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Effect of the Application of Plant Residues Composts on Some Soil Properties and Yield of Wheat and Corn Plants

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THE MAIN objective of this investigation was to study the effect of the composts of some plant residues, *i.e.*, rice straw and cotton stalks on some physical and chemical properties of the sandy soil; the field experiments were conducted in the Experimental Farm of Ismaillia Agriculture Res. Station. Yield of wheat and corn crops as well as the concentrations of macro and micronutrients in their leaves at flowering stage and in their grains were determined.

Application of either cotton stalks or rice straw composts significantly improved the physical properties of the tested soil, *i.e.*, bulk density, hydraulic conductivity and moisture constants namely, field capacity, welting point and available water. Concerning the effect of composts application on chemically available N, P, and K in the cultivated soil, rice straw was better than cotton stalks. Also, DTPA extractable Fe, Mn, Zn and Cu were significantly increased due to the application of such composts after either wheat or corn harvestings. Grain yields of wheat and corn plants as well as concentrations of N, P, K, Fe, Mn, Zn and Cu either in plant leaves or in grains of wheat and corn were significantly increased due to composts application. Generally, rice straw compost was better than cotton stalks concerning the tested properties.

Keywords: Compost, Rice straw, Cotton stalks, Macro and micronutrients, Wheat, Corn, Soil physical properties, Soil chemical properties.

Recently, on the way of sustainable agriculture with minimum pollution effects, the use of natural materials such as plant residues, *i.e.*, cotton stalks and rice straw is recommended to substitute the chemical fertilizers. Organic manures increase soil organic matter, particularly for the sandy soils in Egypt, which record less than 1 % and hence improve its physical, chemical and biological properties. Consequently, the availability of nutrients for plant as well as other soil characteristics should be improved. Zebarth *et al.* (1999) reported that soil water retention increased and soil bulk density was reduced due to addition of 2% organic matter. Abou-Baker and Omar (1996) demonstrated that using organic compost alone or accompanied with NPK fertilizers lowered soil EC when compared to the control and inorganic treated soil. Mahmoud (1994) reported that organic acids resulting from the metabolic breakdown of organic materials form complexes with the inorganic phosphate which was more readily available to higher plants. The precipitation of phosphorus by calcium was relatively inhibited. The continued use of organic manures, alone or in combination with inorganic source improved the available K of soil (Toor and Bishmoi, 1996) and the net N release (Metwally and Khamis, 1998). Dahane and Shukla (1995) reported that DTPA extractable Fe, Mn, Zn and Cu were positively and significantly correlated with organic matter content. In addition, Khalil *et al.* (2000) reported that the use of any organic manure, in addition to the mineral fertilizers (NPK), increased dry matter yield and N, P and K uptake by corn plants, particularly in sandy soils.

This investigation aimed to study the effect of application of cotton stalks and rice straw compost on chemical and physical properties of sandy soil as well as the yield and nutrient concentration of wheat and corn plants cultivated in such soil.

Material and Methods

The main cereal crops wheat (*Triticum aestivum* L.) and corn (*Zea mays* L.) were chosen to evaluate the effect of application of rice straw and cotton stalks composts to sandy soil, Ismaillia Agricultural Research Station, on physical and chemical properties of such soil along with crop yield, and nutrient concentration of such plants. Some physical and chemical properties of this soil are shown in Table la. In a field experiment, wheat (Sakha 8) was planted at November 1996 and followed by corn (Giza 2) cultivation at May 1997 in the same experimental area. In wheat and corn experiments, the following treatments were included:

a- Control (100, 30 and 48 unit/fed of N, P and K, respectively were applied as recommended by Ministry of Agriculture). The used mineral fertilizers were $(NH_4)_2$ SO_4 (20%N), ordinary superphosphate (15.5% P_2O_5 and K_2SO_4 (48%K_2O).

b- Cotton stalks compost added to the soil at the rate of 2 % (20 ton/ fed) by weight, and complementary doses of P (8.29kg P_2O_5/fed) and K (25.59 kg K_2O / fed) were added.

c- Rice straw compost added to the soil at the rate of 2 % by weight, and complementary doses of P (8.02 kg P_2O_5/fed) and K (24.86 kg K_2O/fed) were added.

