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RESIDUAL EFFECTS OF DIFFERENT ORGANIC AND INORGANIC FERTILIZERS ON SPINACH (*SPINACIA OLERACEA L.*) PLANT GROWN ON CLAY AND SANDY SOILS

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ABSTRACT

The present study aims to residual effects of composts (plant residues, animal residues and mixed) with and without inorganic fertilizers on spinach (*spinicia oleracea L.*) plants and soils. The obtained results showed that the finished compost of plant residues was high in germination index (GI) and low in C/N ratio compared with the other composts. The study demonstrated that the spinach yield with 50% N mineral + 50% N organic treatments were higher than the other treatments in the clay and sandy soils especially with the plant compost. The high nitrate accumulation of spinach plants was found in organic and inorganic combinations fertilizers compared with inorganic fertilizer, where as, the nitrate concentrations in the of spinach leaves was lower than the acceptable limit of WHO. The nitrogen and phosphorus remained in the study soils increased with the increase of organic nitrogen applied as well as soil organic C. The combinations of organic and inorganic fertilizers to soils had a greater effect on increasing yield and improvement of the soil fertility.

Keywords: Compost, Mineral fertilizers, Spinach, Nitrate accumulation, Germination index

INTRODUCTION

Crop residues become a very serious problem in Egypt lately that is because of the huge production of residues about 20 million ton year^{-1} (El-Shemy and Aly, 1997). The farmers start to burn crop residues causing the black cloud and severe pollution in Egyptian atmosphere. Composting is one method to increase the recycling of organic by products generated in cities and on the farm. Composting of agricultural wastes is an approved process to a 50% reduction in mass and volume of residues (Abd EL-kader et al., 2007). Composting is the biological decomposition of organic substrates under controlled conditions to a state sufficiently stable for convenient storage and utilization (Diaz and Eggerth, 1993).

Composting transforms organic by products with undesirable properties into a final product, compost, that is a valuable commodity for soil improvement. Around the world, there are many working definitions of compost; however, most agree that compost is an entirely natural product: Compost is simply the final result of nature's own recycling system which breaks down organic wastes and return the nutrients back to the soil (Haight and Taylor, 2000). The evident example is the natural decomposition process that turns leaves and tree trimmings on the forest floor to humus.

Vegetables constitute a major source of nitrate providing more than 85% of the average daily human dietary intake (Gangolli et al., 1994). Most nitrates accumulated in the leaves, especially in the mesophyll. Nitrate accumulation in edible plant is a problem, when eaten; part of the ingested nitrate may be converted to nitrite causing methaemoglobinaemia or even to carcinogenic nitrosamines. Spinach (spinacia oleracea L.) could be considered as one of the most common leafy vegetable crops in Egypt, to be used as fresh during the winter monthes, or as canned as well as frozen product, that may due to the high contentes of several minerals and vitamins of the spinach leaves. The excessive use of nitrogen fertilizers raises the major cost in spinach production and creates pollution of the agricultural environment; therefore it has become essential to use untraditional fertilizers as supplements or substitutes for chemical nitrogen fertilizers. The objective of this study was to assess of the effect of different compost types and then the residual effects with or without inorganic mineral N fertilization on the yield and quality of spinach plants grown on clay and sandy soils.

MATERIALS AND METHODS

Used Composts;

Three piles were prepared and arranged into windrows using different raw materials from several origins. The dimension of each pile was approximately 3 m length, 2.5 m width and 1.5 m height. Each pile was placed on a 10 cm bed of corn stalks and covered with plastic sheet for insulation. The compost piles included: 1- plant residues pile (rice straw, corn stalks, cow pea empty pods, cabbage residues and sugar beet leaves) where these materials were chopped into small pieces and then mixed using handle machine; 2- animal wastes pile (sheep solid and liquid wastes), and 3- mixed pile (plant/ animal mixture of 1:3 ratio by weight). The plant residues and animal wastes were collected for analysis. The moisture content of each pile, was maintained at 60 % and C/N ratio (30-35) as recommended for all piles, which is considered an optimum for composting (Keener et al.,2000). At the end of the composting process (120 days), samples were taken for analysis. Some properties of the materials used are given in Table (1) and the main chemical of the characteristics of the piles are given in Table (2).

