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Application of Compost and Vermicompost as Substitutes for Mineral Fertilizers to Produce Green Beans

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SUSTAINABLE agricultural development need to provide alternatives of mineral fertilizers to produce safe food for humans, maintain of soil fertility and preserve of environment from pollution. Field experiment was conducted at the site of Vegetable Research Departments, Horticulture Research Institutein Giza Governorate, Egypt, to study possibility of using compost and vermicompost (compost of earthworm) as substitutes partial or fully for mineral fertilizers used in the production of green beans. The bean seeds (cv. Paulista) were sown in clay soil during the summer season of 2016 and 2017. Treatments of compost and vermicompost individually or in combination with or without adding 50% of recommended dose of mineral fertilizers,were investigated on bean plants. The effects of these treatments on the growth and yield of green beans were compared to full recommended dose of mineral fertilizers as control. All treatments of compost and vermicompost without mineral fertilizers decreased all the vegetative properties of bean plants. Compost and vermicompost singly or in combination + 50% mineral fertilizers were not showed any significant differences compared to 100% mineral fertilizers. The treatments of 100% mineral fertilizers and 50% mineral fertilizers + vermicompost sole or combined with compost gave the highest early and total yield compared to other treatments. Applying compost and vermicompost with or without mineral fertilizers, decreased nitrate content of bean pods. This study suggested possibility for using compost and vermicompost to reduce the amount of mineral fertilizers to produce good yield, healthy and safe of green beans.

Keywords: Snap bean, Compost, Vermicompost, Organic, Mineral fertilizers.

Introduction

Beans (*Phaseolus vulgaris* L.) are one of the most important leguminous crops in the Egyptian consumer. Beans are grown for local marketing or export, whether for green pods consumption, called snap beans or dry seed consumption, called common beans. The cultivated area of snap beans in Egypt is about 59313 feddans (feddan = 0.4 hectare), produced about 249396 tons (Ministry of Agriculture and Land Reclamation, 2015).

The excessive use of chemical fertilizers in agriculture is an issue of concern. It causes, high level the pollutants in fruits, decrease soil fertility and pollution of groundwater (Hernandez et al., 2010). Organic fertilizers can be used to reduce the amount of toxic compounds (such as nitrate) produced by mineral fertilizers, improving the quality of vegetables produced as well as human health (Abd El-Hamied, 2001 and Mahmoud et al., 2009).

Substitution of chemical fertilizers by the organic amendments is very important for sustainability of agriculture production and maintain of soil fertility (Parakash and Prasad, 2000). The compost and vermicompost quality is the most essential criterion in recycling organic waste and utilization in agriculture as organic amendments, they can meet the nutrient requirements of agriculture crops and significantly reduce the use of chemical fertilizers (Kowalchuk et al., 1999 and Mavaddati et al., 2010).

Compost is an aerobically decomposed organic material derived from plants and animal sources by mesophilic and thermophilic microorganisms (Martens, 2000 and Insam & de Bertoldi, 2007). Vermicompost is product of organic

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matter degradation through interactions between earthworms and microorganisms (Edwards & Bater, 1992 and Arancon et al., 2008). In this process, earthworms fragment the waste, enhance microbial activity and accelerate rates of decomposition, as in composting, but by non-thermophilic process. When the materials pass through the worm body, impregnate with gastrointestinal mucosa, vitamins and enzymes (Inbar et al., 1993, Mavaddati et al., 2010 and Abduli et al., 2013).

Compost and vermicompost are not only the sources of organic matter and nutrient, but also boost microbial population, physical, biological and chemical properties of the soil (Albiach et al., 2000 and Baziramakenga & Simard, 2001). Among organic fertilizers, compost and vermicompost are sources of plant nutrients and produce vigorous plants (Manivannan et al., 2009 and Shehata & El-Helaly, 2010). Compost and vermicompost are soil conditioners that provide nutrients and organic matter within the soil, improve the water and nutrient holding of soil (Giusquiani et al., 1995, Wells et al., 2000 and Cespedes Leon et al., 2006). Application of compost to newly reclaimed lands has a positive effect on green bean growth and production (Abdel-Mawgoud, 2006). Vermicompost has a significant positive influence on plant growth, flowering, fruiting, root development, yield and quality of beans (Fernandez-Luqueno et al.,2010 and Singh et al., 2011). This study aims to evaluate replacing the mineral fertilizers for producing green beans partly or totally using compost and vermicompost.

