kg ha^{-1})	3.33
F-test	ns
C.V. (%)	8.75

ns – non-significant

Yield of husked and unhusk ears (t ha^{-1})

The yields of husked and unhusk ears are shown in figure 1. The data show that the yields in treatments from 1 to 5 differed significantly from the rests of treatments which means that the application of vermicompost in combination with the FP at 50 – 85% had significant improvement in crop production. The rate of 20 t ha^{-1} of vermicompost with 60% of the FP attained the highest yield at 12.50 and 15.81 t ha^{-1} in husked and unhusked ears respectively. The yields of sweet corn applied with vermicompost alone were significantly lower compared to vermicompost with inorganic fertilizer application. The result also suggests that the nutrients present in the vermicompost are released slowly, thus they are not comparable to treatments with inorganic fertilizers (Densilin et al., 2011). The study of (Canatoy, 2018) mentioned that the recommended rate of inorganic fertilizer + 1 ton of vermicompost produced the highest ear yield. The application of compost and inorganic fertilizers improved the yield of corn and at the same time improve the soil organic carbon (Zhang et al., 2016).

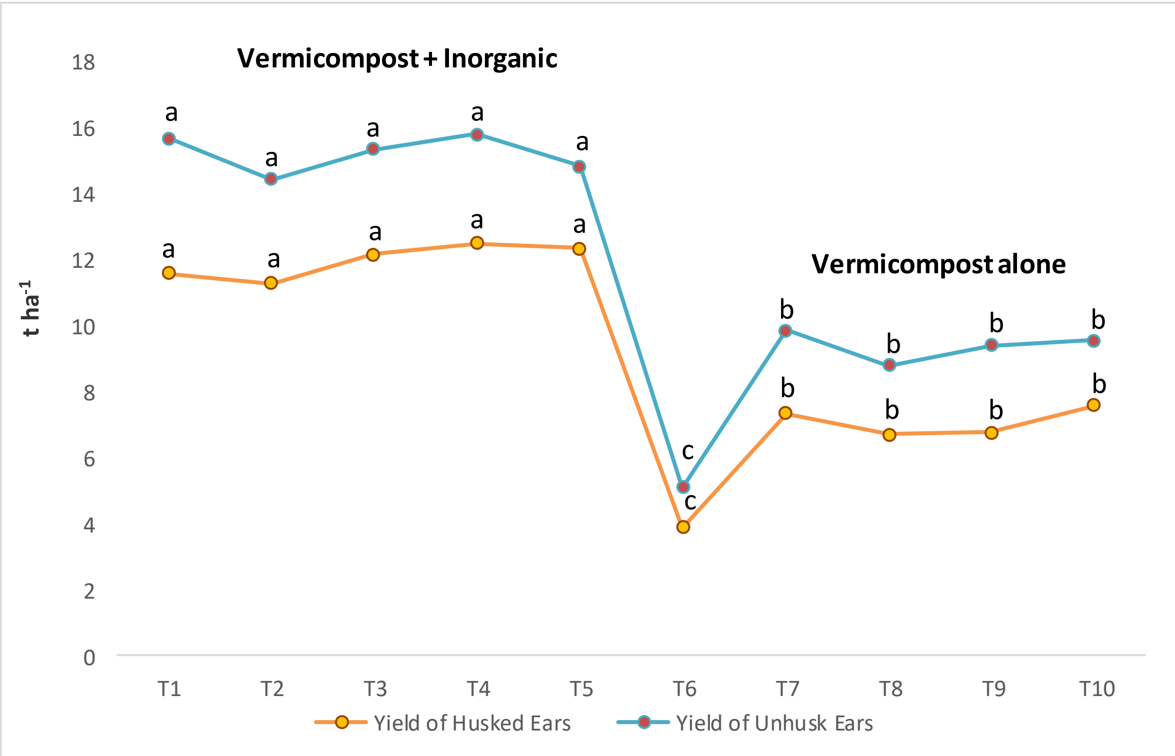

Figure 1. Yield of husked and unhusk ears of sweet corn in response to vermicompost and inorganic fertilizer application in Aurora, Zamboanga del Sur.

