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Full Length Research Paper

Impact of rice straw composts on microbial population, plant growth, nutrient uptake and root-knot nematode under greenhouse conditions

Ferial M. Rashad[1]*, Hosny H. Kesba[2], Waleed D. Saleh[1] and Mohamed A. Moselhy[1]

[1]Agricultural Microbiology Department, Faculty of Agriculture, Cairo University, Giza 12613 – Egypt.
[2]Department of Zoology and Agriculture, Nematology, Facaulty of Agriculture Cairo University, Giza 12613, Egypt.

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The effect of adding various rice straw composts on the rhizosphere soil microorganisms, some physicochemical properties, plant growth and nutrient uptake as well as plant parasitic root-knot nematode was evaluated. All the five types of compost showed a high fertilizer value when applied at the rate of 5% (w/w) as indicated by ameliorating the soil microbial population, chemical properties, plant growth response and subsequently the productivity of sandy soil comparing to the mineral fertilizer. Increasing compost application rate resulted in parallel significant enhancement. Addition of composts at 5% in mishmash with half dose of mineral fertilizer significantly improved all the tested criteria. Composts at rates of 5, 7.5% resulted in reducing root-knot nematode population by 79, 84%, respectively and actualized prodigious depletion in egg production. The most prominent composts which surpassed all treatments including the mineral fertilizer were those contained vinasse.

Key words: Rice straw compost, nutrient uptake, plant growth, physicochemical properties, root-knot nematode.

INTRODUCTION

Soil organic matter helps to retain nutrients, maintain soil structure, and hold water for plant use. This important resource is subject to gain and loss, depending on changes in environmental conditions and agricultural management practices. In Egypt, the fast growth in population year on year increases the demand of food which necessitates the intensive cropping leading to the loss of soil organic matter. Conventional systems of agricultural production, the misuse and excessive use of chemical-based fertilizers and pesticides, have often adversely affect the environment and create many problems in human and animal health as well as in food safety and quality. For these reasons, there has been a growing interest in nature farming and organic agriculture by consumers and environmentalists as possible alternatives to chemical-based, conventional agriculture. Agricultural systems which conform to the principles of natural ecosystems are now receiving a great deal of attention in both developed and developing countries (Higa and Parr, 1994).

Compost is an organic matter resource resulted from exploiting wastes through the controlled bioconversion process. It seems to meet the objectives of alternative agriculture system and the growing consensus of both environmentalists and those concerned with the public health through solving the waste disposal problem and its application in sustainable agriculture instead of ecologically undesirable mineral fertilization. Numerous studies have already shown the benefits of organic amendments in improving physical, chemical and biological properties of soil that depending on the amount and composition. Although, these parameters change slowly and several years are necessary to obtain significant differences, biological and biochemical parameters are more sensitive and can provide earlier measurements of changes produced by soil management (Ndiaye et al., 2000; Madejon et al., 2001; Melero et al., 2007; Courtney and Mullen, 2008; Chitravadivu et al., 2009).

In general, the quality and characteristic of the compost vary depending on composting feed materials which make it difficult to predict its application rates and

*Corresponding author. E-mail: ferialrashad@yahoo.com.

Table 1. Physical and chemical properties of the used soils.

Soil characteristics		Soil (1)	Soil (2)
Physical analysis	Sand (%)	89.30	92.11
	Silt (%)	5.38	3.51
	Clay (%)	5.32	4.38
	Texture class	Sandy	Sandy
Chemical analysis	pH (1:5, soil : water , w/v)	7.82	8.31
	EC^a ($dS. m^{-1}$), 1:5 soil extract	1.48	1.52
	OC^b (%)	0.30	0.21
	OM^c (%)	0.51	0.36
	TN^d (%)	0.037	0.026
	Total phosphorus (%)	0.018	0.015
	Total potassium (%)	0.033	0.030
	NH_4 (ppm)	9.32	8.15
	NO_3 (ppm)	4.18	3.40
	P_2O_5 (ppm)	12.0	10.31
	K_2O (ppm)	90.21	83.17

Soil (1): used for cultivation of beans; Soil (2): used for cultivation of sunflower. [a] EC, electrical conductivity; [b] TC, total carbon; [c] OM, organic matter; [d] TN, total nitrogen.

subsequently need unending researches to evaluate their effects on soil nutrient content, soil conditioning properties, and parasites control before licensing for application. The objective of this work was to examine the impact of applying five types of rice straw composts (Rashad et al., 2010) on the bacterial and fungal population, some chemical properties in rhizosphere soil, plant growth and macronutrient uptake comparing to the conventional mineral fertilizer; and finally on controlling of the nematode root-gall disease.

METHODS

Sandy soils

Air dried sandy soils were crushed to pass a 2 mm sieve and analyzed for major physical and chemical properties as shown in Table 1.

Composts

Five composts were obtained from co-composting of rice straw with certain agro-industrial wastes (Rashad et al., 2010) and the selected properties are provided in Table 2.

Greenhouse experiments

Effect of produced composts on soil properties and plant growth of snap bean

The first experiment was carried out in the Department of Vegetable Crops, Faculty of Agriculture, Cairo University. Thirty six plastic pots of 25 cm diameter were filled with sandy soil at the rate of 6 kg/pot. Pots then were divided into 12 groups each of which consisted of three replicates. One group was served as control, another one was treated with mineral fertilizer (MF) at the recommended dose, five groups were treated with 5% (w/w on the dry weight basis) of the five types composts (Table 2) and the last five groups were treated with combination of the composts at the same rate plus half recommended dose of mineral fertilizers (½ MF).

Composts were added 15 days before cultivation, mixed thoroughly with the soil of each pot, then pots were irrigated immediately (Abdel-Hamid et al., 2004). However, pots received MF were treated 3 days before cultivation. The recommended dose of MF consisted of 1.8 g/pot ammonium sulphate (20% N), 0.6 g/pot super phosphate (15% P_2O_5) and 1.8 g/pot potassium sulphate (48% K_2O).). At cultivation, 6 seeds of snap bean, *Phaseolus vulgaris* c.v. polsta, were sown in each pot and irrigated immediately. After complete germination, plants were thinned to 3/pot, then pots were arranged in a complete randomized block design and horticulturally treated the same to keep pots weed-free and to maintain moisture in an optimum content throughout the experiment (Zayed and Abdel-Motaal, 2005).

Soil samples were taken from the rihzosphere at 0, 2, 4, 6 and 8 weeks after cultivation for determination of total viable counts of culturable bacteria and fungi and for the subsequent physicochemical analysis e.g. pH, EC, organic matter (OM), total available forms of nitrogen, phosphorus, potassium and total available forms of nutrients. Total forms of macronutrients were determined initially at 0 time and finally after 8 weeks. At the end of the experiment, plants were harvested and plant growth parameters (fresh weight, number of pods and leaves, plant length, dry weight of whole plant and pods) were recorded. Also, the macronutrient, total nitrogen, phosphorus and potassium (NPK), were determined in the harvested plants.

Effect of different compost levels on soil properties and plant growth of sunflower

The second experiment was conducted in the greenhouse of Zoology and Agricultural Nematology Department, Faculty of Agriculture, Cairo University, to confirm the quality of the produced

Table 2. Characterization of used composts.