N was added to b and c treatments (243.7g $(NH_4)_2$ SO_4 / plot (97.5 kg/fed) as one dose at the beginning of the experiment).

Both cotton stalks and rice straw were composted at the farm of the Faculty of Agric., Ain Shams Univ. according to the method described by Abou El-Fadle (1960) as follows: 400 kg of each type of plant residues were cut to small pieces and arranged in 10 equal layers to enhance the aeration and decomposition process. To activate the decomposition process, an activator mixture of 15 kg ammonium sulphate, 8 kg rock phosphate and about 40 kg of farmyard manure were added to the composting materials. Some characteristics of the used composts are shown in Table lb.

The organic manures were mixed with the soil surface (0 -15cm layer) 15 days before cultivation. Each treatment in both wheat and corn experiments was replicated 4 times in completely block randomized design.

Representative leaves samples were taken at flowering stage (90 days for wheat or 70 days for corn), wheat and corn grains were taken at harvest stage. The taken plant samples were analyzed for N, P, K and micronutrients contents.

Representative surface (0-15 cm) soil samples were collected from the treated plots after wheat and corn harvestings. The collected soil samples were air dried and prepared for physical and chemical analysis.

TABLE 1a. Some physical and chemical properties of the tested soil.

Physical properties	
Particle size distribution, %	
Coarse sand	66.68
Fine sand	26.39
Bulk density, g/cm^3	1.97
Hydraulic conductivity, cm/min	5.63
Field capacity, %	18.29
Welting point, %	7.82
Available water, %	10.47
Chemical properties	
SP, %	26.6
Soluble cations and anions (soil paste ext.), meq/l	
Ca^{++}	1.97
Mg^{++}	0.87
Na^{+}	1.51
K^{+}	0.45
$CO_3^{=}$	
HCO_3^{-}	2.42
Cl^{-}	1.02
$SO_4^{=}$	1.36
pH (1:2.5)	7.86
ECe, dS/m	0.47
Chemically available nutrients, ug/g	
N	20
P	2
Fe	2.4
Mn	1.5
Zn	0.4
Cu	0.2
CEC, meq/100g soil	1.01
$CaCO_3$, %	2.6
Organic matter, %	0.5

TABLE 1b. Some characteristics of the tested composts after maturing

Characteristics	Cotton stalks	Rice straw
Bulk density, g/cm^3	0.42	0.48
Moisture content, %	29.70	38.17
EC (1:10), dS/m	1.57	1.91
pH (1:10)	7.18	8.06
Organic matter, %	50.04	45.01
CEC, meq/100g	63.52	64.01
Total N, %	1.61	1.68
C/N ratio	10.03	15.54
Chemically available, ug/g		
Phosphorus	474	489
Potassium	465	480
Extracted organic acids, %	25.71	28.52
Humic acid	12.83	15.79
Fulvic acid		

Physical and chemical properties of soil as well as plant residues composts were determined according to the standard methods (Black, 1965 and Jackson, 1973). Chemically available micronutrients were extracted by 0.005 M DTPA according to Lindsay and Norvell (1978) and measured using the Atomic Absorption Spectrophotometric. Humic and Fulvic acids were extracted from mature composts, then determined according to Kononova (1966).

The dried leaves and grains of plant samples were digested in concentrated H_2SO_4 and H_2O_2 at 400C°; N, P, K, Fe, Mn, Zn and Cu were determined in the digested materials.

