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Bio-fortified Compost as A Substitute for Chemical N Fertilizer for Growth, N Accumulation, and Yield of Sweet Corn

Marwanto Marwanto[1*], Shinta Puspita Wati[2], Atra Romeida[1], Merakati Handajaningsih[1], Usman Siswanto[1], Teguh Adiprasetyo[3], Bambang Gonggo Murcitro[3], and Hidayat Hidayat[4]
[1] Department of Agronomi, Faculty of Agriculture, University of Bengkulu, Indonesia
[2] Department of Agronomi, Faculty of Agriculture, University of Bengkulu, Indonesia
[3] Department of Soil Science, Faculty of Agriculture, University of Bengkulu, Indonesia
[4] Departement of Animal Husbandry, Faculty of Agriculture, University of Bengkulu, Indonesia
Jl. WR Supratman, Kandang Limun, Bengkulu 38120, Indonesia

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*Corresponding author:
E-mail:
marwanto@unib.ac.id

ABSTRACT

Finding the appropriate method of fertilizer application to simultaneously enhance farm productivity and ensure ecosystem sustainability has been receiving a lot of attention. A field experiment was carried in the Research Plot Agriculture Faculty Bengkulu University Campus Indonesia in 2017. The purpose of this study was (1) to assess the significant effects of inorganic N fertilizer (IF) substitution with bio-fortified compost (BC) under equal N conditions on growth, N accumulation, and yield of sweet corn, and (2) to determine the appropriate level to which inorganic N fertilizer could be reduced and equivalently replaced by bio-fortified compost to promote sweet corn growth and yield. The treatments consisted of six different proportions of inorganic N fertilizer (IF) substitution with bio-fortified compost (BC). Each treatment was designed on the basis of equal amount of total N input from a combination of both fertilizers (138 kg N ha^{-1}). They were arranged in a randomized block design with 3 replications. They included (1) 100% IF plus 0% BC, (2) 75% IF plus 25% BC, (3) 50% IF plus 50% BC, (4) 25% IF plus 75%, (5) 0% IF plus 100% BC, and (6) no IF and no BC. The results showed that the increasing proportion of IF replaced by BC resulted in an increase for all variables (except for plant height) but they decreased when 100% IF substitution with 100% BC was applied. Among the partial substitution treatments, 50% IF plus 50% BC consistently produced the best growth, N accumulation, and yield increase. Treatments of 50% IF plus 50% BC and 25% IF plus 75% BC produced the highest green cob weight with husk per plot (10.74 – 10.84 kg plot^{-1}), which was 16% to 19% higher than treatment of 100% IF plus % BC. The three partial substitution treatments produced crop yield components as good as treatment of 100% IF plus 0% BC. Treatment of 0% IF plus 100% BC reduced plant growth, N accumulation, and crop yield and its components. The appropriate level to which IF could be reduced and equivalently replaced by BC was at the range of 25% to 75%. Hence, a suitable replacement of inorganic N fertilizer with bio-fortified compost is considered a reasoned way to simultaneously increase crop yield and reduce environmental degradation.

INTRODUCTION

Sweet corn with the scientific name *Zea mays* (L.) *saccharata* Sturt is a specific maize variety that has tender, delicious and sugary kernels. These characteristics make it used much like a vegetable rather than as a cereal grain. Data issued by the Indonesian Ministry of Trade in 2016 revealed that national needs for sweet corn in 2015 extended to 4.1 million tons year^{-1} and became greater in 2016 to reach 5.2 million tons year^{-1}. The tremendous

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increase in demand for sweet corn was not accompanied by an increase in productivity. The average productivity of sweet corn in Indonesia from 2010 to 2015 reached 4.81 tons ha^{-1} (BPS, 2016), which was lower than the average world productivity of 8-9 ton ha^{-1}. To meet the increasing national needs, importing the sweet corn is inevitable. According to BPS (2018), the magnitude of sweet corn import was 1.09 million tons in 2013, 1.12 million tons in 2014, 2.70 million tons in 2015, and 3.08 million tons in 2016. Therefore, a continuous effort to minimize the increased import of sweet corn or to pursue its self-sufficiency by multiplying its production and productivity is compulsory.