Parameters	Composts				
	C1	C2	C3	C4	C5
pH	7.03	6.60	6.95	6.70	6.57
EC $dS.m^{-1}$	0.79	0.88	0.87	1.0	1.04
OM %	63.15	61.39	59.70	56.79	59.31
OC %	36.63	35.58	34.63	32.94	34.40
TN %	1.63	1.86	1.78	2.08	1.94
NH_4^+ ppm	176.66	197.33	228.66	242.33	198.33
NO_3^- ppm	159.0	256.0	265.66	321.66	227.33
NH_4^+/ NO_3^-	1.11	0.77	0.86	0.75	0.87
C/N ratio	22.47	19.12	19.45	15.83	17.73
TP %	1.47	1.76	1.62	2.01	1.95
P_2O_5 ppm	725.66	858	808	987.33	965
TK %	0.821	0.925	0.914	0.966	0.953
K_2O ppm	323	398.66	377.33	433.33	436.33
Humic substances %	7.94	10.97	9.54	12.77	12.55
Humification index	1.86	1.81	1.71	1.79	1.88
Germination index (GI) %	71.77	82.95	73.60	83.38	79.43
Total bacterial counts cfu/g	$1.2x10^9$	$2.7x10^9$	$3.6x10^9$	$6.9x10^9$	$1.9x10^9$
Actinomycetes counts cfu/g	$2.5x10^6$	$4.3x10^6$	$3.1x10^7$	$3.5x10^7$	$5.7x10^7$
Phosphate dissolving bact. cfu/g	$3.6x10^6$	$3.1x10^7$	$9.3x10^6$	$1.5x10^7$	$3.7x10^7$
Total fungal counts cfu/g	$1.8x10^6$	$2.6x10^6$	$4.4x10^7$	$6.5x10^7$	$5.2x10^6$
Phosphate dissolving fungi cfu/g	$1.2x10^5$	$2.2x10^5$	$1.5x10^6$	$1.8x10^6$	$2.2x10^6$
Cellulose decomposers MPN/g	$2.5x10^4$	$5.4x10^5$	$5.4x10^4$	$8.8x10^4$	$7.5x10^5$
Total coliform MPN/ g	14.30	Nil	10.0	Nil	Nil
Faecal coliform MPN/ g	Nil	Nil	Nil	Nil	Nil
Salmonella detection	Nil	Nil	Nil	Nil	Nil

C1: Rice straw + okara + rock phosphate; C2: Rice straw + okara + rock phosphate + buffalo's manure; C3: Rice straw + okara + rock phosphate + composite inoculum; C4: Rice straw + okara + rock phosphate + vinasse + composite inoculum; and C5: Rice straw + okara + rock phosphate + vinasse + buffalo's manure + composite inoculum (Rashad et al., 2010).

composts as good soil amendments and its impact on the proliferation of sunflower, *Helianthus annus* c.v. miak as an exhausting plant. Only two types of compost were applied, compost 1 and compost 4, which gave the lowest and the best results, respectively with snap bean. Of each compost three concentrations, 2.5, 5.0 and 7.5% (w/w at dry weight basis) were applied to clay pots of 15 cm diameter and containing 2 kg virgin sandy soil (Table 1).

As previously described, composts were added, seeds of sunflower were sown and after germination, plants were thinned to one/pot, treatments including control were triplicated and arranged in a complete block randomized design in the greenhouse of 30 ± 5℃ and irrigated the same way. Soil and plant samples were taken the same style followed in snap bean experiment except that flowers (fresh and dry weight) represented the yield instead of pods in the previous experiment; in addition, water holding capacity (WHC) was evaluated.

The effect of compost on the root-knot nematode infecting sunflower

The third experiment was carried out simultaneously with the second one. Sunflower seeds were sown and thinned to one/pot; then the following treatments were conducted: Untreated plants (control healthy), inoculated plants (control infected), compost 1was added at 2.5% one week before nematode inoculation, in concomitant with nematode inoculation and one week after nematode inoculation. Similar treatments were repeated using 5.0 and 7.5% of compost 1. Likewise the same treatments were undertaken using compost 4 to form a total of 20 treatments. Each treatment was replicated three times. Composts were added by incorporation with the top soil surface, while nematode-water suspensions were poured in three holes around the root system. Nematode inoculum level was 2000 second stage juveniles (J_2) of the root-knot nematode, *Meloidogyne incognita*. Pots were then arranged and horticulturally treated the same. After 8 weeks, plants were harvested; nematodes in pots soil and on sunflower roots were calculated, as well as plant growth criteria were recorded.

Microbiological analysis

Ten grams of the rhizosphere soil sample were added to 90 ml sterile saline (0.85% NaCl). Serial decimal dilutions were prepared in the same diluent, then 1 ml of each dilution was transferred aseptically to inoculate appropriate media in triplicate using the pour plate. Total count of bacteria was determined on tryptone glucose extract agar medium at 30ºC for 3 days; total fungi on Rose Bengal agar base medium supplemented with 0.3 ml (1% w/v) streptomycin /100 ml of cooled media , at 30ºC for 5 to 7 days. The microbial numbers were estimated as colony forming unit/g on the basis of dry weight.

Physicochemical analyses

pH and electrical conductivity (EC) values were measured by using a pH digital meter (3020, Jenway, UK) and an EC meter (ESD, 76, USA) in 1: 5 soil / water (Rhoades, 1996). Ash was determined in a muffle furnace at 550ºC for 5 h, and the organic matter (OM) was calculated as the difference between ash and dry weight as a percentage (Tiquia and Tam, 1998). Water holding capacity (WHC) was determined following the methodology of Klute (1986). Total nitrogen (TN) was determined by micro-Kjeldahl and organic carbon (OC) according to the method of Walklay and Black (Cottenie et al., 1982); ammonical and nitrate nitrogen, the available forms of nitrogen, according to the methods described by Page et al. (1982). Total and available phosphorus was determined using the **m**ethods described by David (1966) and Olsen et al. (1954), respectively; total and available potassium using a flame photometric method outlined by (APHA, 1989).

Plant samples were dried at 70ºC for 72 h and their dry weights were recorded, then ground to pass a 0.5 mm sieve for determination of the macronutrients (total nitrogen, N; phosphorus, P; and potassium, K).

Statistical analysis

Data were statistically analyzed using general linear model (GLM) according to (SAS, 2002) and differences between means were analyzed using the least significant difference test (LSD) at p < 0.05.

RESULTS

Effect of composts at rate 5% on soil properties and growth of snap bean plants

As shown in Figures 1a and b, the bacterial and fungal populations in the rhizosphere soil samples increased markedly in all treatments during the first 4 weeks; then slightly declined with the proceed of snap bean growing period until the end of 8 weeks, but still higher than that at the start by at least 2 - 8 folds in fungal and bacterial populations, correspondingly. It is worthy mentioning that the highest increasing rate was achieved after 2 weeks in bacterial population and teetered between the 2nd and 4th week in case of fungal population. Comparing treatments with each other, it is conspicuous that the rhizosphere total microbial populations of treatments received combination of compost and ½ MF were higher than those received compost only or that received the whole dose of MF. The treatment C4* (C4 + ½ MF) overpassed significantly all the other treatments of both bacteria (LSD = 2.1×10^9, P = 0.0001) and fungi (LSD = 9.03×10^6, P = 0.0001).

Initial organic matter content into the soil significantly (P = 0.0001) increased with composts application (4.49 - 4.67%) comparing to plain (0.51%) or mineral fertilized soil (0.50%). Organic matter values were in decreasing order as the growing period progressed (Figure 1c). The rate of mineralization in treatments received mishmash of composts and ½ MF were higher than those received composts only and lower than those of control and MF. It is evidenced that application of composts greatly increased the final OM contents into soil by at least 11 - 13.5 folds comparing to plain unfertilized soil and that received FM, respectively.