Results and Discussion

Bulk density, hydraulic conductivity and moisture constants of soil

The obtained results indicate that, regardless the type of organic residues, soil bulk density and hydraulic conductivity values are lower after corn season than those after wheat season (Table 2). This could be due to the repeated application of organic manure in the corn season which reflects an accumulation of the more stable organic matter presented as heavy and humin fractions. These products improve soil physical conditions and enhance the formation of stable soil aggregates. In addition, humic substances are permanent aggregate- binding agents involved in the stabilization of soil micro-aggregates,<250μm (N'Dayegamiye and Angers, 1993). The effect of both composts on soil behavior toward retaining water is shown in Table 2 and illustrated in Fig. 1. The obtained pF curves show that soil moisture content decreases by increasing the applied pressure, regardless of any other factors. After harvesting of wheat and corn plants, the obtained pF curves took the same trends and slopes at high applied pressures but they differ at the low ones. On the other hand, the role of applied composted cotton stalks and rice straw appear at low applied pressures. This finding is expected according to the effect of applied composts on soil bulk density, aggregation parameters and other structure parameters. Figure 1 shows that the soil retains more moisture under low applied pressure after harvesting wheat plants.

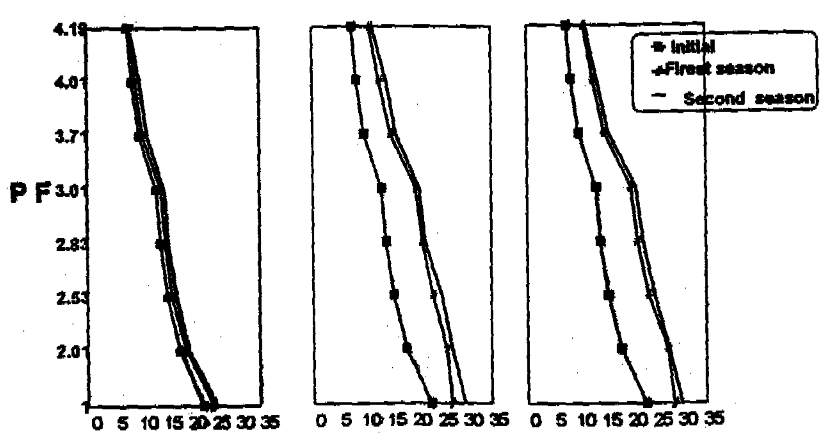
The amount of available soil moisture is relatively high after the second growth season, comparing with the first one. This could be attributed to the increased decomposition rate of organic matter and its role in improving soil

TABLE 2. Effect of composted plant residues application on some physical properties of the studied soil.

Treatments	B.D g/cm^3	H.C cm/mi	F.C %	W.P %	A.W %
	After wheat harvesting				
Control	1.83	3.67	19.61	8.37	11.24
Composted cotton stalks	1.80	2.83	26.17	11.29	14.88
Composted rice straw	1.78	2.50	27.39	11.13	16.04
L.S.D. 5%	0.14	0.17	0.66	0.62	0.86
	After corn harvesting				
Control	1.80	3.43	20.15	8.41	11.74
Composted cotton stalks	1.74	2.48	27.24	11.84	15.40
Composted rice straw	1.72	2.31	27.69	11.58	16.11
L.S.D. 5%	0.13	0.31	0.69	0.86	0.59

B.D = Bulk density, H.C = Hydraulic conductivity, F.C = Soil moisture content at field capacity, W.P = Soil moisture content at welting point, A.W= Available water.

structure. The values of retained soil moisture and moisture contents are, generally, higher and the slopes of pF curves are more gradual in the soil either after the first or the second growth season due to the application of rice straw compost compared with cotton stalks. This can be attributed to the relatively higher soil organic matter content as compared to the treatment of cotton stalks.



Soil moisture content, %

Fig. 1. Effect of adding composted plant residues on soil moisture content after the two cultivation seasons.

EC, pH and organic matter content of soil

Data in Table 3 show that after harvesting of either wheat or corn, the estimated EC_e values are reduced by about 15.7 and 5.3% due to cotton stalks and rice straw application, respectively, as compared with the control (mineral fertilization). The EC_e values of soil after the application of composted rice straw are higher than those treated with composted cotton stalks due to the high EC value in rice straw manure (1.9l dS/m) as compared to cotton stalks one (1.57d5/m).