Table 1 Some properties of the dry initial animal waste and plant residues of the composts :

Samples	pH*	EC** dSm^{-1}	Nitrogen (%)	Carbon (%)	C/N ratio	Phosphorus (%)
Cow pea empty pods	6.10	4.0	0.7	22.8	32.57	0.01
Rice straw	6.89	6.2	0.42	20.7	49.29	0.05
Cabbage residues	6.46	16.2	1.12	18	16.07	0.08
Corn stalks	6.73	2.75	0.42	17.25	41.07	0.03
Animal wastes	7.62	13.7	0.42	22.5	53.57	0.4

Experimental Layout:

Pot experiment was carried out (from November 2005 to January 2006) at Sakha Agricultural Research Station, Kafr EL-Sheikh Governorate, and Egypt. On the same soil (clay and sandy), Some physical and chemical properties of the used soils are given in **Table** (2), ten seeds of spinach (Spinacia Oleracea L.) were sown directly in plastic bags (25 cm in radius and 35 cm in height) containing 9 kg clay and sand soil. The pots were laid out in complete randomized block design and irrigated with tap water to reach the soil moisture content equivalent to the water holding capacity. The common agricultural practices of growing and irrigation without fertilization of spinach plants were carried.

* measured in (1:5) solid – water suspension

** measured in (1:10) solid – water extract.

Table 2: Some physical and chemical properties of the used soils

Variable	Units	Clay Soil	Sand Soil
Particle size analysis			
Sand	%	5.61	85.5
Silt	%	31.59	9.5
Clay	%	62.79	5.0
Texture		clay	Sandy
Bulk density	g cm^{-3}	1.37	1.56
PH (1:2.5)		7.14	7.23
EC	dSm^{-1}	2.10	0.43
Organic carbon	%	1.30	0.07
Organic matter	%	2.20	0.12
NO_3	mg kg^{-1}	5.00	3.00
Available N	mg kg^{-1}	84.00	22.40
Available P	mg kg^{-1}	20.00	2.50

Previous treatments used

The three composts (plant residues, animal waste and mixed) were, (T1) 100% mineral N, (T2) 75% mineral N + 25% compost, (T3) 50% mineral N + 50% compost, (T4) 25% mineral N + 75% compost, and (T5) 100% compost. Plant height (cm), fresh and dry weight (g/ pot) was determined. Total fresh weight was recorded as the total weight of the harvested plants from each pot .Dry weight was determined by drying the leaves of five plants from each treatment at 70C° till constant weight, then the percentage of the dry weight was calculated .The oven dried plants were ground and passed through 2.0 mm sieve. Total N were determined by kjeldahl method (Ahn, 1987), NO_3-N in the leaves was extracted by adding 50 ml of distilled water with 0.5g of ground plant sample and heated on a water bath at 45C° for 1h. Nitrate was determined in the extract colourimetrically by spectrophotometer at 550 nm according to Vogel (1978). Chlorophyll a and b were measured in leaves of spinach plants as follows: Constant weight from the first matured leave (0.5g) was crushed in the presence of 50 ml acetone and filtered. The extract color was measured by spectrophotometer at 644 and 662 nm, and the amount of chlorophyll a was calculated [(9.784 x Reading on 644) – (0.99 X Reading on 644)], and the amount of chlorophyll b equals [(21.426 X Reading on 644) – (4.65 X Reading on 662)] according to Wettstein (1957).The cation exchange capacity (CEC) of the soil was determined using sodium acetate solution (pH 8.2) according to Page, (1982).