Compost application either alone or in combination with ½ MF significantly increased total forms of N, P and K by at least 1031, 114 and 1008%, respectively, comparing to amounts initially presented in plain soil (Table 3). In this respect, MF alone increased the total forms of these nutrients, N by 304, P by 79, and K by 371%. The values of N, P and K decreased at the end of growing period; however the amended soils retained the higher contents comparing to initials of plain soil. The greatest increase in total N was over the range 960 - 1002% in soils treated with composts alone versus 195% when whole dose of MF was applied; 75 - 158% and 35% in total P; 750 - 1106% and 249% in total K, respectively. Also, application of composts in concomitant with ½ MF significantly increased the macronutrients contents into soil by 1059 - 1119 %, 149 - 207 % and 1064 -1211 % for N, P and K, in that order.

Application of MF, composts or combination of composts plus ½ MF significantly increased the available form of the macronutrients; but as usually observed, the highest increase was achieved by compost plus minerals followed by composts alone, however, lonely MF treatment ranked significantly in the last category (Figure 2). Nutrients concentration increased gradually during the growth of snap beans to attain the highest significant levels at the 4th week. At the end of the growing course of snap beans, concentrations of the available nutrients decreased but remained significantly higher than those recorded at the start.

Application of MF increased the initial values of both pH and electrical conductivity (EC), however application of composts alone or in combination with ½ MF slightly reduced the pH and EC values (Figures 3a and b). Irrespective of the type of treatment, the pH and EC of all soil samples decreased gradually during the growing period of snap beans, recording the lowest values at the end of the 8th week.

Concerning the plant growth response, it is obvious that amendments application significantly enhanced all growth parameters (Table 4) comparing to plants grown in plain sandy soils which failed to produce pods. Mineral fertilization (MF) at the whole dose insignificantly augmented such criteria to overcome some compost treatments when added alone. However, growth response to mishmash of composts plus ½ MF was greater than the other treatments. On the whole, it is palpable that C4 alone or in combination with ½ MF overpassed all the produced composts and the recommended dose of MF.

Plant‘s nutrient uptake was affected positively by the

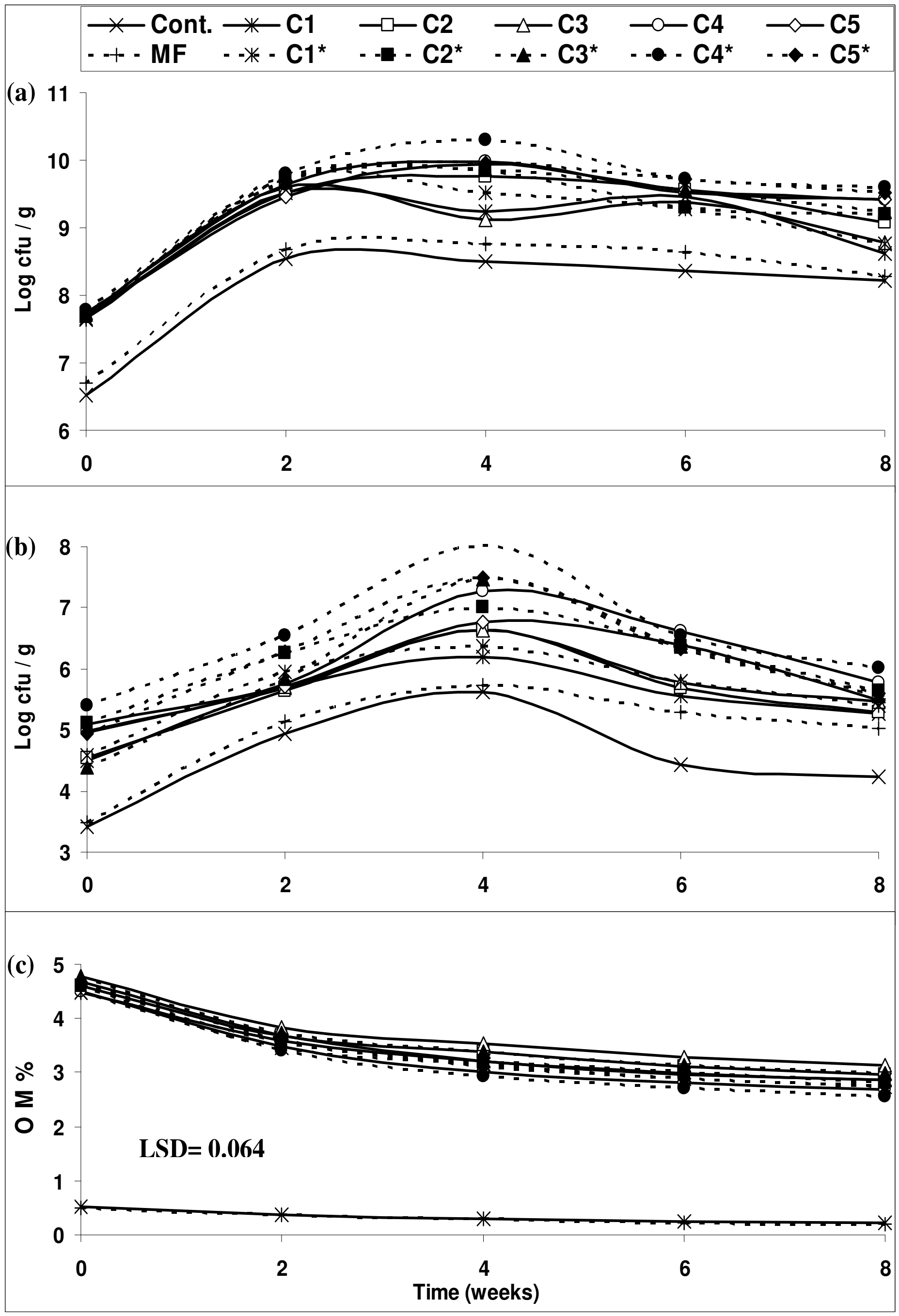

Figure 1. Influence of composts at the rate of 5% and/or MF on: (a) bacterial population, (b) fungal population and (c) OM in the rhizosphere soil of snap beans (* = 5% compost + ½ MF).

Table 3. Influence of composts at the rate of 5% and/or MF on soil content of total forms of macronutrients in the rhizosphere of snap beans.

Treatments	Total N		Total P		Total K	
	Initial	Final	Initial	Final	Initial	Final
Cont.	309.0	200.3	163.3 k	97.33	325.0	231.6l
MF	1250.0	911.33	293.0 j	220.0	1531.6	1133.6

Table 3. Contd.

C1	3496.6	3276.3	349.6 i	285.6	3603.3	2764.3
C2	3781.6	3357.6	450.0 g	356.6	4571.6	3520.6
C3	3677.0	3378.6	414.6 h	361.0	4386.0	3433.6
C4	4010.3	3370.0	538.0 e	403.3	5020.0	3921.3
C5	3915.6	3407.6	495.0 f	421.0	4813.0	3759.0
C1*	4017.6	3638.0	506.0 f	407.3	4947.6	3782.0
C2*	4252.6	3582.3	591.0 c	462.0	5564.6	4224.6
C3*	4212.3	3627.3	563.3 d	436.6	5410.0	4126.0
C4*	4629.0	3768.0	658.3 a	502.0	5891.3	4262.3
C5*	4555.0	3695.3	631.6 b	492.6	5746.3	4250.0
$LSD_{0.05}$	21.04		10.51		18.47	

C = Compost , MF = mineral fertilizer, *= compost + ½ MF.

addition of any soil amendment. All composts increased N uptake by 19 to 48% and 41 to 67% when applied alone or with ½ MF, correspondingly; however, the whole dose of MF gave 24% increase as matched with plants grown on plain soil (Table 4). Likewise, phosphorus uptake increased by 63 to 147%, 126 to 232% and 84%, in that order. Similarly, K uptake was enhanced by 6 to 19%, 17 to 39% and 7, respectively, as compared to unfertilized control. As always found, the highest uptake was attained by application of composts plus ½ MF; C4 and C5 alone or in combination with ½ MF which preponderated all the produced composts and the whole recommended dose of MF (P = 0.0001).