The obtained results show a slight decrease of soil pH values after wheat or corn harvesting in the treatments of both composts compared with control treatment. This may be due to the soil buffering capacity.

Concerning soil organic matter content, it increases after wheat harvesting due to organic residues application, such increases record 30.8 and 48.1% by application of cotton stalks and rice straw composts, respectively as compared with control treatment. However, these increases are significant, but the difference between the two added organic composts is not significant. The obtained data also show that soil organic matter content decreases rapidly in the treatment of composted rice straw. This may be due to the easier decomposition of rice straw compost than cotton stalks.

Concerning organic matter content after corn harvesting, similar trend is observed, whereas applications of cotton stalks and rice straw composts cause 21.6 and 43.13% increase of organic matter, respectively as compared to control. Soil organic matter content after corn harvesting is lower than those after wheat harvesting. This could be due to the rapid oxidation and decomposition of soil organic matter in summer season (corn season).

Chemically available N, P and K in soil

Adding the composts of cotton stalks and rice straw to the sandy soil leads to a significant increase in the amount of chemically available nitrogen in soil after harvesting of wheat. Such increases are 39.8 and 45 % in the soils treated with composted cotton stalks and rice straw, respectively as compared with inorganic fertilizer treatment. After corn harvesting, the available N increases are 13.12 and 14.03 %, respectively. Taking into consideration that the total values of N added to the cultivated soil, either in mineral or in organic forms were equal, organic manuring plays a role in increasing the N availability through

TABLE 3. Effect of the application of composted plant residues on some chemical properties of the studied soil after harvesting of wheat and corn.

Treatments	ECe dS/m	pH (1:2.5)	Organic matter, %	Chemically available nutrients, ug/g						
				N	P	K	Fe	Mn	Zn	Cu
				After wheat harvesting						
Control #	0.38	7.81	0.52	19.1	40.5	298	7.0	3.1	2.0	1.0
Composted cotton stalks	0.32	7.81	0.68	26.7	71.0	347	9.7	4.9	2.3	1.0
Composted rice straw	0.36	7.78	0.77	27.7	73.9	358	10.3	5.2	3.7	1.3
$L.S.D_{5\%}$	0.21	0.81	0.11	0.31	1.7	16	1.6	0.9	0.6	0.3
				After corn harvesting						
Control #	0.45	7.40	0.51	22.1	44.2	313	8.1	3.5	2.6	1.0
Composted cotton stalks	0.36	7.38	0.62	25.0	77.7	379	12.2	6.1	3.3	1.1
Composted rice straw	0.44	7.34	0.73	25.2	90.0	413	14.8	7.4	4.4	1.7
$L.S.D_{5\%}$	0.15	0.21	0.10	0.96	7.7	5.3	1.1	0.7	0.6	0.1

Mineral N, P and K (the recommended rates).

microorganisms activities, beside decreasing N losses by leaching and volatilization (Metwally and Khamis, 1998). Microflora can directly assimilate significant amounts of organic N compounds from plant residues or from dead biomass (Mary *et al.,* 1996).

On the other hand, results show that available P trend is almost similar to that of available N and the addition of composted rice straw resulted in the presence of highest amounts of available P. Such increases reach 75 and 82% in the treatments of composted cotton stalks and rice straw after the first season, while they are 75 and 103 % after the second season, respectively, as compared with control. Such results could be explained according to the decomposition of the organic residues and subsequent release of inorganic and organic acids which enhance the solubility and availability of P. Other possibilities could be: (a) effect of organic residues on lowering the fixation of phosphours through several mechanisms such as chelation and formation of organic complexes relatively available for plants, (b) effect of organic matter through coafing the $CaCO_3$ particles as protective mechanism against precipitation and adsorption of various elements, and (c) carbon production from humus could exchange the adsorbed anions such as phosphates thus should be available (ELgala and Amberger, 1982 and El-Leboudi *et al.*,1988). On the other hand, the increase of available P in the manured treatments may be also due to the production of CO_2, during organic residues decomposition, thus formation of H_2CO_3, which contributes to phosphate solubility (Barsoom, 1998).