Sweet corn has high requirements in nutrients due to its high productivity and fast growth and consequently depletes the tremendous amount of nutrient reserves in the soil. To cover its high requirements in nutrients, heavy chemical fertilizer inputs, especially N in the form of urea, is continuously practiced to reach and secure its high potential yield (Sainju and Singh, 2008). According to the Indonesian Fertilizer Producers Association (APPI), urea consumption increases at a rate of 5% year^{-1} with a magnitude of 6.74 million tons in 2014, 6.92 million tons in 2015, 6.46 million tons in 2016, 6.84 million tons in 2017, and 7.44 million tons in 2018, respectively. This amount exceeded the realization of the consumption of urea fertilizer by 5.32 million tons.

Chemical fertilizers especially N are widely used to add N nutrients to the soil because N is one of the limiting nutrients for crop production and is most needed by plants in large quantities (including sweet corn) (Lawlor, 2002; Massignam *et al*., 2009; Okumura *et al*., 2011; Ciampitti and Vyn, 2012; Hou *et al*., 2012). Excessive and continuous use of inorganic N fertilizer without the addition of organic fertilizers not only causes environmental pollution such as a large amount of N residue in the soil after harvest (De Jong *et al*., 2007) but also deplete soil organic matter and finally cause degradation of soil fertility (Gastal and Lemaire, 2002). To prevent these, the use of organic manures with higher N content (>1.5%) and C: N ratios under 20 and combined with inorganic fertilizer is necessary (Burgos *et al*., 2006). In this way, N mineralization in the soil is aligned with plant requirements for N uptake (Amlinger *et al*., 2003).

The integrated application of organic and inorganic fertilizers has been commonly practiced because the nutrients in inorganic fertilizers are quickly available to plants, while organic fertilizers improve soil structure and water infiltration (Glab *et al*. 2018), and increase the soil organic matter and cation exchange capacity (Guo *et al*. 2016). Previous studies on the effects of the combined use of inorganic and organic fertilizers on crop growth and yield offered encouraging results. The combination of inorganic N and organic fertilizer promoted the growth and yield of muskmelon (Vo and Wang 2015), black rice (Marwanto *et al*. 2018), and corn (Zhang *et al*. 2016; Geng *et al*. 2019). Furthermore, the researchers reported that 25% - 75% of inorganic N fertilizer could be replaced by compost at equal amounts of substitutions. At this substitution, growth and yields op the crops N uptake and soil fertility increased, and N losses were reduced. These findings indicate that the optimal crop yield can be achieved by management practices involving alternative N sources so that the availability of N can be balanced with plant uptake (Kramer *et al*., 2002). In spite of its advantages, organic fertilizer has many disadvantages, such as low nutrients levels, slower nutrient release, and bulkiness. Due to its drawbacks, compost has to be applied at large quantities for effective results (Akanbi *et al*., 2007). Therefore, there is a necessary need to increase the quality of organic-based fertilizer for maximizing their effects on crop growth and yields.

The improvement of compost quality can be accomplished by enriching it with additives and also by the use of particular microbial cultures (Nemat and Turky, 2007). Previous studies reported that application of bio-fortified compost coupled with inorganic fertilizer significantly promoted the growth and yield of wheat (Nemat and Khaled, 2012; Ashmita *et al*., 2017) and chili pepper and pakcoy (Handajaningsih *et al*., 2015) better than a full dose of inorganic fertilizer. These results indicate that the incorporation of certain microbial strains made the compost more effective. In this present study, the enrichment of compost was carried out by incorporating certain microbial consortium (*Bacillus* sp., *Rhizopus* sp., *Saccharomyces* sp., and *Pseudomonas* sp.).

Most of current researches have been carried out to study the effect of N substitution with organic manure for general corn (Zhang *et al*., 2016; Geng *et al*., 2019; Hammed *et al*., 2019) and limited studies have been focused on N substitution with bio-fortified compost in sweet corn. Therefore, the objective of this study was to (1) to assess the significant effects of inorganic N fertilizer substitution with bio-fortified compost under equal N conditions on growth, N accumulation, and yield of sweet corn, and (2) to determine the appropriate level to which inorganic N fertilizer could be reduced and equivalently replaced by bio-fortified compost to promote sweet corn growth.

MATERIALS AND METHODS

Experimental Site

This research was conducted from April to July 2017 involving the production of bio-fortified compost and its application for a field study with sweet corn as a target crop. The bio-fortified compost production and the field study was carried out at the Agriculture Faculty Research Plot Bengkulu University Campus located in Jalan Raya Kandang Limun Bengkulu Indonesia at elevation 15 m above mean sea level. From weather conditions during the study, the location of the research plot was characterized by having an average minimum and maximum temperature of 25-32^{0}C, a monthly average minimum and maximum rainfall of 12.20 mm-27.75 mm, and a monthly average minimum and maximum relative humidity of 82.12 % - 85.80 %. Soil for the experiment was categorized as an Ultisol (Balitanah, 2009) with pH (H_20) 6.5.