Effect of composts at different rates on soil properties and growth of sunflower plants

During the growing period of sunflower, microbial populations were dominated by bacteria as shown by higher bacterial count followed by fungal count (Figures 4a and b). The microbial populations, both bacteria and fungi, increased during the first 4 weeks, then declined after 6 weeks and more or less remained stable till the end. Rhizosphere soil samples received composts contained higher populations than plain soil; the higher the compost level, the higher the population obtained. Finally, soil amended with 7.5% C4 had the highest significant bacterial (LSD = 8.9×10^9) and fungal (LSD = 1.9×10^6) populations in the rhizosphere soil samples (P = 0.0001).

As illustrated in Figure 4c, an increase in the OM content was recorded after adding composts, such increase was interrelated to increasing compost dosage, while showed a gradual decrease along the growth time up to the end of 8 weeks. Although the organic matter was in decreasing order over the growing period of sunflower, the final OM contents was greatly increased into soil by at least 8 to 9, 15 to 17 and 24 to 27 folds when the sandy soil was amended with compost dosages of2.5, 5.0 and 7.5%, correspondingly, comparing to plain unfertilized soil.

It is veridical that all composts application significantly increased the WHC and the sharpness of increase was correlated with compost dosage (Table 5). Always, application of C4 exceeded the other compost in improving WHC (P = 0.0001).

It is noteworthy to underscore that noticeable differences were found between the amounts of total major nutrients (N, P and K) in amended soil with composts and plain sandy soil at the initial time (Table 5), besides, the greatest differences were interconnected with increasing composts dosage (P = 0.0001). At the end of the growing period, although all nutrients content into soil decreased; but it remained significantly higher when compared to those initially present in plain soil at zero time, especially in total N and K. It is arresting that, total N and K contents into soil were increased by 367 to 1170% and 288 - 1006%, respectively, after harvesting. However, total P increased into soil by 60 to 153%, only when soil amended with compost at 5.0 and 7.5%, respectively, comparing to the initial contents of plain soil.

Regarding to the available forms of these macronutrients, significant increase of N, P and K into soil contents was clearly interrelated with proceeding growing period up to the 4^{th} week and the augmentation of composts levels (Figure 5). Besides, more significant increase into soil contents of the major nutrients was observed in treatment that amended with the highest level of C4 when compared to other treatments (P = 0.0001).

Compost application in unremitting levels resulted in a steady decrease in pH values and EC comparing to untreated plain soil (Figures 6a and b). A gradual decrease in both pH and EC values was observed till the end of the growing period in all treatments. The lowest values were recorded for soil received composts, generally; there was a clear relationship between reduced values and the levels of added composts as well as the time progress.

Plant growth of sunflower responded positively to both

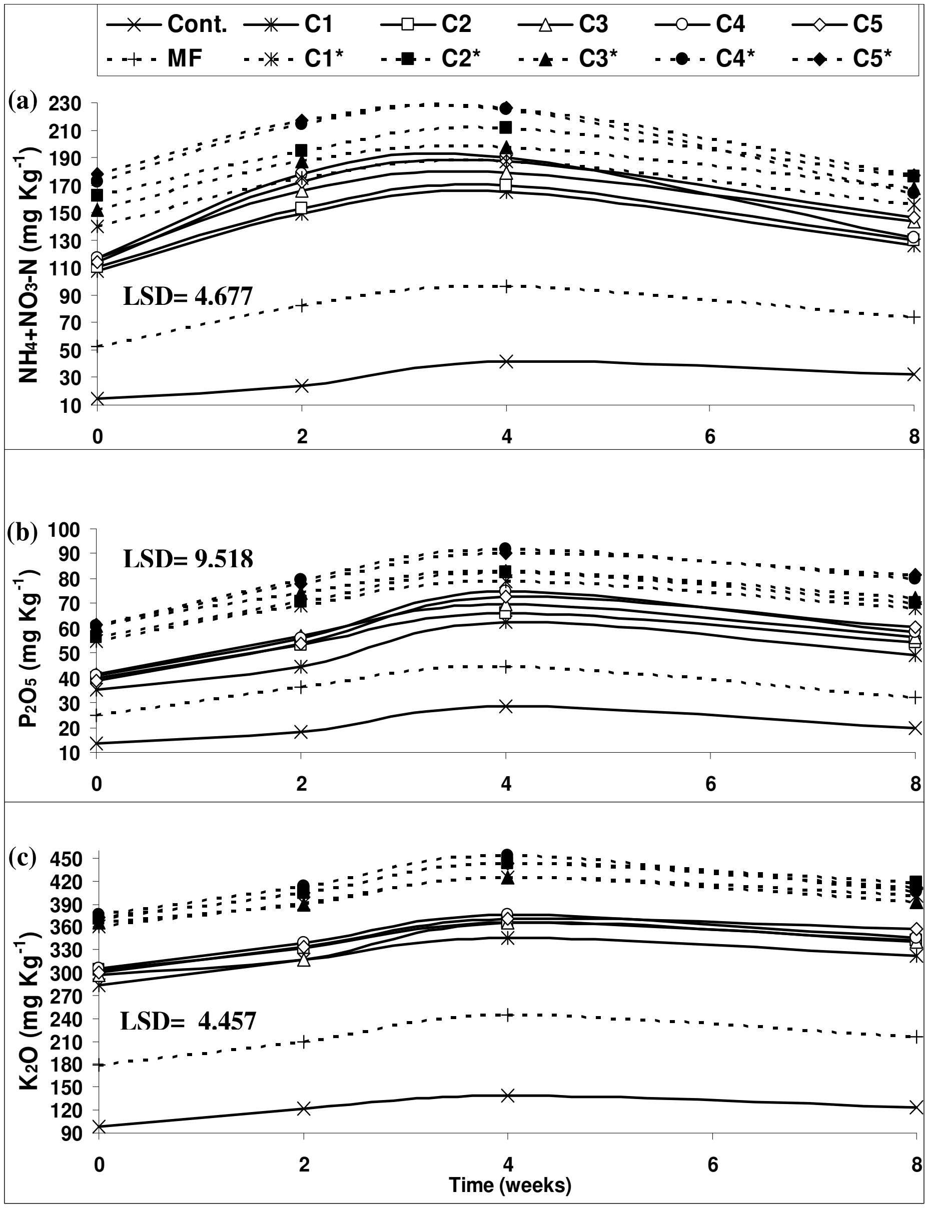

Figure 2. Influence of composts at the rate of 5% and/or MF on the available macronutrients: (a) NH_4 + NO_3-N, (b) P_2O_5 and (c) K_2O in the rhizosphere soil of snap beans (* = 5% compost + ½ MF).

composts as indicated by growth parameters and macronutrients uptake (Table 6). As the compost dosage increased, most of the growth parameters significantly improved with supreme enhancement being the highest when compost 4 was applied (P = 0.0001). Such findings confirmed the previously obtained results with snap beans.

Effect of compost on the root-knot nematode, *Meloidogyne incognita,* infecting sunflower plants

Irrespective of the compost type and application time, significant reductions in numbers of galls formed on plant root, embedded stages and egg production were observed comparing to infected untreated control; however, the highest diminution was obtained when the composts were added before nematode inoculation (Table 7). The highest the compost rate, the highest the reduction of *Meloidogyne incognita* reproduction was observed.