RESULTS AND DISCUSSION

1- Characteristics of composts

The chemical composition of the three compost piles at the beginning and the end composting process are reported in Table (3). The final compost's pH ranged from 7.39 to 7.83, which is considered suitable for supporting growth of many plant species (Dick and McCony, 1993), and the EC ranged from 9.20 to 16.92 dS/m which would cause salt toxicity in agriculture applications except plant compost (BBC Lab, 1999). The increase in total N may be due to the net decrease of dry mass as the loss of C as CO_2 during composting (Viel et al, 1987). Moreover, total N can also be increased by the activities of nitrogen-fixing bacteria at the end of the composting process (Bishop and Godfrey, 1983). The final C/N ratio ranged from 29.0 to 32.5, which higher than the C/N ratio of 15 above which temporary net N immobilization may be induced after soil application (Gilmour, 1998). The CEC values ranged from 50.7 to 75.2 c mol kg^{-1}, and plant compost showed higher CEC values than the 60 c mol kg^{-1} which is described by Harada and Inoko (1980) as an index of maturity. Application of unstable or immature compost inhibits seed germination, reduces plant growth, and damages crops when phytotoxicity occurs, due to insufficient biodegradation of organic matter (Wu et al. 2000). Seed germination index (GI) is good indicator for phytotoxicity (Zucconi et al. 1981). The GI values ranged from 20.2 to 71.6, and accordingly the GI value of plant compost was greater than 50% which eliminates phytotoxicity (Tiquia et al., 1996).

Table 3. The main characteristics of the three compost piles at the initial and final of composting process.

Properties	Units	Plant residue		Animal waste		Mixed	
		Initial	Final	Initial	Final	Initial	Final
pH		6.71	7.39	7.62	7.93	7.10	7.66
EC	dSm^{-1}	5.67	9.20	10.33	16.92	7.92	13.31
TN	%	0.43	0.70	0.42	0.70	0.40	0.70
TC	%	20.85	17.4	22.50	19.5	21.85	19.40
C/N		56.04	29.0	62.5	32.5	54.63	32.3
P	%	0.5	0.09	0.6	0.4	0.6	0.25
CEC	cmol kg^{-1}	42.1	75.2	35.6	50.7	37.4	56.9
GI	%	-	71.6	-	20.2	-	33.2

2- Residual effects of composts with and without inorganic fertilizers on:

1- Vegetative growth of spinach plants.

The highest spinach fresh weight, dry weight and plant height were in the clay and sandy soils treated with the plant compost (100% organic) compared with the other composts (Fig.1, A and B). These results may be due to the low C/N ratio and EC and high GI of the plant residues compost compared with the other composts Table (2) .Figure 2, A and B showed the spinach yield (fresh, dry weight and plant height) in the clay and sandy soils under the different rates of nitrogen fertilizer. In the clay soil, the highest fresh weight, dry weight and plant height were obtained with mixed and plant composts under

50% mineral N + 50% compost fertilizer treatments. While, in the sandy soil the highest fresh weight, dry weight and plant height were obtained with mixed and plant composts under 75% mineral N + 25% compost fertilizer treatments. The spinach yield in clay soil was higher than the sandy soil. This may be attributed to the high CEC, available N, P and K of clay soil compared to sandy soil (Brady, 1990). The increase in total fresh yield may be attributed to the merstimatic activity for producing more tissues and organs, since N play a major role in protein and nucleic acids synthesis and protoplasm formation (Morschmer, 1986). This may increase the proportion of the protoplasm to cell size (Russel, 1973). This can led to high yield because the vegetative growth in spinach was considered as a parameter for yield.

