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Sweet Corn Performance and Rhizosphere Microbial Densities in Response to Mineral and Organic Amendments

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TWO FIELD experiments were conducted at the experimental farm of the Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center, Giza, Egypt, during 2017 and 2018 seasons, toevaluatethe effects of compost and organic extracts on growth and yield of sweet corn (Misthi F1 Hybrid)and microbial populations in rhizosphere. Extracts of compost, vermicompost and chicken manure with adding half dose of compost were compared to full dose of compost and mineral fertilizers. The populations of total bacteria, fungi and phosphate solublizing bacteria were estimated. Results showed that applying half dose of compost with adding vermin compost (50% C + VEx) extract gave the highest growth, yield and ear properties of sweet corn without any significant differences compared to mineral fertilizer treatment. Applying half dose of compost with adding extract of compost or chicken manure decreased growth, yield and ear properties of sweet corn compared to mineral fertilizer. 50% C + ChEx recorded the highest total bacterial counts. The treatments of half dose of compost with adding any organic extracts were superior to full dose of compost (100% C) in all studied traits. This study revealed the possibility of using half dose of compost with adding vermicompost extract for producing satisfactory yield quantity with high quality of sweet corn ears.

Keywords: Sweet corn, Compost extract, Vermicompost extract, Manure extracts, microbial populations.

Introduction

Recently, most of producers shifted to utilization of organic materials as nutrient source in vegetable production, because excessive use of chemical fertilizers deteriorates soil structure, pollutes ground water and increases nitrate concentration in vegetables (Zhang et al ., 2010). Although, the use of mineral fertilizers cannot be overlooked, due to their rising costs and environmental and health hazards, there is a need to supplement or substitute them with available organic sources (Chaudhry et al., 2009). Therefore, integrated nutrient management including application of organic fertilizers and organic compounds (such as compost, vermicompost and manure tea) is practiced to enhance soil fertility and sustain agriculture production (Stella et al., 2001).

Compost is an aerobically decomposed organic material derived from plants and/or animal residues by mesophilic and thermophilic microorganisms (Martens, 2000 and Insamand de Bertoldi, 2007). Vermicompost is a product of organic matter degradation through interactions between earthworms and microorganisms (Edwards and Neuhauser, 1988).

Compost, vemicompost and chicken manure extract are simply liquid extracts made by mixing various kinds of compost or organic manure with water at rate 1:5 and is left for a defined period; either is adding actively aerating, means passive aerated extract or not, means negative aerated extract. This liquid is rich in beneficial nutrients, organic compounds and microorganismsthat positively effect on the plant rhizosphere, besides

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improve soil physical and chemical properties as well as suppress some plant diseases pathogen.

Organic extracts has beneficial effects on plant growth and considered as a soil amendment (Abbasi et al., 2002, Biocycle, 2004, Gharib et al., 2008 and Meshref et al., 2010). Many studies indicated that application of organic extracts enhanced the growth, yield and quality of many crops as tested by Abou-El-Hassan et al. (2002) on cantaloupe, El-Tantawy et al. (2009) on potato, Mahmoud (2011) on faba bean, Bulalin et al. and Kovacik et al. (2015) on maize, Rogelio (2017) on sweet corn, Seran and Shahardeen (2013) on vegetable cowpea, Pokhrel et al. (2017) on tomato and Shaheen et al. (2018) on common bean.