Materials and Methods

The field experiments were carried out at the site of Vegetable Research Departments, Horticulture Research Institute, Agricultural Research Center, Dokki district in Giza Governorate, Egypt, during two successive seasons of 2016 and 2017.

Plant Material

Seeds of snap bean (cv. Paulista) were sown in the field on 10 and 14 of February in the first and second seasons, respectively.

Soil Properties

The experimentwas conducted in clay soil using drip irrigation system. The chemical and physical properties of the soil are shown in Table1.

TABLE 1. Analyses of the experimental soil.

Clay %	Silt %	Sand %	Texture	pH 1:2.5	EC1:10 dS/m	Cationsmeq/l				Anions meq/l			
						Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Co_3^{-}	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
48.40	42.30	9.30	Silty clay	8.25	1.45	2.80	1.55	1.14	1.18	2.44	1.25	1.40	1.58

The Experimental Layout

The experiment was divided into ridges (70 cm width). The seeds were sown at a distance of 15cm in two rows on the ridge, two seeds in each placement.

The Experimental Treatments

- 100% of recommended NPK of mineral fertilizers (MF) as a control
- 100% compost (C) as recommended N
- 100% vermicompost (V) as recommended N
- 50% C + 50% V
- 50% MF + 50% C
- 50% MF + 50% V
- 50% MF + 25% C + 25%V

Experimental Design

The experimental treatments were arranged in complete randomized blocks design with three replicates. The plot area was 4.2 m^2 (6 m length and 0.7 m width).

Quantities of application

The mineral fertilizers of NPK were applied according to Ministry of Agriculture and Land Reclamation (2013) as follow 60kg N/fed. as 179 kg ammonium nitrate (33.5% N), 30kg P_2O_5/fed. as 194kg calcium super phosphate (15.5%P_2O_5) and 48kg K_2O/fed. as 100 kg potassium sulphate (48% K_2O). The quantities of compost and vermicompost were calculated based on nitrogen recommended dose in clay soil (60 kg/fed.), that were 6.316 and 4.880 tons/feddan on respectively. Analyses of the used compost and vermicompost are showed in Table 2.

Time and Method of application

Calcium super phosphate was added as one dose during soil preparation, whereas ammonium nitrate and potassium sulphate were added at three equal portions, during soil preparation, after 20 and 40 days from sowing. Two-thirds of the quantity of both compost and vermicompost were added in solid form during soil preparation, while the other third was added as extract (1:10 v:v) to the soil beside plants every two weeks at rate 1 L/ m^2 (Abou-El-Hassanet al., 2014).

TABLE 2. Analyses of the compost and vermicompost.

Type	pH 1:5	EC 1:10 dS/m	O.M (%)	Macro elements (%)					Micro elements(ppm)			
				N	P	K	Ca	Mg	Fe	Zn	Mn	Cu
Compost	7.53	2.67	27.13	0.95	0.37	0.74	0.36	0.67	644	98	203	11
Vermicompost	8.33	5.09	20.60	1.23	0.67	0.94	0.47	0.64	567	88	205	13

Data Recorded

Growth and nutritional status

In the beginning of fruit set stage, three plants were randomly chosen from each plot to determine plant height, leaf number and fresh shoot weight of plant. Also, chlorophyll reading was measured in the third upper leaf by using Minolta Chlorophyll Meter Spad 501. Nutrient content (NPK) in bean plants were determined in dry matter of the third upper leaf according to Cottenie et al. (1982). Total nitrogen was determined by Kjeldahl method according to the procedure described by FAO (1989). Phosphorus content was determined using spectrophotometer according to FAO (1989). Potassium content was determined photometrically using Flame photometer as described by Chapman and Pratt (1961).