The soil used in this study was analyzed its properties at the time of experiment establishment. Soil sampling for the analysis was obtained in a composite manner at the Research Plot of Agriculture Faculty Bengkulu University Indonesia. The soil samples were taken from several points as a subsample at 0 to 20 cm, mixed and stirred well. The soil mixture was put in a plastic bag, tied, labeled, and analyzed its properties in the Soil Science Laboratory Faculty Bengkulu University according to the methods outlined in Balitanah (2009). For analysis, the soil sample was air-dried at ambient room temperature (25^{0}C), milled, screened to pass through a 5 mm sieve, and mixed well after separating all debris. The sieved soil was put into storage jars before use. Analysis of soil chemical properties included pH H_2O determined in a 1: 1 soil-to-water mixture with a digital pH meter, C-organic based on the Walkley-Black chromic acid wet oxidation method, N-total with Kjeldahl method, P-available using Bray No. 1 method, and K-available according to 1N ammonium acetate (NH_4OAc). The result of the soil analysis was shown in Table 1.

Table 1. Soil chemical propoerties before the field study and nutrient contents of bio-fortified compost.

Properties	Soil	Bio-fortified compost
pH H_2O	4.90	7.5
C (%)	3.43	3.17
N (%)	0.32	0.23
C:N Ratio	-	13.78
P_2O_5	5.68 (ppm)	0.43%
K_2O	0.28 (meq/100g)	0.33%

Bio-fortified Compost Production

The composted material used for bio-fortified compost production was cow manure. The four ligno-cellulotic decomposers were used to bio-fortify the manure. The four strains were owned by private microbial culture collection. The four microbial strain inoculums were produced in flasks. Each strain was proliferated in a flask filled with 250 mL broth for 72 hours under continuous shaking (100 rpm) at room temperature to achieve 10^7-10^8 CFU mL^{-1} cell density. After being multiplied, the four microbial strains were blended in proportions of 1:1:1:1 (v:v) and then well mixed with half-decomposed cow manure by hand at the rate of 50 ml/kg compost.

For the aerobic composting process, 1 L of the liquid inoculant was mixed with 50 kg of the half-decomposed cow manure to make a heap. The composting was carried out in a loose pile kept in an enclosed storage room. The heap was sprayed with water to keep moist, turned over for every week, and left for 3 weeks for complete composting. During composting, its humidity and temperature was recorded every week and maintained at safe levels by covering it with transparent plastic. Composting was terminated when cow manure was fully composted indicated by no smell, black color, water content <30%, and the heap temperature <30^{0}C. When composting completed, the plastic cover was opened and removed. Then, the bio-fortified compost was harvested and its subsample was taken for the analysis of basic chemical properties and nutrient contents before applied in the field. The analysis was conducted by the methods as described in Balitanah (2009) for C organic, N-total, P-available, and K-available. The result of the soil and bio-fortified compost chemical analysis are shown in Table 1.

Experiment Design and Treatments

The treatments consisted of six different proportions of inorganic N fertilizer (IF) substitution with bio-fortified compost (BC). They were arranged in a randomized block design (RBD). Each treatment was repeated 3 times in 3.6 m x 2.0 m plots. They were shown in Table 2. They included (1) P_0 (100% IF plus 0% BC), (2) P_1 (75% IF plus 25% BC, (3) P_2 (50% IF plus 50% BC), (4) P_3 (25% IF plus 75%), (5) P_4 (0% IF plus 100% BC, and (6) P_5 (no IF and no BC). The amount of total N from a combination of IF and BC in each treatment was equal to 138 kg N ha^{-1}. Each treatment (except for P_5) was added with 150 kg SP-36 ha^{-1} and 150 kg KCl ha^{-1}.

Table 2. Six different proportions of inorganic N fertilizer substitution with bio-fortified compost under the same amount of total N input used in this study.