Sweet corn (*Zea mays*) is popular vegetable for consumption in many countries, *i.e.* USA, Canada, Australia, Europe, Japan and South-East Asia. It is different from other corns (field maize and popcorn), its kernels have high sugar content in the milk or early dough stage. Where, the sugar accumulates in the endosperm two to three times more than the normal maize (Doehlert et al., 1993) and serves as raw material to many manufacturing industries in the production of materials such as corn syrup and starch as well use as biofuel (Remison, 2005). Sweet corn is an attractive and profitable crop for producers because it is harvested after short time as 65 – 90 days depending on the cultivar type and has a relatively high price for local market and exportation. So it must be considered as important crops in Egyptian economy in the future. Some workers mentioned the response of sweet corn to organic manures as Arshad et al. (2015) whom they studied the effect of different sources of organic manures. They found that organic manure amendment showed a significant impact on sweet corn growth, with chicken manure having superiority with highest mean value of leaf number, plant height and stem girth compared to non organic cattle and horse manure treatments, similar results were reported by Ojeniyi et al. (2007). Also, Safiullah et al. (2018) investigated the influence of different rate of solid manure and types of liquid organics on yield, nutrient content and uptake of sweet corn. They found that solid compost and/or liquid organic manure increased yield but did not affect significantly on N, P, Fe, K, Mn, Cu and Zn content, but the uptake of these elements by sweet corn plants was higher in solid organic with liquid organic manure treatment compared to solid organic manure treatment.

The target of this investigation was to evaluate the effect of compost manure and/or organic extract on growth yield and component of sweet corn as well as microbial community population in soil compared to mineral fertilization.

Materials And Methods

Two field experiments on sweet corn (*Zea mays*) were carried out at Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center, Giza, Egypt, during two successive seasons of 2017 and 2018.10thof May was the sowing date in both seasons.

Soil properties

The experimental trial was conducted in siltyclay soil using drip irrigation system. Physical and chemical properties of the experimental site are presented in Table 1.

The experimental layout

The experimental site was ploughed and divided into ridges; three ridges per plot, 60cm ridge width along with 3m length and 25cm between hills, one plant per hill.

The experimental treatments

1- Full dose of mineral fertilizer as N, P and K (control)

2- Full dose of compost(100% C)

3- Half dose of compost (50% C) + compost extract (CEx)

4- Half dose of compost (50% C) + vermicompost extract(VEx)

5- Half dose of compost (50% C) + chicken manure extract (ChEx)

Experimental design

The complete randomized block design with three replicates was applied. The plot area was 6 m^2 (3m length and 2m width).

Chemical and organic fertilizer application rates

NPK were applied as follow 80 kg N.fed^{-1}(as 390kg ammonium sulphate (20.5% N), 26kg P_2O_5.fed^{-1}(as 168 kg calcium super phosphate, 15.5% P_2O_5) and 40kg K_2O.fed^{-1} (as 83kg potassium sulphate, 48% K_2O). Full and half doses of compost were calculated based on nitrogen requirement for sweet corn plants (80 kg. fed^{-1}); that were 8.4 and 4.2 tons. fed^{-1}, respectively. The properties of compost, vermicompost and chicken manure used in preparation of extracts are presented in Table 2.

TABLE 1. Physical and chemical properties of the experimental site

Clay %	Silt %	Sand %	Texture	pH	EC dS m^{-1}	Cations meq L^{-1}				Anions meq L^{-1}		
						Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
48.76	40.91	10.33	Silty clay	7.87	1.03	2.32	1.14	5.33	1.52	2.27	4.84	3.13

TABLE 2. Properties of compost, vermicompost and chicken manure

Trait	Compost	Vermicompost	Chicken manure
Density (%)	0.77	0.86	0.54
Mositure (%)	18	22	10
pH 1:10	8.43	8.62	8.82
EC (dS m^{-1}) 1:10	4.09	6.34	5.3
OM (g kg^{-1})	283.9	320.3	433.2
OC (g kg^{-1})	173.2	195.4	264.3
Ash (%)	81.61	77.98	56.68
C/N ratio	18.2	12.6	13.3
Total N (%)	0.95	1.55	1.98
N-NH_4 (mg kg^{-1})	129	48	250
N-NO_3 (mg kg^{-1})	65	157	45
Total P (%)	0.63	2.22	2.76
Total K (%)	1.18	1.90	1.57

Organic extracts

The stock solution of compost extract was prepared by soaking 10L compost in 50L of tap water without chlorine for two days and was filtrated by a plastic net, the clear stock solution was diluted by water without chlorineat rate1 : 10 according to El-Shinawy et al. (1999) and Abou-El-Hassan (2010). The same procedures were followed to prepare extracts of vermicompost and chicken manure. An air composting process was conducted on the chicken manure for three weeks before use.

