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Effects of Composted Municipal Solid Wastes on Phenology and Yield Characteristics of Wheat (*Triticum aestivum* L.) in Eastern Mediterranean Region

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This study was carried out to evaluate the effects of compost application produced from municipal solid wastes on growth and yield of wheat under semi-arid Mediterranean conditions. The compost was produced from mainly house-originated solid wastes, bay leaves and farmyard manure mixture in a ratio of 7.5:1.5:1.0, respectively. The treatments were: chemical fertilizer (160 kg N ha^{-1} and 80 kg P_2O_5 ha^{-1}); 20, 40, 60 and 80 tons compost ha^{-1}; 80 tons animal manure ha^{-1} and control without treatments. The experimental design was randomized blocks with three replications. According to the results of a three-year experiment, application of 20 tons of compost ha^{-1} appeared to be the most suitable treatment for satisfied yield. Moreover, some positive effects of the compost application on growth parameters of wheat were observed.

Key Words: Chemical fertilizer, Compost, Farmyard manure, Municipal wastes, Wheat.

INTRODUCTION

Increasing natural soil erosions, degradation of arable lands to open industrial and dwelling areas have brought about the possibility of municipal solid wastes as a potentially valuable recyclable organic material to improve the quality of soils for agricultural production and to lower the waste disposal cost[1-9].

One important thing in using compost is that it should be sufficiently matured before mixed into soil to avoid harmful phytotoxic effects since municipal wastes contain high amounts of heavy metals which inhibit root and shoot growth, hence, decreasing the crop yield[10,11]. Suitable techniques should be adopted to obtain composts with better quality and richness in minerals[12]. Modified and matured composts increased the soil microbial biomass C, enzyme activities, P and N contents of the soil resulting in high biomass and seed yield in soybean[13]. Another study also showed that municipal solid waste compost increased the organic C and total N contents and enzyme activities of soil[14,15]. Similar improvement was also observed in soil quality and the highest

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growth and yield in jute was recorded on municipal solid wastes (MSW) treatments over control and recommended chemical fertilizer[16]. In a greenhouse study, yield attributes as well as mineral element and protein contents of a winter wheat were improved using municipal wastes compared to the control treatment[17]. Studies have shown that using agro-based or municipal composts could improve the soil quality as well as crop production. Using dewatered sewage sludge cake and lime amended sewage sludge over 50 % grain yield increase were obtained from wheat and triticale[18]. South Carolina, surface application of 15 tons/acre of MSW compost broadcast or banded resulted in a 30 % increase in seed cotton yield[19].

However, such studies on facultative wheat in subtropical climates were limited. Therefore, the objective of this study was to investigate the effect of different MSW doses on the phenology and yield characteristics of a facultative bread wheat *cv.* 'Genc-99' grown in a typical Mediterranean conditions in Antakya, Turkey during 1997-2000.

EXPERIMENTAL

Compost material: The compost produced by Aydin *et al.*[3] was used in the field experiments. The compost material was originated from municipal organic garbage mixed with bay leaves and farmyard manure in a ratio of 7.5:1.5:1.0, respectively. The quality of the compost used was found applicable to the agricultural fields by Aydin *et al.*[20]. Some physical and chemical properties of the composts are given in Table-1. Additionally, some analyses of animal manure used in the trials were: pH 8.08 (in water), total N (0.44 %) and P_2O_5 (0.24 %). As reported by Aydin *et al.*[20], these properties were similar to those of the previous studies by Bahtiyar[21] and Gäth *et al.*[22].

TABLE-1
SOME PHYSICAL AND CHEMICAL PROPERTIES OF COMPOST OBTAINED FROM CITY GARBAGE [Ref. 20]

Property	Level	Property	Level
Water content (during packaging, % w/w)	30.00	Na (%)	0.24
pH (in water, 1:1)	7.33	Si (%)	0.22
Soluble total salt (%)	0.33	Fe (%)	0.64
Organic matter (burning loss, %)	30.80	Cd (mg kg^{-1})	0.38
C/N	15.44	Pb (mg kg^{-1})	10.00
Total N (%)	1.16	Cu (mg kg^{-1})	13.90
P (%)	0.10	Zn (mg kg^{-1})	127.00
K (%)	0.52	Mn (mg kg^{-1})	323.00
S (%)	0.11	Ni (mg kg^{-1})	155.00
Ca (%)	2.44	B (mg kg^{-1})	36.30
Mg (%)	2.03	Cr (mg kg^{-1})	68.50

Field trials: In order to investigate the effects of compost utilization on wheat yield and yield component traits, three field trials were conducted during 1997-98 at Demirköprü District (DK), 1998-99 and 1999-00 at the experimental farm of the

Agricultural Faculty, Mustafa Kemal University, Hatay, Turkey. All experimental sites were located in Amik plain lies between 36º10' -36º27' northern latitudes and 36º13'-36º29' eastern longitudes. Climate and soil data for experimental areas were given in Tables 2 and 3, respectively. As the plant material cv., "Genc-99", which is a facultative wheat cultivar, was used in the experiment. The treatments were as follows: C2, C4, C6 and C8 corresponding to 20, 40, 60, 80 tons compost ha^{-1}, respectively and C0 (control). In order to make a comparison and interpret the effect of compost applications, traditional chemical fertilizer (G; 160 kg N ha^{-1} and 80 kg P_2O_5 ha^{-1}) and animal manure (A8; 80 tons ha^{-1}) were also applied as treatments.