Code	Treatment
P_0	100% IF + 0% BC (138.00 kg N ha^{-1} + 0.00 kg BC ha^{-1})
P_1	75% IF + 25% BC (103.50 kg N ha^{-1} + 2,653.84 kg BC ha^{-1})
P_2	50% IF + 50% BC (69.00 kg N ha^{-1} + 5,307.69 kg BC ha^{-1})
P_3	25% IF + 75% BC (34,5 kg N ha^{-1} + 7,961.53 kg BC ha^{-1})
P_4	0% IF + 100% BC (0.00 kg N ha^{-1} + 10,615.38 kg BC ha^{-1})
P_5	0% IF + 0% BC (0.00 kg N ha^{-1} + 0.00 kg BC ha^{-1})

Sweet Corn Planting and Management

Before planting, a 20 X 12 m^2 of land for the field study was prepared and manually cleared from weeds and other unwanted vegetation a week before planting. The cleared land was tilled manually with a hoe to make a plot. The plot was then divided into 30 subplots. The dimension of each subplot was 3.6 m long by 2.0 m wide. The subplots were arranged in 5 rows and each row was set 40 cm apart containing 6 hills at 60-cm intervals.

The sweet corn hybrid Bonanza variety bred by the Thailand East-West Co. was planted. A distance of 60 cm X 40 cm was made between the crops planted. Each subplot was over-seeded and thinned from three seedlings into one. The thinning was conducted 14 days after sowing (DAS) and before fertilizer application.

Urea, SP-36, and KCl were assigned as a source of the N, P, and K nutrients, and applied at 300 kg ha^{-1}, 150 kg ha^{-1}, and 150 kg ha^{-1}, respectively. The amount of N needed was decided according to the recommended N applied by local farmers. The application of urea was carried out 2 times; half dose at three days before sowing together with the full dose of SP-36 and KCl and bio-fortified compost and the rest at the V6 stage (six fully open leaves). The bio-fortified compost was applied by the ring method. The fertilizers were placed in 3 cm deep and 5 cm away from the sweet corn stem.

Manual weeding and pest control were employed. Watering was carried out every other 2 days to keep the soil moist; no watering was done at 5 days before harvest. The plants were kept in the field until harvest at 74 DAS.

Data Collection and Analysis

Three representative plants were randomly chosen from each plot, labeled, and assigned for data collection. Data were collected from the plant samples and included plant height, shoot fresh and dry weight, root fresh and dry weight, and chlorophyll content for plant growth, leaf N content, and N uptake for N accumulation, dehusked cob girth, dehusked cob length, number of kernels per row, number of kernel rows per cob for crop yield components, and green cob weight with husk per plot for crop yield.

Plant height was recorded at 74 DAS using a wooden meter ruler from the soil level to the top of the plant without straightening the leaves. The shoot and root biomass were measured at the end of the study. Sweet corn shoots were harvested by cutting at the soil surface. Measurement of shoot fresh weight was carried out at harvest in each sample plant by separating the shoot from its roots. The fresh shoots were then weighed using a 5 kg capacity scale. The harvested fresh shoots were then oven-dried at 65^0C for 96 hours to obtain the constant dry weight. Sweet corn roots were harvested by digging all underground roots. The soil attaching to the roots were carefully removed by washing with water in a container for 30 minutes. The harvested roots were dried overnight at room temperature and then weighed using a 5 kg capacity scale to record their fresh weight. The harvested roots were then put into an oven at 65^0C for 96 hours to obtain their constant dry weight. Measurement of the chlorophyll content was conducted using the chlorophyll meter (SPAD-502 meter, Konica-Minolta, Japan). Twelve independent SPAD measurements were conducted per treatment and expressed as the SPAD index.

The leaf N content was analyzed at the V6 stage on the third leaf from the soil surface by the micro Kjeldahl methods (Balitanah, 2009). Plant N uptake was obtained by multiplying the leaf N content by the shoot dry weight (Balitanah, 2009).

The dehusked cob girth from selected three plants was determined at the center of the cob and the mean was expressed as dehusked cob girth in centimeters. The dehusked cob length from selected three plants was assessed from the base to tip of the cob and the mean was calculated as cob length in centimeters. The number of kernels per row from the three cobs was calculated and expressed as the number of kernels per row. The total number of kernel rows per cob from the three fresh cobs (dehusked) was calculated and expressed as the number of kernel rows per cob. Green cob weight with husk per plot was determined by harvesting green cobs (with husk) from the net plots, weighed, and expressed in kg per plot.

Data were subjected to analysis of variance (ANOVA). Significant differences among treatment means were separated using the Least Significant Different at the 95% level of probability (Gomez and Gomez, 1995). All data were subjected to normality and homogeneity tests and transformed when necessary.