Time and method of application

NPK were applied as follow:calcium super phosphate was added as one dose during soil preparation, whereas ammonium sulphate and potassium sulphate were added at three equal doses; after 2, 4 and 6 weeks from sowing. All quantities of compost were added as one dose during soil preparation. All organic extracts were applied to the soil surface weekly at a rate of1L/m^2. Organic extract treatments started at two weeks after sowing and continued for two months.

Measurements

After 75 days from sowing, the ears were harvested and total yield was recorded for each plot. Six plants were randomly taken from each experimental plot for measuring plant growth characteristics as follows: plant height from soil surface to the highest point of plant, number of leaves per plant, fresh weight of plant and stem diameter,as well aschlorophyll reading in the fourth upper leafwas recorded by using Minolta Chlorophyll Meter SPAD501. Nutrient content (NPK) in sweet corn plants were determined in dry matter of the fourth upper leaf according to Cottenie et al. (1982). Total nitrogen, phosphorus and potassium were determined by Micro Kjeldahl, Spectrophotometer and Flame photometer, respectively, according to FAO (1980). Ten ears from each plot were taken randomly at harvest to measure weight, length and diameter of ear.

Microbiological analysis of maize rhizosphere

Sampling and sample preparation

Plant roots were harvested and the loosely attached soils were removed. Five grams from roots were placed in sterile Stomacher bags and treated by a Stomacher 400 Circulator for 60s at middle speed after adding 45 ml sterile 0.85% NaCl. The Stomacher blending step was repeated three times and the rhizosphere / rhizoplane fraction was obtained

Total viable count of bacteria, fungi and phosphate solubilizers

Tenfold serial dilution of microbial suspensions obtained with the protocols described above made with sterile 0.85% NaCl were plated into (1) plate count agar medium for the estimation of total viable counts, (2) Rose bengal agar supplemented with 100 mg/l Chloramphenicol for the estimation of total fungi, (3) National botanical research institute's phosphate growth medium (NBRIP)for the estimation of phosphate solubilizing bacteria as described by Nautiy et al. (1999). Colony forming units (CFU) were enumerated after 3 days of incubation at 28°C for the estimation of both total bacteria and phosphate solubilizing bacteria counts while the incubation period was extended to 5 days at 25°C for total fungi counts. After incubation, CFU counts were calculated per gram root fresh weight, and colonies surrounded by clear zones on NBRIP medium were considered as phosphate solublizing bacteria.

Statistical analysis

Data of the two seasons were arranged and statistically analyzed by the analysis of variances according to Snedecor and Cochran (1980) with SAS software, version 2004. Treatment means were compared using Tukey test at significance level 0.05.

Results And Discussion

Plant height, leaf number, plant weight, stem diameter and chlorophyll content differed significantly among mineral, compost and/or organic extract treatments in the first and second seasons (Tables 3 and 4). Mineral fertilizer and 50% C + VEx treatments gave the highest values in all pervious growth characteristics of sweet corn plants without significant differences compared to other treatments, followed by 50%C + ChEx, 50%C + CEx and the lowest values in all growth characteristics of plants were resulted from 100% compost treatment.

TABLE 3. Effect of treatments on vegetative growth characteristics of sweet corn plants during 2017 and 2018 seasons

Treatments	Plant height(cm)				Leaf No.				Plant weight(kg)			
	1st season		2nd season		1st season		2nd season		1st season		2nd season	
100% MF	233.00	a	237.67	a	17.43	a	17.23	a	1.35	a	1.38	a
100% compost	214.33	c	216.33	c	14.27	c	14.53	c	1.02	d	1.06	d
50%C + CEx	219.33	bc	221.67	bc	15.77	b	15.86	b	1.16	c	1.18	c
50%C + VEx	228.00	ab	232.00	ab	17.27	a	17.38	a	1.34	a	1.40	a
50%C + ChEx	226.33	ab	229.00	ab	16.93	a	17.00	ab	1.25	b	1.28	b