Yield and quality characters

After 60 days from sowing, the pods were harvestedweekly for four times. Early yield was recorded during the first two harvests. Total yield was recorded per plot after each harvesting accumulatively until the end of harvesting season. Five plants from each replicate were randomly chosen to measure weight and number of pods per plant. Ten pods from each replicate were randomly chosen to determine length, diameter, weight and dry matter percent of pod. Total soluble solids (TSS) were measured by using Digital Refractometer. Percentage of fiber and protein were determined according to AOAC (2005). As well as, nitrate contentof pods was determined using Cardy Nitrate Meter Model HORIBA, Spectrum Technologies, Inc., as described by Al-Moshileh et al. (2004).

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 9. Comparison of treatment means was donebyTukey test at significance level 0.05.

Results and Discussion

The effect of treatments on vegetative properties of bean plants present in Table 3. Data showed that all applications of compost and vermicompost without mineral fertilizers decreased all the vegetative properties (height, leaf number, chlorophyll reading and fresh shoot weight) of bean plants compared to 100% mineral fertilizers in both seasons.The lowest values of vegetative growth parameters were resulted from 100% compost treatment. While all treatments of organic fertilizers (compost and vermicompost singly or combined) + 50% mineral fertilizers were not showed any significant differences compared to 100% mineral fertilizers. The maximum growth obtained by mineral fertilizer may be due to high composition of nitrogen available in mineral fertilizer, which supplement to the plant's vegetative phase. The result was in harmony with the findings of Sharma et al. (2003) and Deshmukh et al. (2005). On another hand, low values in the parameters of vegetative growth with applying organic fertilizers only might be due to its slow release, thus the nutrients available of them are not sufficient for the plant requirements and this let to reduce vegetative growth of plant as was mentioned by Abdel-Mawgoud (2006) and Abou-El-Hassan et al. (2014).

The effect of treatments on the nutritional statusinbean plantsshow in Table 4. The highest concentrations of N and K were preceded by 100% mineral fertilizers treatment followed by 50% mineral fertilizers + compost and vermicompost in dividual or in combination. On the other hand,the lowest concentrations of N and K were obtained by compost without mineral fertilizers treatment. No significant differences were detected on P content of leaves among all treatments except compost without mineral fertilizers treatment, which decreased the concentration of P in the leaves. The high content of N and K in bean leaves with treatment of mineral fertilizer only might be due to it is easy decomposition, so the plants absorb nutrients from it in large quantities. These results are in agreement with those obtained by Sharma et al. (2003), Singh & Chauhan (2009) and Mitova & Stancheva (2013).

TABLE 3. Effect of treatments on vegetative growth of bean plants during 2016 and 2017 seasons.

Treatments	Plant height cm		Leaf No		Chlorophyll SPAD		FSW g / plant	
	First season							
100% MF	68.00	a	17.00	a	33.27	a	83.33	a
100% C	42.00	c	11.00	c	28.70	b	53.33	c
100% V	51.33	b	13.00	b	29.30	b	66.67	bc
50% C + 50% V	45.67	bc	12.67	b	29.13	b	63.33	bc
50% MF + 50% C	63.33	a	15.33	a	30.67	ab	73.33	ab
50% MF + 50% V	66.00	a	16.67	a	32.33	a	81.67	a
50% MF +25% C + 25%V	64.67	a	15.67	a	30.47	ab	75.67	ab
	Second season							
100% MF	58.85	a	14.67	a	36.33	a	70.67	a
100% C	39.43	c	10.33	d	31.93	b	46.53	d
100% V	44.96	b	11.33	cd	32.67	b	56.60	bc
50% C + 50% V	41.57	b	11.00	cd	32.37	b	53.87	cd
50% MF + 50% C	54.67	a	12.33	bc	34.17	ab	62.00	abc
50% MF + 50% V	58.11	a	14.33	a	35.40	a	68.27	a
50% MF + 25% C + 25%V	55.71	a	13.67	ab	34.23	ab	65.50	ab

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.
FSW = fresh shoot weight MF = mineral fertilizer
C = compost V = vermicompost

TABLE 4. Effect of treatments on NPK contentof bean plants during 2016 and 2017 seasons.