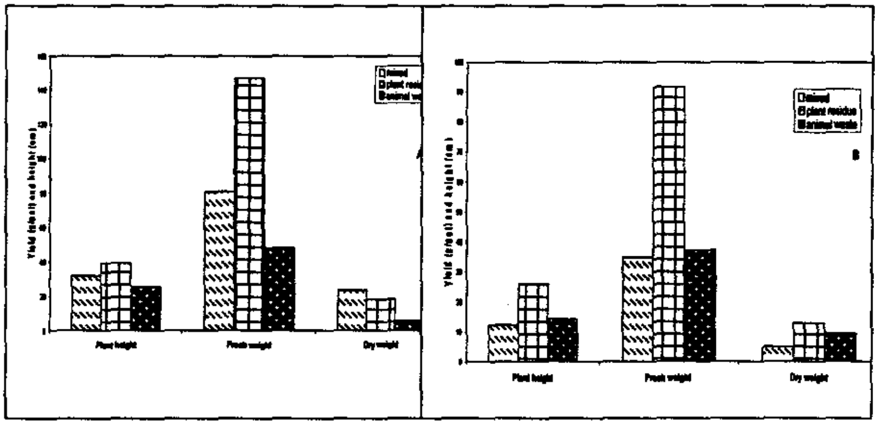


Fig. 1: Residual effect of the compost types (100% organic) on vegetative growth of spinach in the clay (A) and sandy (B) soils

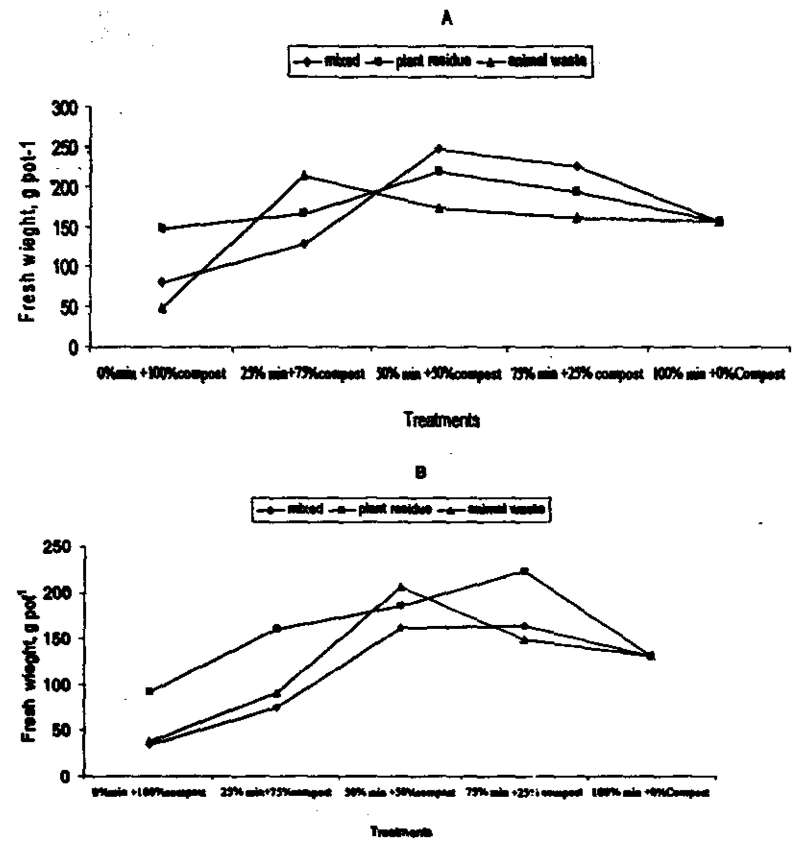


Fig. 2: Residual effect of the compost types and mineral N fertilizer treatments on vegetative growth of spinach in the clay (A) and sandy (B) soils