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

MF = Mineral fertilizers C = Compost

CEx = Compost extract VEx = Vermicompost extract

ChEx = Chicken manure extract

TABLE 4. Effect of some chemical and organic amendments on vegetative growth characteristics of sweet corn plants during 2017 and 2018 seasons

Treatments	Stem diameter(cm)				Chlorophyll(SPAD)			
	1st season		2nd season		1st season		2nd season	
100% MF	3.620	a	3.367	a	55.167	a	64.333	a
100% compost	2.983	c	2.833	c	43.907	c	49.333	d
50%C + CEx	3.303	b	3.100	b	49.840	b	56.000	c
50%C + VEx	3.647	a	3.433	a	54.180	a	63.000	ab
50%C + ChEx	3.587	a	3.233	ab	52.173	ab	60.667	b

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

MF = Mineral fertilizers C = Compost

CEx = Compost extract VEx = Vermicompost extract

ChEx = Chicken manure extract

Data illustrated in Fig. 1 show that the highest N concentration obtained by mineral fertilizer treatment followed by 50%C + VEx, 50%C + ChEx, 50%C + CEx and 100% compost treatment in a descending order, whereas 50%C + VEx recorded the highest P and K concentration in sweet corn plants in both seasons. It's worth noticed that 100% MF, 50%C + VEx and 50%C + ChEx did not differ significantly.

Sweet corn yield and ear characteristics asaffected by the applied different treatments in the first and second seasons arepresented in Table 5 and graphically illustrated in Fig. 2. The results indicate that the highest yield 11.92 and 11.58 ton. fed^{-1} in the 1st season and 12.08 and 12.01 ton.fed^{-1} in the second season recorded by 100% MF and 50%C + VEx, respectively, without significant differences. Both treatments produced the highest yield per plant as well as gave the best ear characteristics compared to other treatments. The treatment of 50%C + ChEx came in second order, whereas the treatment of 100% compost produced the lowest values of yield and ear characteristics. Applying 50%C + ChEx treatment increased sweet corn yield by 22.99 21.48% compared to 50%C + CEx and increased by 41.78 and 39.46% compared to 100%C treatment in the first and second seasons, respectively.

Microbiological analysis

The count of colony forming units (CFU) determined in rhizosphere sampleson PCA agar medium were not significantly differed withthe different treatments (Table 7). However, the CFU determined in rhizosphere treated with 50%C + ChEx tended to be higher in total bacterial counts (TVC) (Log CFU g^{-1}= 7.91± 0.10) compared to other treatments. Among the different treatments, maize rhizosphere treated with the mineral fertilizers showed the highest CFU counts of phosphate solubilizing bacteria (Log CFU g^{-1}=6.53 ± 0.04) followed by (50%C + VEx and 100% Compost)with no significant differences ($P < 0.05$)then by (50%C + ChEx), while (50%C + CEx) characterized by the lowest phosphate solubilizing bacterial population. The fungal CFU counts were significantly higher for (50%C + CEx) followed by (50%C + ChEx), while (100% MF,100% compost and 50%C + VEx) characterized by the lowest fungal population.