Treatments	N %		P %		K %	
	First season					
100% MF	5.02	a	0.390	ab	3.71	a
100% C	3.42	e	0.387	b	2.26	d
100% V	4.11	d	0.410	ab	2.78	c
50% C + 50% V	3.62	e	0.403	ab	2.58	c
50% MF + 50% C	4.39	c	0.390	ab	3.22	b
50% MF + 50% V	4.77	b	0.437	a	3.44	b
50% MF + 25% C + 25%V	4.62	b	0.430	ab	3.27	b
	Second season					
100% MF	5.28	a	0.426	ab	3.86	a
100% C	3.55	e	0.405	b	2.45	d
100% V	4.22	d	0.429	ab	2.99	c
50% C + 50% V	3.76	e	0.418	ab	2.76	c
50% MF + 50% C	4.54	c	0.422	ab	3.44	b
50% MF + 50% V	4.94	b	0.452	a	3.61	b
50% MF + 25% C + 25%V	4.74	bc	0.449	a	3.46	b

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.
MF = mineral fertilizer C = compost V = vermicompost

The effect of different treatments on yieldpresent in Table 5. Data showed that the treatments of 100% mineral fertilizers, 50% mineral fertilizers + vermicompost sole or combined with compost gave the highest early and total yield compared to other treatments. The treatments of 50% mineral fertilizers + compostand vermicompost without mineral fertilizers came in the second order of yield. The lowest early and total yield was obtained by compost without mineral fertilizers treatment in the two seasons. This trend was true with number of pods on plant. The effect of treatments on properties of snap bean pods show in Table 6.

The results indicated that all treatments of organic fertilizers without mineral fertilizers decreased length and weight of pod in both seasons. No significant differences were detected on pod diameter among all treatments except compost only treatment which decreased pod diameter compared to other treatments. All treatments of organic fertilizers + 50% mineral fertilizers gave similar results to 100% mineral fertilizers of length, diameter and weight of pod with no significant differences among them. These findings are agreement with those obtained by Singh & Chauhan (2009), Fernandez-Luqueno et al. (2010), Singh et al. (2011), Kadam & Pathade (2014) and Alhrout et al. (2016) on bean.

TABLE 5. Effect of treatments on yield components of green beans during 2016 and 2017 seasons.

Treatments	Early yield kg/m²		Total yield kg/m²		Yield/plant g		Pod No/plant	
	First season							
100% MF	0.44	a	1.43	a	54.63	a	12.33	a
100% C	0.07	e	0.76	c	29.51	d	8.33	d
100% V	0.26	cd	1.07	b	41.67	c	10.33	bc
50% C + 50% V	0.22	d	0.82	c	31.50	d	9.17	cd
50% MF + 50% C	0.33	bc	1.20	b	45.33	bc	10.83	b
50% MF + 50% V	0.40	ab	1.39	a	53.40	a	12.27	a
50% MF + 25% C + 25%V	0.39	ab	1.36	a	49.67	ab	11.50	ab
	Second season							
100% MF	0.51	a	1.24	a	46.69	a	11.26	a
100% C	0.20	d	0.74	d	29.59	e	8.38	d
100% V	0.30	cd	0.97	bc	35.77	cd	9.62	c
50% C + 50% V	0.27	cd	0.85	cd	34.36	de	10.00	bc
50% MF + 50% C	0.38	bc	1.08	ab	40.33	bc	10.61	abc
50% MF + 50% V	0.48	a	1.22	a	45.95	a	11.11	ab
50% MF + 25% C + 25%V	0.45	a	1.17	ab	43.35	ab	10.96	ab

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.
MF = mineral fertilizer C = compost V = vermicompost

TABLE 6. Effect of treatments on properties of green bean pods during 2016 and 2017 seasons.