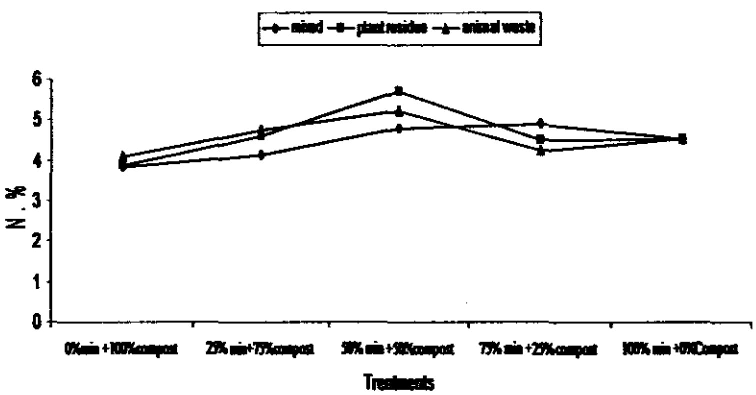
2- Chemical constituents of spinach plants

1- Nitrogen percentages

Nitrogen percentage (N%) of spinach plant of N organic 100% treatments decreased from 9% to 27% in the clay soil and from 30%

to34% in the sandy soil compared with 100% N mineral treatment. The higher N % was obtained with 50% N mineral + 50% N organic treatments in the clay and sandy soils compared with the other treatments for three compost types (Fig. 3, A and B). The trend of N % was similar to dry weights (Fig. 2, A and B). The high N% of spinach plant with the interaction between the compost and mineral N fertilizer compared with the 100% compost or 100% mineral N fertilizer in the study soils. It possibly due to the effect of compost and mineral N fertilizer on improving soil physical properties and increase plant availability of macro-micronutrients which led to high vegetative growth and more absorption of nitrogen.

A



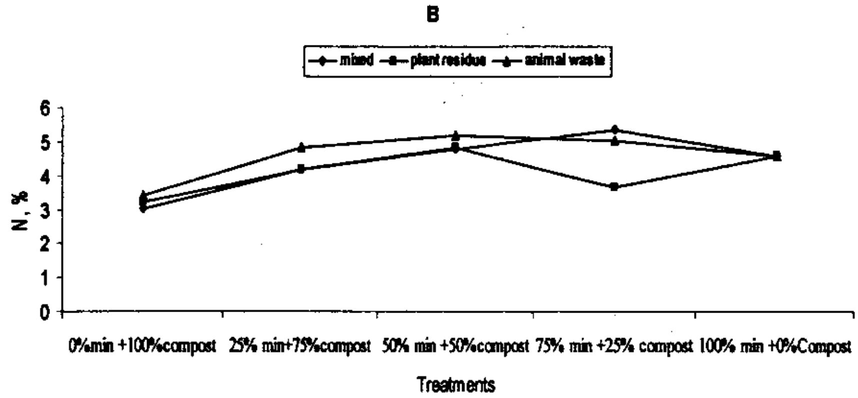


Fig. 3: Residual effect of the different compost types and mineral N rate fertilizer treatments in the clay (A) and sandy (B) soils on the nitrogen percentage of spinach.

2- Nitrate accumulation

Nitrate (NO_3-N) concentrations of spinach plant in the clay and sandy soils were lower with N 100% organic treatments than the other treatments (Fig. 4). This was attributed to supply of readily available nitrate from mineral N fertilizers to the plants while, in the organically treated pots, nitrate release was comparatively slow. The NO_3-N concentrations of spinach plant was higher with 50 % N mineral + 50 % N organic than other treatments in the study soils, indicating higher N availability from these treatment than other treatments. Nitrate concentrations of spinach leaves increased with compost and N fertilizer combinations, indicating that the rate mineralization of the organic matter increased with mineral nitrogen applied. Similar finding was obtained by Anga (2001) who found that nitrate concentration of the spinach leaves increased with biofertilizer and N fertilizer combinations. The maximum acceptable nitrate content of vegetables has been standardized in only a few countries, and the recommended limit to 700 ppm fresh product as described by the W.H.O (1978). Spinach leaves in the presented study approached this

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slandered. Nitrate accumulation in spinach leaves of the clay soil was higher than the sandy soil. This may be attributed to low CEC, clay content and specific surface of sandy soil which led to more leaching of nitrate (Brady, 1990).