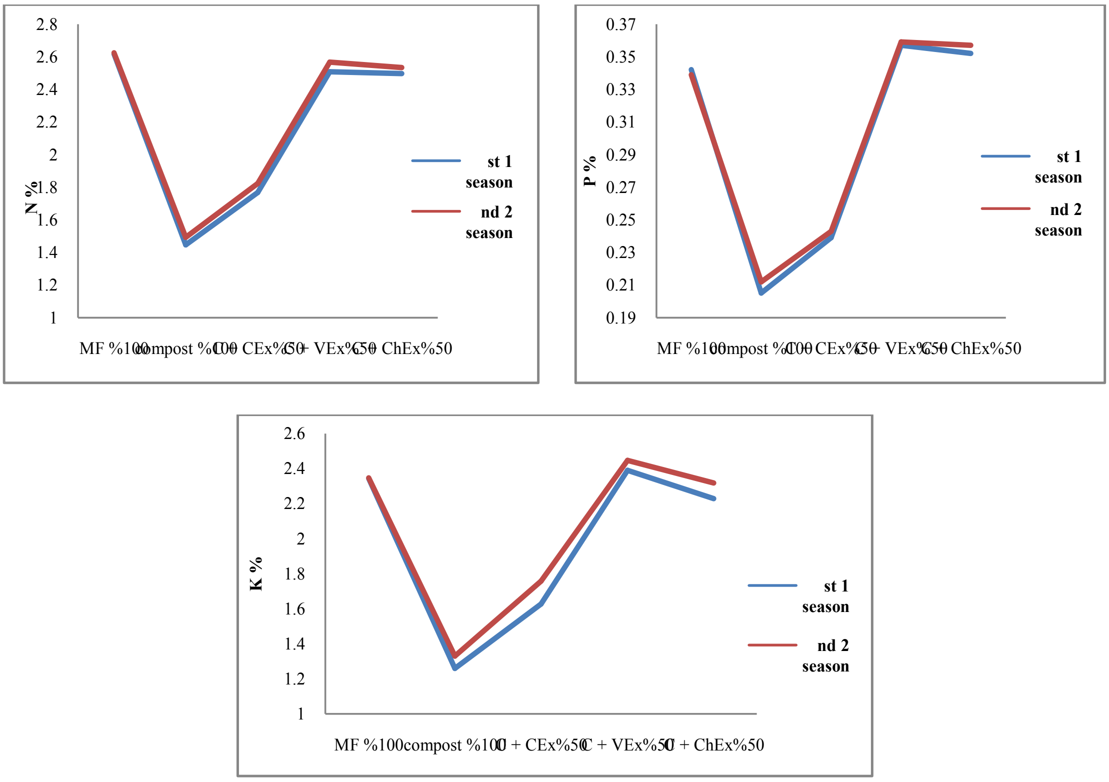

Fig. 1. Effect of some chemical and organic amendments on nutritional status of sweet corn plants during 2017 and 2018 seasons

TABLE 5. Effect of mineral and organic amendments on yield component of sweet corn plants during 2017 and 2018 seasons

Treatments	Yield/plant(kg)				Yield(ton.fed^{-1})			
	1[st] season		2[nd] season		1[st] season		2[nd] season	
100% MF	0.579	a	0.631	a	11.920	a	12.077	a
100% compost	0.386	d	0.405	d	7.660	d	8.113	d
50%C + CEx	0.443	c	0.467	c	8.827	c	9.310	c
50%C + VEx	0.572	a	0.624	a	11.583	a	12.013	a
50%C + ChEx	0.538	b	0.575	b	10.863	b	11.307	b

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.

MF = Mineral fertilizers C = Compost
CEx = Compost extract VEx = Vermicompost extract
ChEx = Chicken manure extract