Taken as a whole, 7.5, 5 and 2.5% of compost 4 reduced the nematode population by 84, 79 and 71%, respectively, versus to 78, 72 and 60% reduction by compost 1 when they added one week before nematode

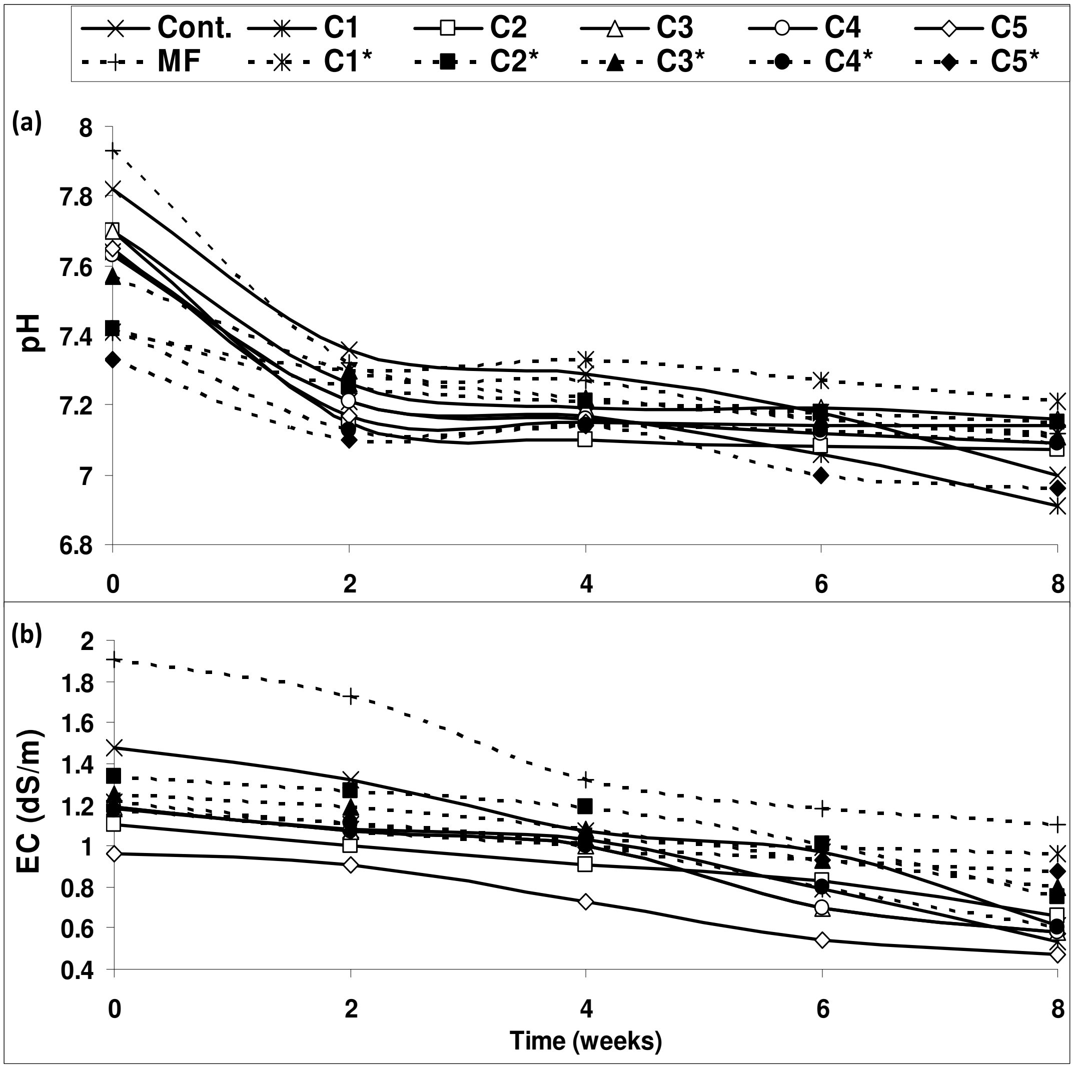

Figure 3. Influence of composts at the rate of 5% and/or MF on: (a) pH and (b) EC in the rhizosphere soil of snap beans (* 5% compost + ½ MF).

inoculation. Compost 4 actualized prodigious depletion in egg production when compared with the check and all treatments.

DISCUSSION

It is meaningful to assess the produced composts by studying their effects on the biological and physicochemical properties of sandy soil, besides their effects on plant growth and nutrient uptake as well as plant parasites to lend more validity to the conclusion. Although, the effect of application of such compost on the physical and chemical properties needs many years to provide any significant results, microbiological and biochemical properties are very responsive and provide immediate and precise information on small changes occurring in soil. In fact, they also indicate the soil's potential to sustain microbiological activity (Kennedy and Papendick, 1995; Odlare et al., 2008).

In the present study, composts application resulted in marked increase of organic matter content into soil in relation to initial value of plain sandy soil which affirmatively exaggerated the bacterial and fungal populations; as the compost dosage increased the maximum population obtained. In addition, apart from microbial proliferation may be referred to plant root exudates which support the microbial growth in the rhizosphere even in untreated control. The combination of compost + ½ MF was found to enhance soil microbial populations differently than the MF alone. Such increase of microbial population might be imputed to the availability of growth nutrients and the positive effect of organic matter on the physical properties of soil which support the microbial growth and activity in the soil. Subsequently, the added OM into the soil was in

Table 4. Influence of compost at the rate of 5% and/or MF on the growth parameters and nutrient uptake of snap beans grown in sandy soil under greenhouse conditions.

Treatments	Whole plant length (cm)	Leaves no.	Pods no.	Fresh weight (g)		Dry weight (g)		Macronutrient uptake %		
				Whole plant	Pods	Whole plant	Pods	N	P	K
Cont.	25.86	9.0	0.0	3.51	0.0	1.0	0.0	1.11	0.19	1.131
MF	38.12	18.0	8.0	6.60	25.83	1.81	3.26	1.38	0.35	1.21
C1	34.29	14.0	5.0	6.14	16.33	1.42	2.25	1.32	0.31	1.20
C2	36.66	16.0	7.3	6.94	23.63	1.86	2.89	1.45	0.37	1.27
C3	35.36	13.0	6.0	6.40	21.85	1.60	2.67	1.40	0.34	1.23
C4	49.73	21.0	10.0	15.56	27.75	4.67	4.25	1.64	0.47	1.34
C5	44.80	18.33	7.6	13.14	24.11	2.24	3.85	1.54	0.43	1.31
C1*	44.89	21.0	9.0	14.59	26.89	2.62	4.08	1.56	0.43	1.32
C2*	47.62	22.0	11.3	20.17	29.70	5.0	4.85	1.73	0.55	1.46
C3*	51.23	23.0	10.6	18.68	28.47	4.41	4.50	1.65	0.50	1.40
C4*	54.93	28.0	14.0	23.51	32.15	6.68	5.29	1.85	0.63	1.57
C5*	49.53	20.0	11.0	20.26	29.08	5.0	4.63	1.76	0.58	1.50
$LSD_{0.05}$	3.509	3.854	1.296	2.136	1.85	0.97		0.0576	0.0349	0.0268

decreasing rate as a result of its mineralization to CO_2 through the microbial activity. The higher loss of organic matter content was observed when mineral fertilizer was applied either alone at the recommended dose or in combination with compost at half the recommended dose. These results are in line with those obtained by many researchers (Li et al., 2008; Odlare et al., 2008; Tognetti et al., 2008).