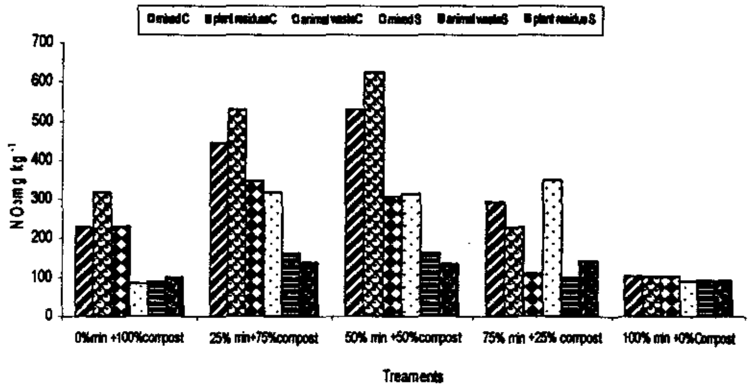

Fig. 4: Residual effects of the different compost types and mineral N rate fertilizer treatments in the sandy (S) and clay (C) soils on the nitrate accumulation of spinach.

4-Chlorophyll content

Chlorophyll (A and B) increased through the use of the interactions between the compost and mineral N fertilizers. The higher chlorophyll A and B contents were obtained with 50% mineral N + 50% compost fertilizer treatments compared with the other treatments in the study soils. Chlorophyll (A and B) with 100% N mineral treatment were higher than 100% N organic treatments (Fig. 5, A and B). This increase of the chlorophyll content corresponds to the nitrate (Fig.4, A and B).

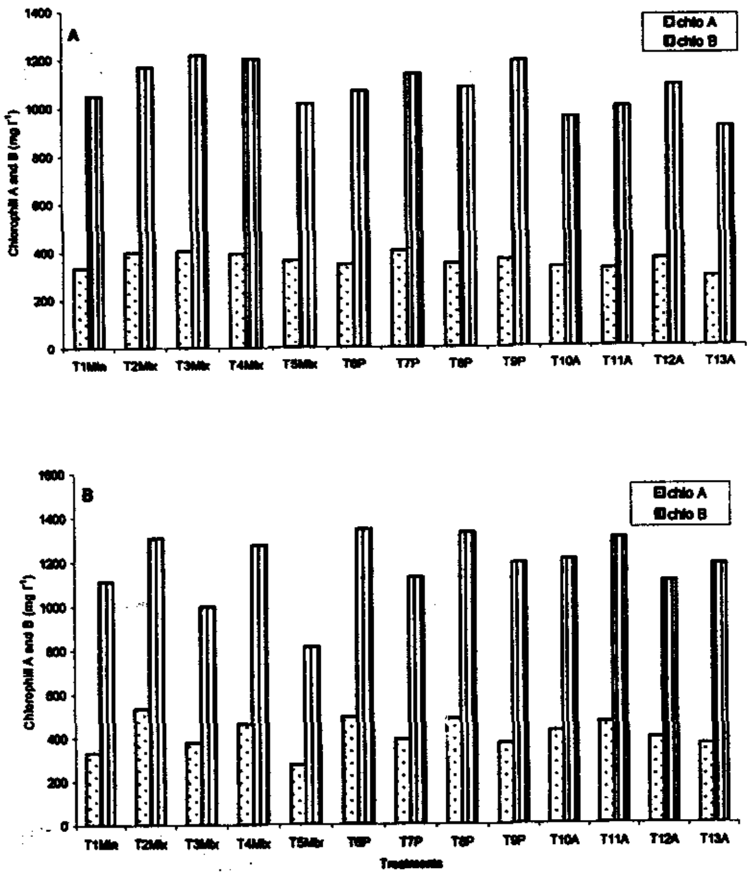

Fig 5: Residual effect of the different compost types and mineral N rate fertilizer treatments in the clay (A) and sandy (B) soils on the chlorophyll A and B of spinach.