RESULTS AND DISCUSSIONS

Plant Growth

As shown in Table 3, .significant ($P < 0.05$) variations in plant growth indicators were observed among treatments. They increased with an increasing proportion of IF replaced with BC but decreased when 100% IF was substituted by 100% BC under the same total amount of N input. These findings were similar to a previous study conducted by Vo and Wang (2017) in muskmelon who reported that complete substitution of NPK fertilizer with poultry manure compost reduced plant growth. The better plant growth in this study in response to 100% inorganic fertilizer treatment than that in response to100% compost treatment was attributed to the fact that the release of N inorganic fertilizers is immediate than that in organic fertilizers. The released nutrients typically N was in a readily accessible form. Conversely, the full compost application without N fertilizer addition promoted N deficiency in the soil (Herencia *et.al*., 2011).

The increase in plant height was in the order of $P_2 \approx P_3 \approx P_1 \approx P_0 > P_4 \approx P_5$. The order means there were no significant differences among P_2, P_3, P_1, and P_0 and between P_4 and P_5, but P_2, P_3, P_1, and P_0 were significantly different from P_4 and P_5. The plant height in response to P_2, P_3, P_1, and P_0 was higher than that in response to P_4 and P_5. The lowest average of plant height was observed in P_5 followed by P_4, which was in order 12% and 9% lower than those in P_0. Based on this result, soil amendment with biofortified compost was successfully able to reduce the required inorganic N fertilizer by 25% to 75% without inhibiting plant height.

The increase in shoot fresh weight was in the order of $P_2 \approx P_3 > P_1 \approx P_0 > P_4 > P_5$ (Table 3). The order means that P_2 and P_3 were the best treatments due to produce higher shoot fresh weight than P_1, P_0, P_4, and P_5. Treatments of P_2 and P_3 produced higher the shoot fresh weight

Table 3. Effects of addition of different proportions of inorganic N fertilizer substitution with bio-fortified compost on sweet corn growth.

Treatments	Plant height (cm)	Root weight (g plant^{-1})		Shoot weight (g plant^{-1})		Chlorophyll content (SPAD index)
		Fresh	Dry	Fresh	Dry	
P_0 (100% IF + 0% BC)	199.88 a	372.00 b	93.44 b	103.90 bc	22.88 b	46.88 b
P_1 (75% IF + 25% BC)	199.92 a	387.56 b	99.30 ab	111.26 ab	23.54 ab	52.18 a
P_2 (50% IF + 50% BC)	201.54 a	480.00 a	109.56 a	120.88 a	28.06 a	53.62 a
P_3 (25% IF + 75% BC)	200.06 a	443.00 a	100.28 ab	105.16 bc	25.68 ab	51.62 a
P_4 (0% IF + 100% BC)	182.74 a	328.00 c	71.12 c	92.30 c	21.68 bc	34.74 c
P_5 (0% IF + 0% BC)	177.96 b	240.00 d	41.76 d	42.94 d	17.22 c	28.42 d

Note: Means within the same column possessing the same letter (s) demonstrate a statistically significant different ($P < 0.05$). IF = Inorganic N Fertilizer; BC = Bio-fortified compost.

than P_0 by 19% to 29%. There was no significant ($P < 0.05$) different between P_1 and P_0. A significant ($P < 0.05$) difference was observed between P_0 and P_4. Treatment of P_0 produced the shoot fresh weight higher than P_4 by 13%. The lowest shoot fresh weight was noticed in P_5 followed by P_4. The order of $P_2 > P_0 > P_4 > P_5$, $P_2 \approx P_3 \approx P_1$, and $P_0 \approx P_1 \approx P_3$ applied for shoot dry weight. The highest value of shoot dry weight was noticed in P_2, which was 17% higher than that in P_0. There was no significant ($P < 0.05$) difference between P_0, P_1, and P_3. There was a significant ($P < 0.05$) difference between P_4 and P_5. The lowest shoot dry weight was noticed in P_5, which was 31% lower than P_0. The results of this study suggest that IF could be partially replaced by BC to increase shoot weight. The recommended IF that could be replaced by BC was at the range of 25% to 75%.

As shown in Table 3, root fresh weight in P_2 was 16% higher than P_0. There was no significant ($P < 0.05$) between P_3, P_1, and P_0. The lowest value of the root fresh weight was observed in P_5 (no fertilizer application), which 141% lower than that in P_0. This response occurred due to the lack of available nutrients in the soil. Root dry weight varied among treatments. The highest value of the root dry weight was attained in P_2 even though this treatment was not statistically ($P < 0.05$) different from P_1 and P_3. The root dry weight in response to P_2 treatment was 23% higher than P_0. There was no significant ($P < 0.05$) difference between P_0, P_1, P_3, and P_4. The lowest value of root dry weight was observed in P_5 even though this treatment was not statistically different from P_4. These results demonstrate that incomplete organic substitution of N is beneficial to root growth.