In agricultural soils, microorganisms are known to exert profound influences on the status of soil fertility, in particular on the availability of plant nutrients and sustaining the productivity of soils (Kennedy and Smith, 1995; Vineela et al., 2008). Applying organic amendments has been shown to increase soil microbial activity, microbial diversity, and bacterial densities (Van Bruggen and Semenov, 2000; Liu and Ristaino, 2003; Girvan et al., 2004). Bacteria and fungi generally comprise > 90% of the total soil microbial biomass, and they are responsible for the majority of soil organic matter decomposition. The ratio of fungal: bacterial biomass has been shown to be particularly sensitive to soil disturbance, with lower ratios associated with increased intensity of cultivation (Bailey et al., 2002) and increased N fertilization inputs (Frey et al., 2004). Substrate quality also alters fungal: bacterial ratios, with low quality substrates (high C/N) favoring fungi and high quality (low C/N) substrates favoring bacteria (Bossuyt et al., 2001). In soil, fungi, although numerically much less abundant than bacteria, can account for twice the weight of bacteria and actinomycetes combined (Vig et al., 2003).

In the current study, a major limitation of the traditional method used in determination of soil bacterial and fungal populations is that only a small portion (lower than 10%) of the soil microbial population can be cultured on laboratory media (Amann et al., 1995). However, the association between microbial biomass carbon and total microbial populations was found to be significant. It has been documented that the addition of organic amendments increased the microbial biomass and resulted in a positive correlation between microbial biomass carbon and cfu values of microbial populations (Li et al., 2008; Vineela et al., 2008; Chitravadivu et al., 2009).

Although, the organic matter decreased by 34 to 44% at the end of cultivation period, the most part of the added organic matter (56 to 66%) remained in the soil after harvest and resulted in significant enhancement of the water holding capacity. Consequently, applying a stable source of organic matter such as compost will result in a net accumulation of organic matter in soils on the long term. On the whole, soil organic matter is

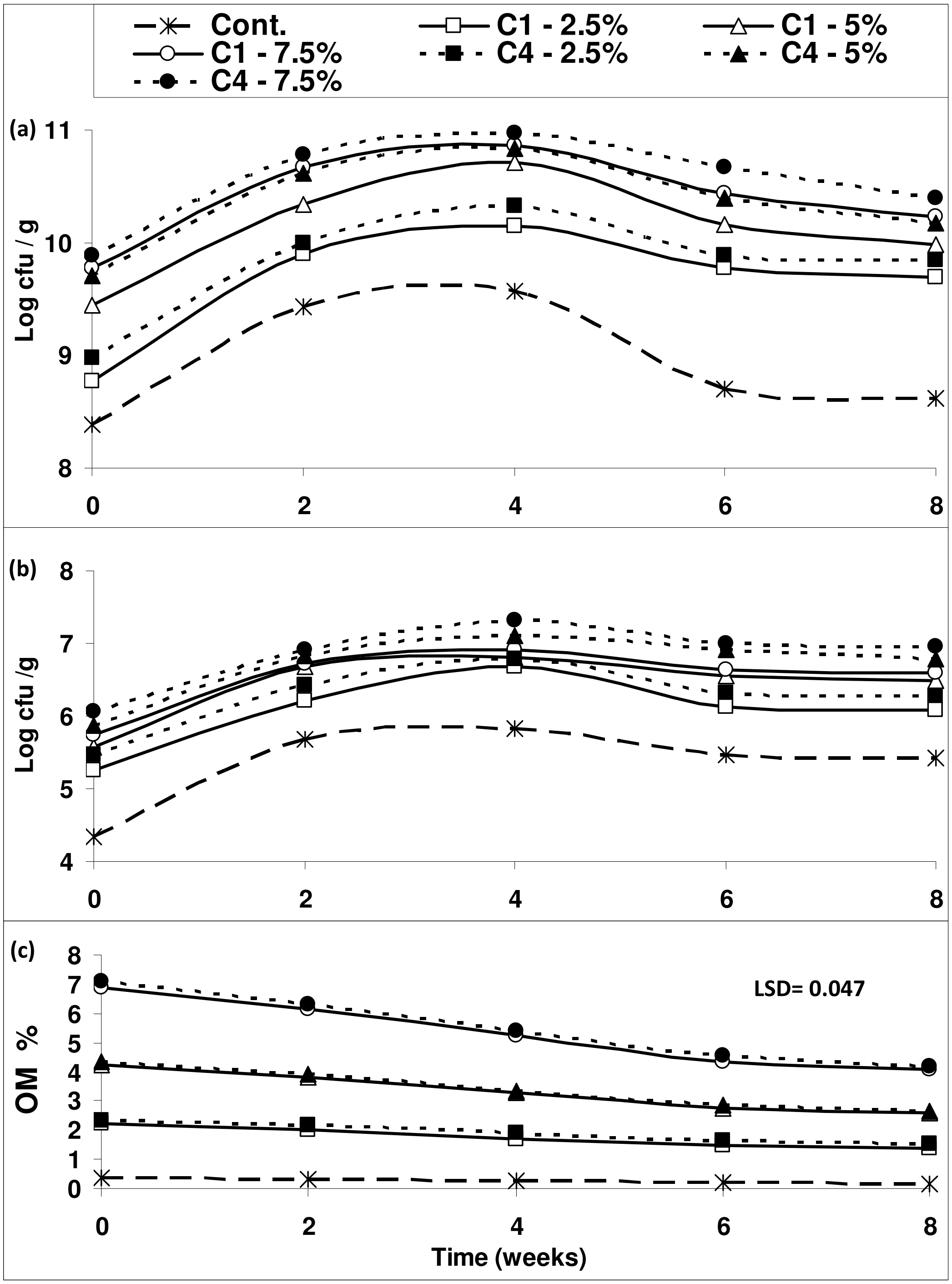

Figure 4. Influence of different levels of composts on: (a) bacterial population, (b) fungal population and (c) OM in the rhizosphere soil of sunflower.

Table 5. Influence of different levels of composts on the total forms of N, P and K (mg/kg^{-1}) and water holding capacity (WHC) in sunflower rhizosphere sandy soil.

Treatments	Total N		Total P		Total K		WHC	
	Initial	Final	Initial	Final	Initial	Final	%	% I*
Cont.	298.0	189.0	163.3	89.3	320.6	216.6	30.0	--

Table 5. Contd.

C1-2.5%	1662.6	1415.0	197.6	122.3	1837.6	1243.3	40.66	35.53
C1-5%	3520.0	3241.3	351.6	261.6	3633.0	2690.3	45.33	51.10
C1-7.5%	4814.3	3773.6	511.0	409.6	5121.0	3866.6	52.0	73.33
C4-2.5%	1701.0	1391.3	227.0	118.6	1911.3	1235.3	42.0	40.0
C4-5%	4067.6	3294.6	554.3	390.6	5091.0	3812.0	47.33	57.77
C4-7.5%	4943.0	3783.3	561.3	412.6	5185.0	3857.0	58.0	93.33
$LSD_{0.05}$	21.973		9.563		25.403		4.21	

I* = Increase in WHC over control.