Concerning the values of available K, data show similar trend to that obtained previously for P. Generally, the applications of composted cotton stalks and rice straw significantly increase the amounts of available K in soil.

Table 3 shows that the amount of available K in soil after addition of composted rice straw is higher comparing to that of cotton stalks after the two cultivation seasons. This could be due to the higher K content in the composted rice straw. Tan (1980) found that humic and fulvic acids are capable for dissolving very small amounts of potassium from the soil minerals by chelating, complex reaction or both with released amounts of K being increased with time.

Chemically available Fe, Mn, Zn and Cu in soil

Data in Table 3 show that generally, the application of composted cotton stalks and rice straw increases the availability of Fe, Mn, Zn, and Cu as compared with mineral fertilizer treatment (control). This indicates that the availability of these micronutrients due to manuring can be arranged as follow: Fe>Mn> Zn >Cu. The organic material can influence the solubility of such elements in soils in different ways causing an increase in the solubility of micronutrient cations by forming relatively stable organic complexes. However, the ability of organic material to immobilize that nutrients has also been reported. The mobilization or immobilization effect of organic materials are dependent on the soil reaction which influences the behavior of organic form of these nutrients (Abou-Seeda *et al.,* 1992). The obtained results show that the amounts of DTPA- extractable Fe, Mn, Zn and Cu resulted from treating soil with composted rice straw are significantly higher than those treated with cotton stalks. This could be related to the relatively higher contents of humic and fulvic acids in the composted rice straw than cotton stalks, as previously reported in Table Ib.

Grain yield, concentration of macro and micronutrients in wheat and corn plants

Data presented in Table 4 indicate that the amounts of grain yield and weight of 1000 grains of both wheat and corn crops significaritly increased due to the application of composted cotton stalks and rice straw as compared with control. In the first season, such increases record 29.9 and 47.2% for wheat grain yield and 40.5 and 41.7% for weight of 1000 wheat grains in the treatments of composted cotton stalks and rice straw, respectively. In the second season, the corresponding increases are 11.8 and 27.1% for corn grain yield and 18.6 and 34.8 % for weight of 1000 grains, respectively. Such increases could be due to the positive effect of composts on improving nutritional status and nutrients release and hence their availability to the growing plants as well as on improving soil physical properties. The composted rice straw is generally superior as compared with that of cotton stalks.

The obtained results indicate a significant increase in nitrogen concentration in wheat leaves and grains in the treatments of composted plant residues as compared to control treatment. The superiority of rice straw treatment, particularly at the late growth stage, is clear.

Phosphorus and potassium concentrations significantly increase due to the application of cotton stalks and rice straw composts. The obtained results indicate, also, the superiority of rice straw compost treatment relative to cotton

TABLE 4. Effect of composted plant residues application on the grain yield and nutrients concentrations in leaves at flowering stage and grains of wheat and corn plants.

Treatments	Grain yield, kg/fed	Weight of 1000 grains, g	Macronutrients concentration, %						Micronutrients concentration, ug/g							
			N		P		K		Fe		Mn		Zn		Cu	
			L#	G	L	G	L	G	L	G	L	G	L	G	L	G
Wheat																
Control *	836	42.4	1.12	1.23	0.21	0.28	1.12	0.97	211	217	19	22	69	60	24	28
Composted cotton stalks	1086	59.8	2.38	2.81	0.46	0.61	1.87	1.41	352	359	43	47	78	87	36	40
Composted rice straw	1229	60.1	2.62	3.01	0.61	0.68	2.29	1.87	368	372	46	61	89	90	42	44
L.S.D 5%	61	10.1	0.09		0.06		0.08		8		3		4		5	
Corn																
Control *	1281	214.3	2.11	2.17	0.30	0.33	1.27	1.21	219	221	25	30	72	80	30	32
Composted cotton stalks	1432	264.1	2.62	2.76	0.61	0.66	2.71	2.29	362	370	42	43	85	93	36	38
Composted rice straw	1628	288.9	3.13	3.83	0.64	0.62	3.09	2.88	370	378	43	43	101	103	36	40
L.S.D 5%	78	69	0.13		0.07		0.08		7		3		4		4	