TABLE-2
SOME MONTHLY CLIMATIC DATA OF THE EXPERIMENTAL SITES FOR THE STUDIED PERIOD

Month	Locations								
	DK-97			MKU-98			MKU-99		
	T (ºC)	P (mm)	RH (%)	T (ºC)	P (mm)	RH (%)	T (ºC)	P (mm)	RH (%)
November	14.7	103.1	62.3	17.0	147.9	59.8	14.7	24.6	61.0
December	6.5	109.2	74.0	10.7	256.4	73.2	11.3	143.5	70.2
January	7.3	98.4	73.7	9.1	64.5	73.6	6.7	310.7	75.1
February	8.7	58.2	58.9	10.0	70.2	67.6	9.2	185.7	70.3
March	11.1	181.8	66.0	11.8	91.9	61.5	12.2	64.5	71.5
April	17.2	64.1	61.2	16.6	75.5	63.1	18.1	116.7	75.1
May	20.7	37.3	59.9	22.7	0.0	48.3	21.4	73.2	76.4

T = Temperature; P = Precipitation; RH = Relative Humidity.

TABLE-3
SOIL PROPERTIES OF THE EXPERIMENTAL LOCATIONS

Location	Soil depth (cm)	pH	Total soluble salt (%)	Sand (%)	Silt (%)	Clay (%)	Texture	Lime	Organic matter (%)	Total N (%)
DK-97	0-10	7.64	0.024	13.6	47.7	38.7	SiCL	19.04	0.95	0.09
	10-20	7.65	0.024	13.6	47.7	38.7	SiCL	19.24	0.82	0.09
	20-30	7.63	0.026	24.8	47.4	27.8	CL	18.93	0.89	0.08
MKU-98 and MKU-99	0-10	7.63	0.052	13.6	27.6	58.8	C	64.08	1.13	0.13
	10-20	7.58	0.055	11.7	30.4	57.9	C	67.74	1.05	0.13
	20-30	7.59	0.054	11.9	30.1	58.0	C	67.74	0.98	0.12

The experiment was designed as completely randomized block in split-plot arrangements where year by environments was considered as locations. Therefore, location 1 (DK-97), location 2 (MKU-98) and location 3 (MKU-99) consisted of Demirköprü in 1997, Mustafa Kemal University Experimental Station in 1998 and 1999, respectively. Years by environments were main plots and treatments were split plots. Planting was performed first year on 13 November 1997, second year on 5 January 1998, third year on 15 December 1999. Plant characteristics such as heading time, spike maturity time, hectoliter weight, the weight of 1 L of kernel determined using a standard hectoliter apparatus and grain yield were measured.

Statistical analysis: We used PROC MIXED procedure in the statistical analysis system software package[23] to analyze the present data. Year by environment or location and treatments was considered as fixed while blocks (year) was random. The LSMEANS statement was used to assess means of main and interaction effects. Heterogeneity of variances was tested by Barlett's test.

RESULTS AND DISCUSSION

Partial analysis of variance table, main and interaction effects tables were presented in Tables 4 and 5. As depicted on the tables, all the traits were significantly affected by the treatments applied. It should be also noted that dramatic differences existed among locations probably due to apparent variation in climatic factors and soil properties (Tables 2 and 3).

TABLE-4
PARTIAL ANALYSIS OF FIXED VARIABLES AND THEIR p VALUES

	HDT (day)	SMT (day)	HLT (kg 100^{-1} L)	GYL (kg ha^{-1})
Locations	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Treatment	0.0109	0.0161	< 0.0001	< 0.0001
Location × Treatment	0.0105	0.0038	0.0087	< 0.0001

HDT = Heading time; SMT = Spike maturity time; HLW = Hectoliter weight; GYL = Grain yield.

The analysis of variance showed that heading times were significantly different for locations ($p < 0.01$, Table-4). The longest heading time was observed in DK-97, while shortest in MKU-98 location (Table-5). Treatments did also change the heading time and C6 treatment resulted in the shortest heading time in the individual and combined locations (Table-5). There was also significant location × treatment interaction for heading time ($p < 0.05$). The G treatment had the longest heading time in DK-97 while it had the shortest in MKU-98 and C8 treatment had the longest heading time in MKU-98 while it had the shortest one in DK-97 (Table-5). The other heading time values showed similar trend in location by treatment combinations.