There are many research studies on the effect of chemical fertilizer replacement with organic compost on plant growth, yield attributes, and yield in different crops. Nemat and Khaled (2012) reported that the reduced rate of inorganic fertilizer compensated with compost or bio-fortified compost produced wheat growth that was statistically similar to the full dose of inorganic fertilizer application. The findings in this study were in a good agreement with Nemat and Khaled (2012). One reason for the explanation of this result may be due to the inoculation of compost with specific microorganism strains which improved the effectiveness of bio-fortified compost. This reason could be utilized to explain the results of this study.

Another study by Vo and Wang (2017) showed that an equal compensation to the reduced rate of NPK application with poultry manure compost resulted in greater muskmelon biomass than a single compost application. The results of this study were in line with the findings reported by Vo and Wang (2017). The possible reason to explain this response is that the complementary effect of compost and inorganic fertilizers promoted cooperation and coordination between nutrient release from both fertilizers and the proportion of the nutrients taken up by the crops. This synergetic and synchronized mechanism ultimately led to better crop growth and yield (Huang *et al*., 2010). The use of chemical fertilizer alone to maintain high crop yield had not been successful due to the increase in soil acidity, nutrient leaching, degradation of soil physical properties, and organic matter status (Nortridge *et al*., 2005).

Based on this current experiment results, P_2 was considered a better treatment than P_1 and P_3 for promoting sweet corn growth under the same total amount of N input. The possible explanation for this result was probably because soil fertilized with BC increases the efficiency of inorganic fertilizer, which in turn reduces the required inorganic fertilizer for promoting better plant growth. The presence of the selected microorganisms in bio-fortified compost in this study increased the performance of its bio-mineralization (Below, 2001). A similar mechanism may work for this current study. According to Palanivell *et al.* (2015), the greatest increase in plant growth in response to the appropriate substitution of inorganic fertilizer with compost was attributed to high nutrient uptake (especially N). This reason was similar to the effect of P_2 as this treatment exhibited the highest N uptake compared with the other treatments (Table 4). Under the same total amount of N input, the minimum level to which inorganic N fertilizer could be safely reduced and equivalently replaced with bio-fortified compost to promote sweet corn growth was at 50% of the recommended N fertilizer dose. Overall, appropriate organic replacement of N fertilizer is advantageous to sweet corn growth; excessive organic fertilizer replacement will cause N deficiency.

The increase in chlorophyll content followed the order of $P_2 \approx P_3 \approx P_1 > P_0 > P_4 > P_5$. The order means that the lowest average of chlorophyll content was observed in P_5, which was 65% lower than P_0. Following P_5, the second lowest value of chlorophyll content, was observed in P_4, which was 35% than that in P_0 (100% IF alone). This finding is equivalent to the previous study reported by Vo and Wang (2017) in muskmelon.

A significant difference for chlorophyll content was observed when P_1, P_2, and P_3 were compared with P_0; meanwhile, there was no significant ($P < 0.05$) difference between P_1, P_2, and P_3 (Table 4).The highest chlorophyll content was recorded in P_2, which was 14% higher than that in P_0. The increase in chlorophyll content in this study indicates that BC not only meets the needs of N for sweet corn to grow but also maintain the balance of nutrients in the soil. Due to its advantageous impact, it can be used as a substitute for inorganic N fertilizer. The best leaf chlorophyll content is obtained in a fertilizer substitution with a proportion of 50% IF plus 50% BC.

Table 4. Effects of addition of different proportions of inorganic N fertilizer substitution with bio-fortified compost on N uptake.

Treatments	Total –N content in the leaf (g kg^{-1})	N uptake (g plant^{-1})
P_0 (100% IF + 0% BC)	20.80 c	194.36 c
P_1 (75% IF + 25% BC)	24.00 b	238.32 b
P_2 (50% IF + 50% BC)	27.20 a	298.00 a
P_3 (25% IF + 75% BC)	20.80 c	208.58 c
P_4 (0% IF + 100% BC)	15.20 d	108.10 d
P_5 (0% IF + 0% BC)	12.00 e	50.12 e

Note: Means within the same column possessing the same letter (s) demonstrate a statistically significant different ($P < 0.05$). IF = Inorganic N Fertilizer; BC = Bio-fortified compost.