Percentage of marketable ears, barren plants, and double ears

Percentage of marketable ears, barren plants, and double ears are shown in table 4. As shown, T_4 got the highest percentage of marketable ears as revealed by 93.91% while T_6 obtained the least at 52.99%. The highest percentage of barren plants was attained in T_6 at 29.17%. Highest percentage of double ears was significantly higher in T_4. Pests and diseases greatly affected the percentage of marketable ears. Asian corn borer, corn earworm, and fall armyworms are the most damaging pests in corn (Lima et al., 2010). Reduction of sizes and grain filling due to weed competition (Silva et al., 2010) also influenced the percentage of marketable ears. Sufficient application of fertilizers such as nitrogen, phosphorus, and potassium improved the sizes, grain filling and double ears (Ma et al., 2012) and (Silva et al., 2013). Insufficient supply of fertilizers increased the percentage of barren plants (Kumar et al., 2015).

Table 4. Percentage of marketable ears, barren plants and double ears.

Treatments	Marketable ears (%)	Barren plants (%)	Double ears (%)
T_1 – 0 t ha^{-1} VC; 120-90-60 NPK (kg ha^{-1})	84.53^{ab}	0.00^{b}	18.75^{ab}
T_2 – 5 t ha^{-1} VC; 102-76.5-51 NPK (kg ha^{-1})	84.86^{ab}	0.00^{b}	17.19^{ab}
T_3 – 10 t ha^{-1} VC; 96-72-48 NPK (kg ha^{-1})	88.58^{ab}	0.00^{b}	18.23^{ab}
T_4 – 20 t ha^{-1} VC; 84-63-42 NPK (kg ha^{-1})	93.91^{a}	0.52^{b}	7.29^{b}
T_5 – 40 t ha^{-1} VC; 60-45-30 NPK (kg ha^{-1})	80.70^{abc}	0.00^{b}	29.69^{a}
T_6 – 0 t ha^{-1} VC; 0-0-0 NPK (kg ha^{-1})	52.99^{d}	29.17^{a}	0.00^{b}
T_7 – 5 t ha^{-1} VC; 0-0-0 NPK (kg ha^{-1})	70.26^{bcd}	0.52^{b}	6.77^{b}
T_8 – 10 t ha^{-1} VC0-0-0 NPK (kg ha^{-1})	61.75^{cd}	0.00^{b}	6.77^{b}
T_9 – 20 t ha^{-1} VC; 0-0-0 NPK (kg ha^{-1})	61.84^{cd}	0.00^{b}	15.10^{ab}
T_{10} – 40 t ha^{-1} VC; 0-0-0 NPK (kg ha^{-1})	70.24^{bcd}	0.00^{b}	7.29^{b}
F-test	**	**	**
C.V. (%)	9.54	32.00	53.20

***-significant at 1% level of Tukey's pairwise comparisons*

Yield components of sweet corn

The yield components of sweet corn are presented in table 5. Statistical analysis reveal any significant difference in all treatments in terms of the the kernels per ear and weight per ear. Treatment 4 achieved the highest number of kernels per ear at 670. Treatments 3 and 4 got the heaviest weight per ear at 313.33 and 305 g respectively. Increased in the number of rows, kernels per ear, and weight per ear are influenced by NPK fertilization (Mukhtar et al., 2011) and (Baral et al., 2016). The results of the study was similar to the findings of (Marlina et al., 2017), (Pangaribuan & Hendarto, 2018), and (Sofyan et al., 2019) in which the yield components are increased with the application of inorganic and organic fertilizers at the highest rates of 10 to 20 t ha^{-1}.

Table 5. Yield components of sweet corn as influenced by vermicompost and inorganic fertilizer application.