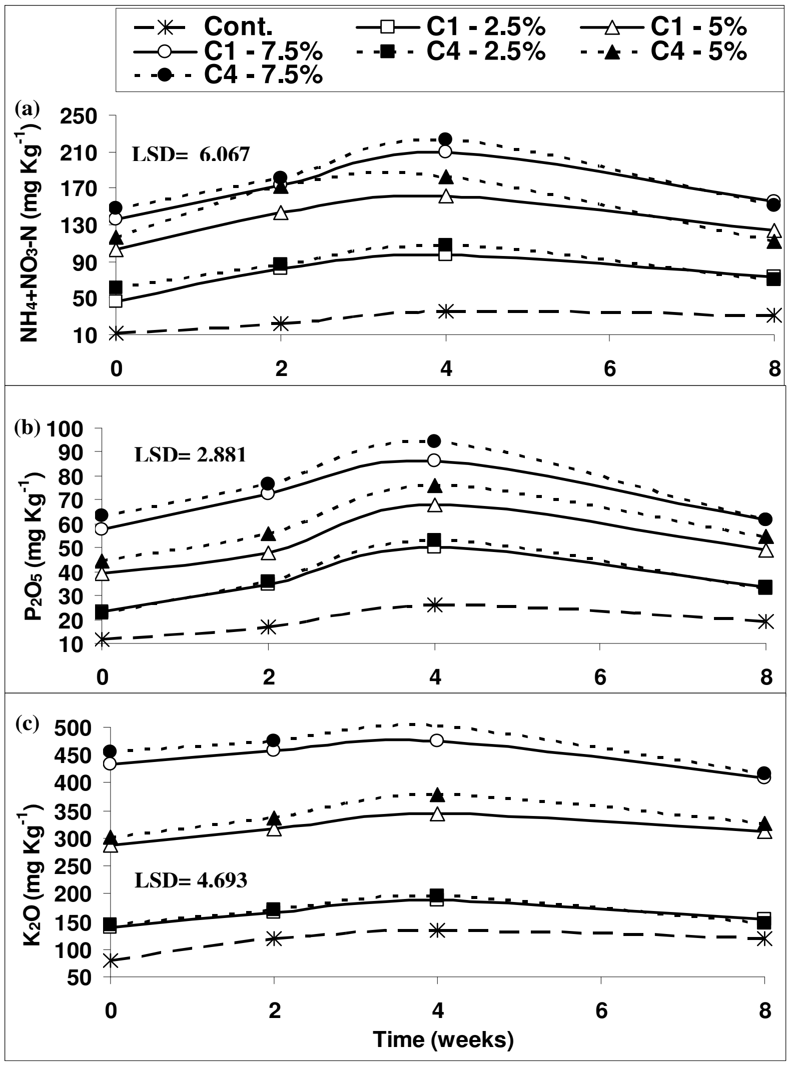

Figure 5. Influence of different levels of composts on the available macronutrients: (a) NH_4 + NO_3-N, (b) P_2O_5 and (c) K_2O in the rhizosphere soil of sunflower.

essential for maintaining soil quality by improving the biological, physical and chemical soil conditions. These findings are confirmed by many workers (Soumare et al., 2003; Courtney and Mullen, 2008).

The availability of macronutrient (N, P and K) in horticultural soils is the key for crop growth. In the current study, all composts application at the rate of 5% significantly increased both the total and available

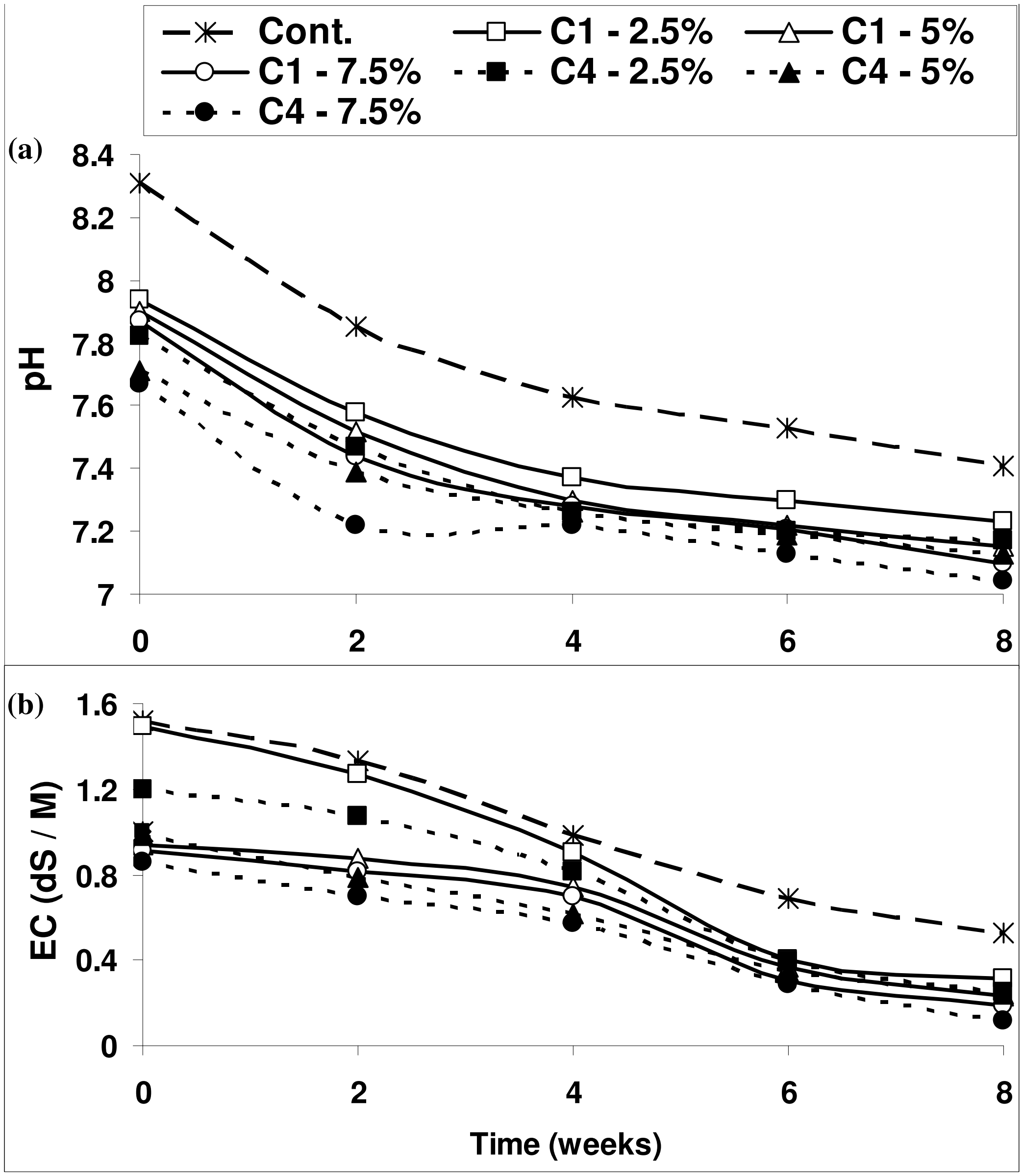

Figure 6. Influence of different levels of composts on: (a) pH and (b) EC in the rhizosphere soil of sunflower.

macronutrients (N, P and K) in the soil, either initially or after harvesting as well as enhanced their uptake by the treated plants, comparing to the values recorded for MF when added alone at the recommended dose.

Furthermore, significant increase of their contents was obtained with increasing the dose of compost or when compost added in concomitant with the half recommended dose of mineral fertilizer. Our results are in harmony with those obtained by Soumare et al. (2003); Zayed and Abdel-Motaal (2005); Courtney and Mullen (2008) and Odlare et al. (2008).

The present results proved that the tested composts at the rate of 5% were good nutrient supplier equal to or surpass the mineral fertilizer at the recommended dose as indicated by the improvement of different plant growth criteria and nutrient's uptake. C4 and C5, which derived from piles received vinasse, significantly provided plants with higher amounts of nitrogen, phosphorous and potassium and subsequently enhanced plant growth as compared to other treatments. Greater improvement was obtained when combination of composts with MF at the half recommended dose was added. Amelioration in nutritional status, plant growth response and productivity as a result of compost addition to soil had been reported (Madejon et al., 2001; Soumare et al., 2003; Abdelhamid et al., 2004; Courtney and Mullen, 2008; Cherif et al., 2009).

Table 6. Influence of different levels of composts on the growth parameters and nutrient uptake of sunflower grown in sandy soil under greenhouse conditions.