#L = Leaves at flowering stage, G = Grains at harvesting stage and *Mineral N, P and K (the recommended rates).

stalks one. This finding could be, as mentioned before, due to the quality and rapid decomposition rate of rice straw. The organic manure induces the soil P supplying power through either direct or indirect effect. The direct effect includes the continuous release of organic P into soluble orthophosphates, while the indirect effect is due to the role of organic acids and other compounds of acidic effect, which solubilize more P from insoluble potential P bearing compounds (El-Ghozoli, 1994).

Results also show significant incrcases in K and micronutrients concentration in both wheat and corn leaves or grains compared to control. The increase of nutrients content may be due to one or more of the following reasons: (1) the more efficiency of these nutrients in the soils treated with organic residues compared with the untreated one, (2) increasing CEC of the treated soil through organic manuring, (3) improving soil chemical, biological and fertility properties and (4) the improvement of soil physical properties which is reflected on water behavior and decreasing nutrient losses by leaching and deep percolation. On the other hand, it can be noticed that, micronutrients concentrations in wheat and corn plants due to composted rice straw application are generally higher than those of cotton stalks. This could be due to the relatively high contents of Fe, Mn, Zn and Cu in rice straw compost (Table 1b). Generally, the release of organic acids during the decomposition of plant residues increases the micronutrients availability to the growing plants via their abilities to chelate Fe, Mn, Zn and Cu (Allam,1999).

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تأثير إضافة البقايا النباتية المكمورة على بعض خــواص الأرض وعلى مــحــصــول القــمــح والذرة

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أجريت دراسة حقلية بمحطة بحوث الإسماعيلية - مركز البحوث الزراعية لدراسة تأثير إضافة كومة من البقايا النباتية المكمورة Compost (قش الأرز وحطب القطن) على بعض الخواص الطبيعية والكيميائية للأرض الرملية، وكذلك إنتاجية محصول القمح والذرة ومحتواهما من العناصر الغذائية خلال مرحلتى التزهير والحصاد.

وقد أوضحت النتائج أن إضافة مكمورة قش الأرز أو حطب القطن أدى إلى تحسين معنوى فى الخواص الطبيعية للأرض الرملية خاصة الكثافة الظاهرية، التوصيل الهيدروليكى وكذلك ثوابت الرطوبة المائية مثل السعة الحقلية، نقطة الذبول و٪ للماء الميسر. وبتتبع تأثير المكمورة على الخواص الكيميائية وجد أن تأثير قش الأرز على الصورة الكيميائية الميسرة من النتروجين، الفوسفور والبوتاسيوم أفضل من حطب القطن كما دلت النتائج على حدوث زيادة معنوية فى قيم الحديد، المنجنيز، الزنك والنحاس المستخلصة بمركب ال DTPA بعد حصاد القمح والذرة لكل من قش الأرز وحطب القطن.

أوضحت النتائج أيضا حدوث زيادة معنوية فى وزن محصول الحبوب لكل من القمح والذرة مقارنة بمعاملة الكنترول كما حدث زيادة معنوية فى تركيز كل من النتروجين، الفوسفور، البوتاسيوم، الحديد، المنجنيز، الزنك والنحاس فى أوراق النباتات (مرحلة التزهير) وكذلك فى الحبوب (مرحلة الحصاد) لكل من القمح والذرة وبصفة عامة فان قش الأرز المكمور أعطى نتائج أفضل من حطب القطن لكل الخواص المدروسة.