5- Soil properties

The highest pH values of 7.3 and 7.46 were obtained with 100 % mineral fertilization in the clay and sandy soils, respectively. Application of composts to soils caused a slightly decrease in soil pH.

This may be due to the produce of some organic acids and CO_2 in soil results from the oxidation of soil organic matter by heterotrophic microorganisms and from root respiration which affected soil pH. EC increased with increase organic carbon applied. The amount of nitrogen and phosphorus left in the soil at harvest with 100% mineral nitrogen treatment were lower than in the other treatments. The nitrogen and phosphorus remained in the soil increased with the increase of organic nitrogen applied as well as soil organic C. We found that soil N was significantly correlated with soil organic C (R^2=0.78, n=26) (Fig.6), indicating that more fixation of applied N in soils depended on increase in soil organic C. Similarly, Guo et al. (2007) found good correlation between soil organic C and soil N (R^2=0.97, n=7). The highest organic matter still at the end of the trials of 4.14 % and 3.50 % were recorded with 100 % organic fertilization under the plant residues compost in both soils type used Table (4). The increase in the EC, C, P and N which may be attributed to the release of easily decomposable compounds into the soils and high EC, C, P and N in three composts (Table 2). These data showed that the application of organic C to soils had a greater effect on increasing soil organic C, N and P which led to improve the soil fertility.

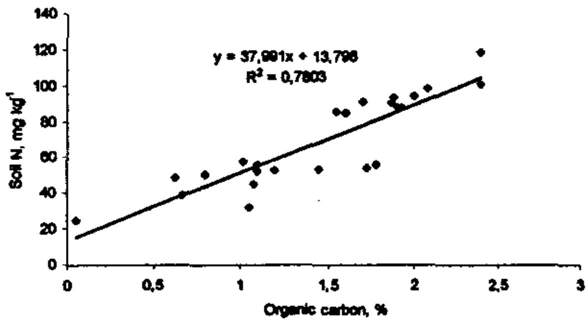

Fig 6 The relation soil organic C and soil N remaining in the study soils at harvest.

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Table 4 : Residual effect of the fertilization treatments and compost types on some properties of the used soils after spinach harvest (the end of experiments)

Fertelizer treatment	Clay soil						Sand soil					
	pH	EC (dS m^{-1})	C (%)	N (mgk g^{-1})	OM (%)	P (mgk g^{-1})	pH	EC (dS m^{-1})	C (%)	N (mgk g^{-1})	OM (%)	P (mgk g^{-1})
T1 Min	7.3	1.44	1.02	57.87	1.75	12.1	7.46	0.34	0.05	25.2	0.086	12.1
T2 Mix	7.21	2.2	1.26	86.0	2.17	21.8	7.32	1.14	1.05	32.2	1.81	21.8
T3 Mix	7.18	2.35	1.87	90.77	3.22	25.6	7.3	1.33	1.10	52.27	1.90	25.6
T4 Mix	7.12	2.14	1.88	94.00	3.24	30.3	7.3	2.05	1.10	56.0	1.90	30.3
T5 Mix	7.06	2.08	2.08	98.4	3.59	46.3	7.26	2.61	1.78	56.0	3.07	46.3
T6 P	7.15	1.55	1.55	85.68	2.67	21.3	7.41	1.16	0.63	49.0	1.09	21.3
T7 P	7.15	1.68	1.7	91.47	2.93	23.3	7.36	1.05	0.80	50.4	1.38	23.3
T8 P	7.09	1.9	2.4	101.0	4.14	38.1	7.32	1.26	1.45	53.4	2.50	38.1
T9 P	7.05	2.08	2.4	119.0	4.14	55.0	7.21	1.29	2.03	59.7	3.50	55.0
T10 A	7.26	1.78	1.6	85.13	2.76	21.4	7.43	1.05	0.67	39.2	1.16	21.4
T11 A	7.21	2.03	1.9	88.0	3.28	27.8	7.36	1.65	1.08	44.8	1.86	27.8
T12 A	7.14	2.13	1.93	88.0	3.33	34.4	7.35	2.13	1.20	53.2	2.07	34.4
T13 A	7.13	2.56	2.00	94.6	3.45	10	7.33	2.32	1.73	54.1	2.98	10