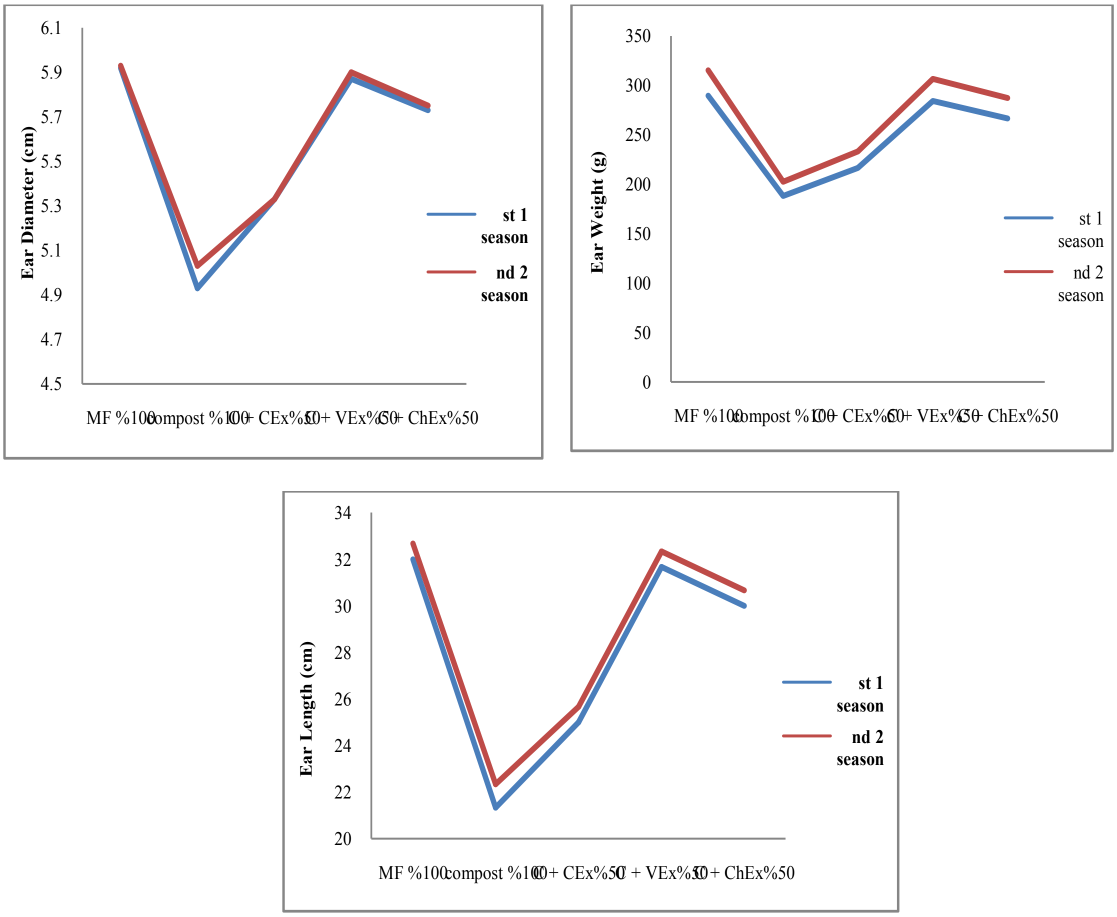

Fig. 2. Effect of mineral and organic amendments on the characteristics of sweet corn ears during 2017 and 2018 seasons

TABLE 7. Population densities (log CFU.g-1root) of some rhizosphere microorganisms of corn plants received some chemical and organic amendments

Treatment	TVC	Total fungi	P-solubilizing
100% MF	7.58 ± 0.15 a	3.95 ± 0.10 c	6.53 ± 0.04 a
100% Compost	7.20 ± 0.61 a	3.89 ± 0.25 c	6.42 ± 0.046 ab
50%C + CEx	7.71 ± 0.15 a	4.62 ± 0.17 a	6.24 ± 0.046 c
50%C + VEx	7.71 ± 0.10 a	3.91 ± 0.46 c	6.43 ± 0.10 ab
50%C + ChEx	7.91 ± 0.10 a	4.29 ± 0.37 a	6.36 ± 0.12 bc

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.
MF = Mineral fertilizers C = Compost
CEx = Compost extract VEx = Vermicompost extract
ChEx = Chicken manure extract Log cfu/g root fresh weight

Field experiments were conducted during two successive seasons 2017 and 2018 to evaluate the effect of mineral fertilizer, compost manure and organic extracts on growth and yield of sweet corn as well assoil bacterial functional diversity. The improvement in the growth of sweet corn plants with treatment of 50% compost + vermicompost extract may be due to the role of this extract in the development of the root and improved vegetable growth of the plant. Where, vermicompost extract contains high levels of beneficial microorganisms that can sustain soil fertility and health, soluble nutrients, organic acids and soluble plant growth regulators (Keeling et al., 2003; Edwards et al., 2006; Arancon et al., 2007).These results confirming those obtained by Rogelio (2017), whom mentioned that application of vermicompost tea could be used as alternative growth enhancers of sweet corn considering that it improves the vegetative growth of plants such as plant height, number of leaves and stalk diameter. Accordingly,in this studymaize rhizosphere treated with 100% compost or 50%C + VEx characterized by the lowest fungal population. This could beattributedto thepresence of bacterial populations carrying the antifungal secondary metabolites related genes (*fenD* and *ituD*), while high fungal population was detected in 50%C+ CEx, hence lower abundance of bacterial population bearing the antifungal related genes.