Treatments	Diameter (cm)	Length (cm)	Number of rows	Kernels per ear	Weight per ear (g)
T_1 – 120-90-60 NPK (kg ha^{-1})	4.92	17.69	16	584^{ab}	270.00^{ab}
T_2 – 5 t ha^{-1} VC; 102-76.5-51 NPK (kg ha^{-1})	4.88	16.42	16	603^{ab}	273.33^{ab}
T_3 – 10 t ha^{-1} VC; 96-72-48 NPK (kg ha^{-1})	4.80	17.26	16	617^{ab}	313.33^{a}
T_4 – 20 t ha^{-1} VC; 84-63-42 NPK (kg ha^{-1})	4.88	18.56	17	670^{a}	305.00^{a}
T_5 – 40 t ha^{-1} VC; 60-45-30 NPK (kg ha^{-1})	4.77	17.64	17	606^{ab}	256.67^{abc}
T_6 – Control group	4.57	14.34	16	471^{b}	183.33^{c}
T_7 – 5 t ha^{-1} VC; 0-0-0 NPK (kg ha^{-1})	4.59	16.13	15	522^{ab}	225.00^{bc}
T_8 – 10 t ha^{-1} VC0-0-0 NPK (kg ha^{-1})	4.80	15.03	16	474^{b}	215.00^{bc}
T_9 – 20 t ha^{-1} VC; 0-0-0 NPK (kg ha^{-1})	4.58	15.37	16	526^{ab}	221.67^{bc}
T_{10} – 40 t ha^{-1} VC; 0-0-0 NPK (kg ha^{-1})	4.50	15.66	16	534^{ab}	236.67^{abc}
Test of significance	ns	ns	ns	**	**
C.V. (%)	4.87	10.24	4.50	9.10	10.76

ns-non significant

***-significant at 1% level of Tukey's pairwise comparisons*

Principal component analysis of yield and yield components of sweet corn

Scree plot

The scree plot of yield and yield components of sweet corn as influenced by vermicompost and inorganic application is presented in figure 2. As shown, the first principal component (PC) accounts for most of the total variability in the data as reflected in the eigenvalues. The remaining PCs account for a smaller portion of variability which is smaller than one and is not important. As mentioned by Hair et al., (1998) and (Shegro et al., 2013), the components attained an eigenvalue less than 1 should be eliminated and the eigenvalues greater than 1 with component loadings greater than ±0.3 are considered significant.