Min: Mineral, Mix: Mixture compost, P: Plant compost, A: Animal compost

CONCLUSION

This study demonstrated that the crop residues could be successfully composted, return the nutrients back to the soil, decrease the used high cost mineral fertilizers and increase environmental health which the nitrate concentration in spinach leaves well below the W.H.O limits under the all treatments. Spinach yield increased with compost and N fertilizer combinations. The application of compost to soils had a greater effect on increasing soil organic C, N and P which led to improve the soil fertility.

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الملخص العربي

التأثير المتبقى لبعض الأسمدة العضوية والغير عضوية المختلفة على نمو السبانخ وبعض خواص التربة

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١– قسم الاراضى والمياة – كلية الزراعة– جامعة طنطا – مصر

٢– مركز البحوث الزراعية – معهد بحوث الاراضى والمياة. قسم تغذية النبات – سخا. كفر الشيخ

أجرى هذا البحث بهدف تقييم ثلاثة انواع من الكمبوست (بقايا نباتية، مخلفات حيوانية، بقايا نباتية مختلطة بمخلفات حيوانية) ودراسة الاثر المتبقى للتسميد العضوى على هيئة كمبوست مختلط مع او بدون سماد معدنى على نبات السبانخ وبعض الخواص الكيميائية للتربة. ولتحقيق ذلك اجريت تجربة زراعية على محصول السبانخ فى نوعين من الاراضى (طينية ورملية) بعد معاملتها بخمسة معاملات من ثلاثة انواع كمبوست (نباتى، حيوانى ومختلط) ولجريت التجربة تحت الصوب السلكية بمزرعةمركز البحوث الزراعية بسخا– كفر الشيخ وكانت المعاملات هى ١٠٠% نيتروجين معدنى ، ٧٥% نيتروجين معدنى + ٢٥% سماد عضوى ، ٥٠ % نيتروجين معدنى + ٥٠ % سماد عضوى ، ٢٥ % نيتروجين معدنى + ٧٥ % نيتروجين عضوى ،١٠٠ % سماد عضوى . واخذت القياسات التالية على محصول السبانخ: طول النبات، الوزن الطازج والجاف ،تراكم النترات والمحتوى من الكلوروفيل بالاضافة الى تقدير بعض خواص التربة الكيميائية قبل وبعد الحصاد. اوضحت النتائج ان اعلى قيم لكل من نسبة الانبات، السعة التبادلية الكاتيونية والنسبة المئوية للفسفور كانت فى الكمبوست النباتى مقارنة بنوعي الكمبوست الاخرين. واعطى الكمبوست النباتى اعلى محصول طازج للسبانخ مع المعاملة٥٠ % معدنى + ٥٠% عضوى فى الارض الطينية ومع المعاملة ٧٥ % معدنى + ٢٥% عضوى فى الارض الرملية. وكان اعلى تراكم للنترات فى نبات السبانخ فى الاراضى المعاملة بخليط من السماد العضوى مع المعدنى بالمقارنة بالاراضى المعاملة بالسماد المعدنى فقط مع الاخذ فى الاعتبار ان تركيز النترات فى السبانخ لم يصل الى حدود منظمة الصحة العالمية. بصفة عامة نجد ان الخلط بين الاسمدة العضوية والمعدنية المستخدم فى الدراسة يلعب دورا اساسى فى زيادة المحصول والمحتوى من الكلورفيل فى نبات السبانخ وتحسين بعض الصفات الكيميائية للتربة.