N Accumulation

As shown in Table 4, .significant variations in the N accumulation were observed. They increased with an increasing proportion of IF replaced with BC but decreased when 100% IF was substituted by 100% BC under the same amount of total N input. Their increase followed the order of $P_2 > P_1 > P_3 \approx P_0 > P_4 > P_5$ for total N content in the leaf, and $P_2 > P_1 > P_3 \approx P_0 > P_4 > P_5$ for N uptake. The order of increase in total N content in the leaf means that the lowest average of total N content in the leaf was observed in P_5, which was 73% lower than P_0 (100% IF alone). In addition to total N content in the leaf, P_5 also gave the lowest effect on N uptake, which was 288% lowered than that in P_0. The smallest values for N accumulation in response to unfertilized treatment (P_5) were also reported by Mahmood *et al.* (2017) in corn.

Following P_5, the second lowest value of total N content in the leaf and N uptake were observed in P_4, which was in order 37% and 80% lower than those in P_0 (100% IF alone). This finding is equivalent to the previous study reported by Xin *et al.* (2017) in corn and wheat, Mahmood *et al.* (2017) in corn, Vo and Wang (2017) in muskmelon, and Geng et al. (2019). Geng et al. (2019) reported that an obvious increase in N uptake under partial substitution of N fertilizer with manure was observed. However, full replacement of N fertilizer with compost reduced N uptake due to insufficient N availability.

A significant ($P < 0.05$) difference was observed between P_1, P_2, and P_3 for total N content in the leaf (Table 4). A significant ($P < 0.05$) difference was also noticed when P_1 and P_2 were compared with P_0, but no significant difference was observed between P_3 and P_0. The highest total N content in the leaf was recorded in P_2, which was 31% higher than P_0 and followed by P_1. The total N content in P_1 was 15% higher than P_0.

A significant difference was noticed between P_1, P_2, and P_3 for N uptake (Table 4). A significant ($P < 0.05$) difference was also observed when P_1 and P_2 were compared with P_0, but no significant difference was observed between P_3 and P_0. The highest N uptake was recorded in P_2, which was 53% higher than P_0 and followed by P1, which was 23% higher than P_0. This result demonstrates that partial replacement of inorganic N with BC is beneficial for N uptake.

The reason for the explanation of these results may be due to the inoculation of compost with specific microorganism strains which improved its nutrient availability. Vo and Wang (2017) and Varvel *et al*. (1997) reported that an increase in N availability in the soil significantly increased the leaf chlorophyll content measured by SPAD readings and N uptake. Chapman and Barreto (1995) stated that the increase in SPAD readings for the estimation of chlorophyll content occurred because of the important roles of N nutrients derived from compost and inorganic fertilizers. They further stated that the N nutrients were important components for various biological compounds and part of specific enzymes associated with chlorophyll synthesis for photosynthesis. Based on these findings, the application of 75% IF plus 25% BC (P_1), 50% IF plus 50% BC (P_2, and 25% IF plus 75% BC (P_3) are conducive to promote N accumulation. Thus, 25% to75% N fertilizer was able to be reduced and substituted by an equal amount of N from BC.

Crop Yield and Its Components

As shown in Table 5, significant variations in crop yield and its components were observed among treatments. They increased with the increasing proportion of IF replaced by BC but decreased when 100% IF was substituted by 100% BC under the same total amount of N input. The increase in the crop yield components followed the order of $P_0 \approx P_3 \approx P_2 \approx P_1 > P_4 > P_5$ for dehusked cob girth, $P_3 \approx P_0 \approx P_2 \approx P_1 > P_4 > P_5$ for dehusked cob length, $P_3 >$ P2 $> P_1 \approx P_2 \approx P_0 > P_4 > P_5$ for number of kernels per row, and $P_0 \approx P_3 \approx P_2 \approx P_1 > P_4 > P_5$ for number of kernel rows per cob, and $P_2 \approx P_3 > P_0 \approx P_1 > P_4 > P_5$ for green cob weight with husk per plot.

The lowest average for dehusked cob girth, dehusked cob length, the number of kernels per row, the number of kernel rows per cob, and the green cob weight with husk per plot was observed in P_5, which was in order 47%, 92%, 104%, 28%, and 304% lower than those in P_0. The smallest values for the crop yield and its indicators in

Table 5. Effects of addition of different proportions of inorganic N fertilizer substitution with bio-fortified compost on sweet corn yield and its components.