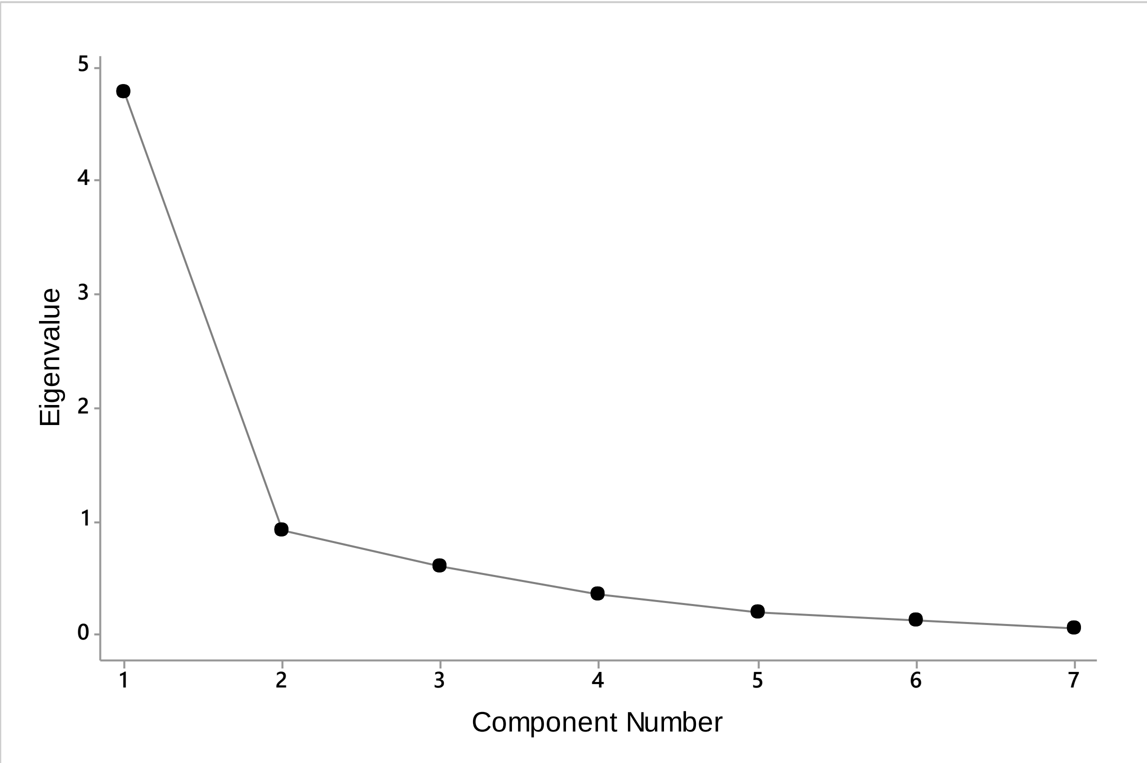

Figure 2. Scree plot of yield and yield components of sweet corn.

Principal component analysis

The principal component analysis of yield and yield components of sweet corn is presented in table 6. The first principal component has an eigenvalue greater than 1 represents 68% of the total variability suggesting that the first PC adequately explains the variation of the study. For the data on yield (0.420), weight per ear (0.411), percentage of marketable ears (0.414), kernels per ear (0.432), and length (0.351) had the highest positive loadings on component 1. Results suggest that the yield is increased when the weight per ear, percentage of marketable ears, kernels per ear, and length also increased (Yazdani et al., 2009), (Maske et al., 2018) and (Villaver, 2019). Increasing its size can be attained through proper fertilizer application (Asghar et al., 2010). Increased percentage of marketable ears can be achieved with proper cultural practices to attain damage-free ears (Cruz et al., 2015). An increase in length and kernels per ear is influenced by sufficient application of potassium (Anser Ali & Hussain, 2012).

Table 6. Principal component analysis of yield and yield components of sweet corn in response to vermicompost and inorganic fertilizer application.

	Component Loadings				
Variables	PC1	PC2	PC3	PC4	PC5
Yield (t ha^{-1})	0.420	0.133	-0.130	0.362	0.232
Weight per ear (g)	0.411	0.243	-0.084	0.206	-0.783
% of marketable ears	0.414	0.146	0.022	0.447	0.494
Diameter	0.293	-0.392	0.866	-0.006	-0.070
Length	0.351	0.480	0.106	-0.724	0.224
Number of rows	0.295	-0.705	-0.416	-0.208	0.099
Kernels per ear	0.432	-0.144	-0.204	-0.244	-0.157
	Eigenanalysis of the Correlation Matrix				
Eigenvalue	4.775	0.913	0.599	0.350	0.187
Proportion	0.682	0.130	0.086	0.050	0.027
Cumulative	0.682	0.812	0.898	0.948	0.095

-1- perfect negative linear relationship; -0.70- strong negative linear relationship; -0.50- moderate negative linear relationship; 0- no linear relationship; +0.30- weak positive linear relationship; +0.50- moderate positive linear relationship; +0.70- strong positive linear relationship;+1- perfect positive linear relationship.

Conclusion

The application of vermicompost and inorganic fertilizers did not influence on the plant height, ear height, leaf area index, diameter, length, and the number of rows. However, a significant increase in the yield of husked and unhusk ears was observed when applied with vermicompost and inorganic fertilizers. The yield of sweet corn applied with pure vermicompost is not comparable to inorganic fertilizers. The percentage of marketable ears and kernels per ear were significantly higher when applied with 70% of farmers' practice and 20 t ha^{-1} vermicompost. Highest percentage of double ears was achieved by the plants applied with 50% of farmers' practice and 40 t ha^{-1} vermicompost. Highest weight per ear was achieved in T_3 and T_4 with 313.13 and 305.00 g respectively. Control treatment (no fertilization) obtained the highest percentage of barren plants. The yield of sweet corn greatly affected with the increasing weight per ear, length, kernels per ear, and percentage of marketable ears. The results of this study show the effect of using pure vermicompost at the optimum rate which is incomparable to vermicompost with the farmer's practice. This would provide valuable information to the farmers who want to engage in sweet corn production using vermicompost and inorganic fertilizer. Further study is recommended to include parameters like fertility of the soil, water holding capacity, and bulk density after the experiment conducted.

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