Treatments	Pod length cm		Pod diameter mm		Pod fresh weight (g)		Pod dry weight (g)	
	First season							
100% MF	15.33	a	7.33	a	4.71	a	0.357	a
100% C	13.60	b	6.00	b	3.63	d	0.257	d
100% V	13.67	b	6.50	ab	3.96	cd	0.297	bcd
50% C + 50% V	13.67	b	6.67	ab	3.66	d	0.277	cd
50% MF + 50% C	14.50	ab	7.00	ab	4.19	bc	0.317	abc
50% MF + 50% V	15.33	a	7.33	a	4.49	ab	0.337	ab
50% MF + 25% C + 25%V	15.00	ab	7.17	a	4.28	bc	0.320	ab
	Second season							
100% MF	13.67	a	6.99	a	4.37	a	0.354	a
100% C	11.67	c	5.67	b	3.38	c	0.266	d
100% V	12.00	bc	6.27	ab	3.58	bc	0.285	cd
50% C + 50% V	12.33	abc	6.37	ab	3.72	bc	0.304	bc
50% MF + 50% C	13.33	ab	7.00	a	4.24	a	0.344	a
50% MF + 50% V	11.67	c	6.17	ab	3.50	c	0.280	cd
50% MF + 25% C + 25%V	13.00	abc	6.57	ab	4.05	ab	0.323	ab

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.
MF = mineral fertilizer C = compost V = vermicompost

Overall, all treatments of compost and vermicompost without mineral fertilizers reduced yield and properties of snap bean pods. This reduction may be due to organic fertilizers are slow release fertilizers, which leads to the nutrients available from them are insufficient for the plant requirements and thus reduce the vegetable growth, which reflected on reducing yield of beans. While the combination of mineral and organic fertilizers, could improve yield and its components compared to organic fertilizers only. This may be attributing to that organic fertilizers enhance soil aeration and increase nutrient hold capacity and offer good environmental conditions for the root system. These favorable conditions create better nutrients absorption and enhance the growth, which reflect improving of vegetative growth, photosynthetic activity, dry matter accumulation and consequently higher yield and good properties of pods. Concerning organic treatments, using vermicampot produced the highest yield and properties of pods compared to compost only or combined with vermicompost. Vermicompost superiority on compost might be due to that conventional compost is higher in ammonium content, while the vermicompost is higher in nitrate content, which is the more available form of nitrogen for plant absorption. In addition, vermicompost releases nutrients during short time compared to conventional compost. This was verified by Atiyeh, et al. (2000), Singh & Chauhan (2009), Manivannan et al. (2009), Mupondi et al. (2010) and Metkari et al. (2011).

The effect of treatments on some compositions of green bean pods show in Table 7. Data reveled that there were no statistical differences on all pod compositions except protein and nitrate contains in bean pods. All treatments of compost and vermicompost without mineral fertilizers decreased protein percent in pods. The low protein content of the pods may be due to the low amount of nitrogen available for plant absorption from organic fertilizers, where nitrogen is the basis of amino acids synthesis that are essential components of protein. This was supported by the findings of Metkari et al. (2011), Shehata et al. (2011) on snap bean and Khaim et al. (2013) on soybean. As well as all treatments of compost and vermicompost with or without mineral fertilizers, decreased nitrate content in bean pods. The lowest values of nitrate content in pods obtained when plants were treated organic fertilizers without mineral fertilizers. This may be due to the release of nitrate from mineral fertilizers is fast while, in organic fertilizers, it is slow. These findings are harmony with those obtained by Stancheva et al. (2004) on garden beans, Mahmoud et al. (2009) and Abou-El-Hassan et al. (2014) on cucumber.

TABLE 7. Effect of treatments on compositions of green bean pods during 2016 and 2017 seasons.