The superiority of nutrient contents in plants resulting from vermicompost extract treatment on compost extract might be due to the fact that compost contains higher ammonium nitrogen, while the vermicompost is higher in nitrate nitrogen content, which is the more available form for plant absorption. In addition, the nutrients are released from vermicompost during short time compared to compost and chicken manure. These results are in harmony with those obtained by Pant et al. (2011), Seran and Shahardeen (2013), Bulalin et al.(2015), Kovacik et al. (2015) and Shaheen et al. (2018).

The superior yield achieved by plants received the vermicompost extract treatmentover those treated with other extracts and compost only can be attributed to its superiority in stimulating vegetable growth of plants. Application ofvermicompost extract improved vegetative growth characteristics as shown in Table 4 and 5, might led to an increase in photosynthesis and better carbohydrate building up, improved yield and ear parameters of sweet corn. These results are consistent with those obtained by Bulalin et al. (2015), Kovacik et al. (2015) and Rogelio (2017). They indicated that vermicompost extract when used as a fertilizer can significantly improve the growth, yield and quality of corn ears. This might be due to the presence of plant growth promoters and its ability to improve the condition in rhizosphere zone. Fouda and Ali (2016) reported that the population of the different microorganisms were greater in compost treatment, and increased with time as well. Compost could improve significantly the availability of soil macro and micro nutrients and hence, increase their uptake by (Elshony et al., 2019). As general diversity of microbes, by parading macro and micro nutrients essential for plant growth, and by suppressing diseases, which indirectly increase plant growth (Heather at al., 2006). Also, microbial activities and population are positively affected by organic matter (Yaseen and Yossif, 2019).

Conclusion

The obtained results refer to the possibility of using the half dose of compost combined with vermicompost extracts to substitute mineral fertilizers for production of highyield and good quality of sweet corn. Application of half dose of compost with adding any extracts of compost, vermicompost or chicken manure improved yield and quality of sweet corn compared to use compost alone.

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استجابة نباتات الذرة السكرية وكثافة ميكروبات الريزوسفير للتسميد المعدنى والعضوى

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أجريت تجربتان حقليتان بالمزرعة التجريبية التابعة للمعمل المركزي للمناخ الزراعي (CLAC) ، مركز البحوث الزراعية ، الجيزة ، مصر ، خلال موسمين متتاليين لعامي ٢٠١٧ و ٢٠١٨. تقيم هذه التجربة دور الكمبوست والمستخلصات العضوية في إنتاج الذرة السكرية (هجين Misthi). وتمت مقارنة مستخلصات من الكمبوست والفيرميكبوست وسماد الدواجن مع إضافة نصف جرعة الكمبوست بالجرعة الكاملة من الكمبوست والجرعة الكاملة من الأسمدة المعدنية. تمت دراسة تأثير هذه المستخلصات على أعداد البكتيريا و الفطريات في التربة بالإضافة إلى أعداد البكتيريا الميسرة للفوسفات.أظهرت النتائج أن تطبيق نصف جرعة الكمبوست مع إضافة مستخلص الفيرميكومبوست أعطى أعلى معدلات من النمو الخضرى والإنتاج وخصائص كيزانالذرة السكرية دون أي اختلافات معنوية مقارنة بمعاملة الأسمدة المعدنية. إن تطبيق نصف جرعة الكمبوست مع إضافة مستخلص الكمبوست أو سماد الدواجن قد أدى إلى انخفاض خصائص النمو والإنتاج وكيزان الذرة السكرية مقارنة بالأسمدة المعدنية. تفوقت معاملات نصف جرعة الكمبوست مع إضافة أي من المستخلصات العضوية على معاملة الجرعة الكاملة من الكمبوست في جميع الصفات المدروسة. كشفت هذه الدراسة عن إمكانية استخدام نصف جرعة الكمبوست مع إضافة مستخلص الفيرميكبوست لإنتاج محصول جيد وكيزان ذرة سكرية عالية الجودة.