Treatments	Whole plant length (cm)	Leaves no.	Fresh weight (g)		Dry weight (g)		Macronutrient uptake %		
			Whole* plant	Flower	Whole* plant	Flower	N	P	K
Cont.	85.62	14.66	4.66	2.20	1.34	0.36	0.68	0.17	0.70
C1-2.5%	99.50	17.66	11.02	6.16	3.31	1.23	0.91	0.29	0.85
C1-5%	112.53	20.66	20.15	10.18	5.79	2.19	1.25	0.37	0.98
C1-7.5%	106.53	22.0	27.08	16.41	7.96	3.99	1.45	0.47	1.22
C4-2.5%	96.32	20.0	14.31	7.98	4.40	1.67	1.09	0.31	o.93
C4-5%	117.82	22.33	27.17	18.48	8.53	4.59	1.40	0.44	1.18
C4-7.5%	123.16	23.33	36.05	21.09	10.02	4.97	1.55	0.55	1.36
$LSD_{0.05}$	16.2	1.294	4.09	3.6	1.301	0.786	0.0608	0.0424	0.0855

*Root and shoot.

Improvement in other soil properties was also clearly observed; all applied composts decreased both pH and EC of sandy soil over the growing period of the cultivated plants. The reduction of pH may be attributed to the production of organic acids resulted from the microbial activity (Abdelhamid et al., 2004). However, El-Etr et al. (2004) attributed the reduction of EC to the increase of salt leaching into the deepest layers of soil because of the formation of dry stable aggregates resulting from compost application. The obtained results are in concurrence with the findings of other researchers (El-Etr et al., 2004); but are not in concert with those observed the increase in soil pH and EC when composts added to soil (Soumare et al., 2003; Courtney and Mullen, 2008).

Such discrepancy in results could be referred, in one hand, to the nature of the pH and EC of the experimental soil; on the other hand, to the salinity of pre-composting materials that might affect the EC of the produced composts. Subsequently, salinity and pH of the produced compost will assuredly affect the soil properties. As extracted from the literature, increases in pH and EC values were associated with acid soils and the salinity degree of applied composts. In the present study, the experiments were carried out in a sandy soil with a basic pH over the range 7.82 to 8.31 and EC 1.48 to 1.52 $dS.m^{-1}$. However, the values of pH and EC of the produced composts were over the range 6.57 to 7.03 and 0.79 to 1.04 $dS.m^{-1}$, respectively.

Pertaining to the effect of composts on the plant-parasitic root-knot nematode, *Meloidogyne incognita*, the present study proved that composts significantly supported the growth of sunflower and enabled infected plants to overcome nematode infection. Concerning the influence of compost on the reproduction of the root-knot nematode, our results showed that composts significantly reduced galls formation on plant roots, the embedded stages, the final population as well as the rate of nematode reproduction (pf / pi). Increasing the compost dose from 2.5 to 7.5% w / w resulted in a significant parallel reduction in such nematode criteria. Time of compost addition, one week before, in concomitant with or one week after nematode inoculation must be considered. The best results were achieved when composts applied at the high rate before nematode inoculation which resulted in reducing final nematode population by 78 to 84%. These findings are in agreement with those obtained by other researchers (Akhtar and Malik, 2000; Cayuela et al., 2008; Renčo et al., 2009).

Effectiveness of organic amendments in suppressing nematode population generally depends on the amount of amendment used, C / N ratio and time of decomposition. At narrowest C / N ratio less than 20, N will be mineralized in the form of NH_4^+-NO_3^- for absorbance and uptake by plant roots (Jones, 1982). The availability of more nitrogen enhances the ability of amendment to control nematode (Miller et al., 1973). The nematode management potential of an organic soil amendment is directly related to N, C content and inversely related to C / N ratio (Mian and Rodriguez-Kabana, 1982; Renčo et al., 2009).

Additionally, the adverse influence of compost on nematode reproduction could mainly be attributed to the direct effect of chemicals produced during compost degradation in the soil (Kesba and Al-Shalaby, 2008). Furthermore, the indirect effect is related to the role of compost in supplying and encouraging microorganisms many of which exhibits some antagonistic action against nematodes either as direct parasites or predators or by their metabolites produced during their activities (Mankau, 1963). This could explain the great reduction in root-knot nematode population when introduced to soil treated previously with compost.

Conclusion

It is forte palpable that compost is indispensable for the sustainability of agriculture and for organic farming

Table 7. Influence of different levels of composts on the reproduction of *Meloidogyne incognita* on sunflower roots.

Treatments	Compost application	% dose	Galls	Embedded stages	Final population (Embedded + in soil)	Pf/Pi	% Nematode reduction	% Egg production	Total dry weight (shoot+ root+flower) (g)	Flower dry weight (g)
Cont.	-	-	-	-	-	-	-	-	4.63	1.33
Infected	-	-	565	1130	4170	2.09	0	276	3.61	0.98
Compost 1	Before nematode inoculation	2.5	154	403	1663	0.83	60	79	8.70	2.07
		5.0	132	293	1173	0.59	72	25	11.65	3.25
		7.5	126	256	936	0.47	78	21	10.76	2.53
	With nematode inoculation	2.5	356	711	3381	1.69	19	116	5.56	1.43
		5.0	351	650	3020	1.51	28	98	8.16	2.06
		7.5	326	604	2494	1.25	40	87	10.65	2.61
	After nematode inoculation	2.5	431	810	3890	1.95	7	113	9.92	2.50
		5.0	390	739	3609	1.80	13	104	11.33	2.23
		7.5	376	680	2780	1.39	33	73	13.53	2.80
Compos 4	Before nematode inoculation	2.5	120	228	1208	0.60	71	13	10.15	2.90
		5.0	99	199	859	0.43	79	9	11.90	3.23
		7.5	89	179	659	0.33	84	8	13.37	3.95
	With nematode inoculation	2.5	457	687	4427	2.21	-6	46	6.95	1.75
		5.0	409	655	3065	1.53	26	39	8.78	2.77
		7.5	362	542	2742	1.37	34	31	10.46	2.98
	After nematode inoculation	2.5	683	1023	6613	3.31	-59	100	9.03	1.53
		5.0	524	839	4189	2.09	0	63	10.22	2.00
		7.5	503	703	3523	1.76	16	34	9.63	2.17
$LSD_{0.05}$			27.916	20.881		0.185			1.651	0.725

Pf: final population; Pi: initial population (= 2000).

$$\% \text{ Nematode reduction} = \frac{\text{Final population of check - Final population of treatment}}{\text{Final population of check}} \times 100.$$

$$\% \text{ Egg production} = \frac{\text{Eggs per egg mass} \times \text{number of egg masses (treatment)}}{\text{Eggs per egg mass} \times \text{number of egg masses (highest Pf)}} \times 100.$$

systems. All the tested composts have a positive effect as it improved the soil properties, ameliorated the plant growth, enhanced nutrient's uptake and, in the same time, reduced the populations of plant parasitic nematodes by 78 to 84%. Composts (C4 and C5) obtained from inoculated piles supplemented with vinasse showed the highest quality. Composts application at the rate of 5% was good nutrient supplier equal to or surpasses the mineral fertilizer at the recommended dose as indicated by the improvement of different plant growth criteria and nutrient's uptake. Increasing compost application rate resulted in parallel significant enhancement. Combination of composts at 5% + ½ MF significantly improved all tested criteria; therefore, it is recommended to obtain higher yields for high nutrient-demanding crops. Overcoming nematode infection by compost was depended on adding time and dose, so, it is recommended to control plant parasitic nematodes or at least to keep nematode populations always under the economic threshold especially in organic farms.

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