Treatments	% TSS		% Fiber		% Protein		% DM		NO_3(ppm)	
First season										
100% MF	5.067	a	1.137	a	1.688	a	7.520	a	444	a
100% C	5.033	a	1.106	a	1.558	c	7.307	a	189	f
100% V	5.100	a	1.103	a	1.580	bc	7.413	a	224	de
50% C + 50% V	5.033	a	1.150	a	1.561	c	7.473	a	206	ef
50% MF + 50% C	5.000	a	1.148	a	1.666	a	7.613	a	240	cd
50% MF + 50% V	5.067	a	1.175	a	1.677	a	7.453	a	272	b
50% MF + 25% C + 25%V	5.000	a	1.170	a	1.665	ab	7.427	a	245	c
Second season										
100% MF	5.320	a	1.255	a	1.661	a	8.103	a	507	a
100% C	5.193	a	1.224	a	1.526	b	7.870	a	245	e
100% V	5.253	a	1.221	a	1.547	b	7.943	a	280	d
50% C + 50% V	5.243	a	1.235	a	1.534	b	8.013	a	267	d
50% MF + 50% C	5.240	a	1.234	a	1.634	a	8.167	a	308	c
50% MF + 50% V	5.287	a	1.237	a	1.650	a	8.117	a	340	b
50% MF + 25% C + 25%V	5.273	a	1.240	a	1.624	a	7.989	a	309	c

Means followed in same column by similar letters are not statistically different at 0.05 level according to Tukey test.
DM = dry matter MF = mineral fertilizer
C = compost V = vermicompost

Conclusion

It could be concluded that the using compost and vermicompost as substitutes partial of mineral fertilizers producing good yield and healthy of green beans.

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إستخدام الكمبوست والفيرميكمبوست كبدائل للاسمدة المعدنية لانتاج الفاصوليا الخضراء

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التنمية الزراعية المستدامة تحتاج إلى توفير بدائل للأسمدة المعدنية لإنتاج غذاء آمن للانسان، والحفاظ على خصوبة التربة والمحافظة على البيئة من التلوث. تم إجراء تجربة حقلية في موقع أقسام بحوث الخضر التابع لمعهد بحوث البساتين في محافظة الجيزة، مصر، لدراسة إمكانية استخدام الكمبوست والفيرميكمبوست كبدائل جزئية أو كلية عن الأسمدة المعدنية المستخدمة في إنتاج الفاصوليا الخضراء.

تم زراعة بذور الفاصوليا صنف بوليستا فى تربة طينية خلال العروة الصيفى من اعوام٢٠١٦ و٢٠١٧. تم اجراء معاملات من الكمبوست والفيرميكمبوست (كومبوست دودة الأرض) منفردة او مخلوطة مع أو بدون إضافة ٥٠٪ من الأسمدة المعدنية الموصى بها على نباتات الفاصوليا.تم مقارنة تأثيرات هذه المعاملات على نمو ومحصول الفاصوليا بالمعدل الكامل الموصى به من الأسمدة المعدنية.

كل معاملات الكمبوست والفيرميكبوست بدون اضافة الأسمدة المعدنية خفضت من جميع الخصائص الخضرية لنباتات الفاصوليا. ولم يظهر أي فروق معنوية بين معاملات الكمبوست والفيرميكمبوست منفردة او مخلوطة + ٥٠٪ اسمدة معدنية مقارنة بالاسمدة المعدنية بنسبة ١٠٠٪. أعطت معاملة ١٠٠٪ أسمدة معدنية ومعاملات ٥٠٪ أسمدة معدنية + فيرميكومبوست منفردا او مخلوطا مع الكمبوست أعلى محصول مبكر وكلى مقارنة مع المعاملات الاخرى. استخدام الكمبوست والفيرميكمبوست مع أو بدون أسمدة معدنية، خفض من محتوى النترات فى قرون الفاصوليا. أشارت هذه الدراسة إلى إمكانية استخدام الكمبوست والفيرميكمبوست لتقليل كمية الأسمدة المعدنية لإنتاج محصول جيد، صحى وآمن من الفاصوليا الخضراء.