Treatments	Sweet corn yield and its components				
	Dehusked cob girth (cm)	Dehusked cob length (cm)	Number of kernels per row	Number of kernel rows per cob	Green cob weight with husk per plot (kg plot^{-1})
P_0 (100% IF + 0% BC)	5.24 a	18.50 a	37.52 ab	16.96 a	9.14 b
P_1 (75% IF + 25% BC)	5.06 a	15.92 a	35.24 b	16.98 a	8.76 b
P_2 (50% IF + 50% BC)	5.18 a	17.76 a	36.56 b	16.36 a	10.84 a
P_3 (25% IF + 75% BC)	5.52 a	16.18 a	41.98 a	17.62 a	10.74 a
P_4 (0% IF + 100% BC)	4.34 b	11.74 b	20.72 c	14.92 b	4.78 c
P_5 (0% IF + 0% BC)	3.56 c	9.62 c	18.38 d	13.26 c	2.26 d

Note: Means within the same column possessing the same letter (s) demonstrate a significant difference ($P < 0.05$). IF = Inorganic N Fertilizer; BC = Bio-fortified compost response to unfertilized treatment (P_5) were also reported by Mahmood *et al.* (2017) in corn.

After P_5, the second-lowest value for crop yield and its components was noticed in P_4, which was in order 27% lower than those in P_0 (100% IF alone) for dehusked cob girth, 58% for dehusked cob length, 81% for the number of kernels per row, 13% for the number of kernel rows per cob, and 91% for the green cob weight with husk per plot. These observations mean that substitution of all IF with 100% BC reduces the crop yield and its components due to the slow nutrient availability of BC. This finding is equivalent to the previous study reported by Xin *et al.* (2017) in corn and wheat, Mahmood *et al.* (2017) in corn, Vo and Wang (2017) in muskmelon, and Geng *et al.* (2019) in spring maize. Geng *et al.* (2019) further stated that partial substitution of N fertilizer with manure caused an increase in yield. However, the full replacement of N fertilizer with compost promoted yield reduction.

As shown in Table 5, treatments of P_1, P_2, and P_3 showed the same effects on crop yield components as P_0. These findings are in agreement with Sheika (2016) who reported that an increase in the yield component of corn in response to the different level of inorganic N fertilizer substitution with compost. Sheika (2016) further states that it was due to the increase in total nutrient input.

The green cob weight with husk per plot as crop yield measurement in response to P_2 and P_3 was 18% to19% higher than that in response to P_0. In contrast, the green cob weight with husk per plot in response to P_1 was not statistically different from that in P_0. This finding is similar to the previous study reported by Geng *et al.* (2019). They reported that appropriate replacement of N fertilizer with compost was advantageous to crop yield attributes. The result of this study is along with the findings reported by Bharalia *et al.* (2017) who reported that *Azolla* compost + NPK application promoted higher dry weight of the kernels at harvest along with higher grain productivity. According to Sakamoto *et al.* (2011), this response was due to an efficient translocation of the crop photosynthetic substance from source leaves to the developing kernel.

Based on the results of this study, partial substitution of inorganic N fertilizer with BC under equal N condition especially P_2 (50% IF plus 50% BC) and P_3 (25% IF plus 75% BC) is favorable to crop yield and its components. Consequently, 25% to 50% N fertilizer could be substituted by the same amount of N from BC to compensate the N fertilizer reduction.

CONCLUSIONS

The effects of inorganic N fertilizer replacement with bio-fortified compost under equal N conditions on sweet corn growth, N accumulation, and crop yield and its components varied depending on the proportion of the substitution. Partial substitution of N fertilizer with bio-fortified compost increased plant growth (except for plant height), N accumulation, and crop yield. The partial substitution treatment (50% IF plus 50% BC) consistently produce the best plant growth, N accumulation, and crop yield increase. It was considered an effective method for fertilizer application. Treatments of 50% IF plus 50% BC and 25% IF plus 75% BC produced the highest green cob weight with husk per plot increase. The three partial substitution treatments (75% IF plus 25% BC, 50% IF plus 50% BC, and 25% IF plus 75% BC) produced crop yield components as high as the full (100%) N fertilizer application without BC addition. The full substitution of N fertilizer with 100% BC reduced all the parameters except for root biomass. The appropriate level to which inorganic N fertilizer could be reduced and equivalently replaced by bio-fortified compost was at the range of 25% to 75%. A long term field experiment may contribute to the full understanding of the above treatment effects on sweet corn growth and yield.

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