The difference among locations was statistically significant ($p < 0.01$, Table-4). The difference in spike maturity time was also significant with respect to treatments ($p < 0.05$, Table-4). The shortest spike maturity time was in A8 and the longest was in C6, when the three locations were combined (Table-5). However, there was also significant location × treatment interaction for spike maturity time (Table-4). Although G treatment resulted in the shortest spike maturity time in DK-97, it had the longest spike maturity time in other locations (Table-5). While C8 had the shortest spike maturity time in MKU-98 it had the second longest spike maturity time in DK-97 and no significant difference existed between the first and second longest ($LSD_{0.05}$, Table-5).

TABLE-5
LEAST SQUARE MEANS OF HEADING DATE, SPIKE MATURITY DATE, HECTOLITER WEIGHT AND GRAIN YIELD IN THREE LOCATIONS

Traits	Locations	Treatment							
		A8	G	C0	C2	C4	C6	C8	Grand mean
HDT (day)	DK-97	130.3	131.3	131.0	130.3	130.7	129.0	129.0	130.2a
	MKU-98	114.7	113.0	113.3	113.7	114.0	113.0	115.3	113.9c
	MKU-99	122.0	120.7	121.7	122.0	121.7	120.3	121.7	121.4b
Grand mean		122.3a	121.7a	122.0a	122.0a	122.1a	120.8b	122.0a	121.8
SMT (day)	DK-97	60.33	59.00	60.00	60.33	60.33	62.00	61.00	60.43a
	MKU-98	33.67	36.00	35.67	35.33	34.67	36.00	33.67	35.00c
	MKU-99	48.67	49.67	49.33	48.67	49.33	49.33	49.33	49.19b
Grand mean		47.56c	48.22b	48.33bc	48.11bc	48.11bc	49.11a	48.00bc	48.21
HLT (kg)	DK-97	79.33	75.73	79.13	77.67	77.83	79.37	79.53	78.37b
	MKU-98	81.93	79.70	81.97	82.23	79.43	81.60	78.93	80.83a
	MKU-99	74.50	69.87	76.33	77.20	74.67	72.53	73.80	74.13c
Grand mean		78.59ab	75.10c	79.14a	79.03a	77.31b	77.83ab	77.42b	77.78
GYL (kg ha^{-1})	DK-97	3980	3846	3114	3745	3818	3920	3889	3759b
	MKU-98	2152	1862	1433	2442	2284	1613	1765	1936c
	MKU-99	5327	3727	3840	4707	4237	4387	4550	4396a
Grand mean		3820a	3145c	2796d	3631ab	3446b	3307b	3401b	3364

LSMEANS followed by the same letters in the same row or column is not significantly different from each other ($p < 0.05$). Location × treatment interaction LSDs for HDT = 1.35 d, SMT = 1.33 d, HLT = 2.43 kg and GYL = 333 kg ha^{-1}. HDT = Spike maturity time; SMT = Hectoliter weight; GYL = Grain yield. 80 tons animal manure ha^{-1} = A8; Traditional chemical fertilizer (160 kg N ha^{-1} and 80 kg P_2O_5 ha^{-1}): G = control: C0; 20, 40, 60, 80 tons compost ha^{-1}: C2, C4, C6, C8, respectively.

In present study, response of different compost dosages was comparable to that of animal manure and chemical fertilization. There was dramatic difference among locations which significantly affected the response variables probably because of the different climate and soil conditions in that specific year and location. Additionally, the rainfall amount varied during the growing period of each year (Table-2). Amount and duration of precipitation probably affected both heading and spike maturity times. For example, DK-97 had about two times more rainfall than MKU-98 and three times more than MKU-99 during March while in January, MKU-99 had about five times more rainfall than MKU-98 and three times more than DK-97 (Table-2). That may be the reason that the longest heading and the shortest spike maturity time were observed in DK-97 in which more rainfall, especially during March, probably prolonged the flower development but immediate increase in temperature shortened the spike maturity time. Compost dosages, animal manure and chemical fertilization treatments were significantly affected by the environment indicating that one should be careful about the rainfall regimes or irrigation when using one of the treatments. When the rain was considered as the most limiting factor, the present results showed that compost treatments as responsive to water as chemical fertilizer and animal manure.

There were significant differences among locations and varying doses of compost treatments also resulted in statistical differences in hectoliter weight of Genc-99 (Table-4). The highest hectoliter weight was obtained in MKU-98 while the lowest in MKU-99 (Table-5). The lowest hectoliter weights were obtained from G treatment while the highest was in C0 (Table-5). The location x treatment was also highly significant for hectoliter weight ($p < 0.01$) and C8 treatment had the highest hectoliter weight in DK-97 while it had the lowest in MKU-98 (Table-5). Similar trend was also observed for C4 (Table-5). In general, the treatments (*e.g.* A8, C0 and C2) having higher hectoliter weight in one location had higher hectoliter weight in others or *vice-versa* (*e.g.* G; Table-5).

In general, the longer the grain filling period was the higher the hectoliter weight[24]. However, in present findings more hectoliter weight was observed in low yielding environments where heading time and spike maturity time were the shortest (Table-5). The reason for this may be that the stress conditions such as less water and late planting especially in MKU-98 lead to more grains per spike but grains were smaller and took up less space.

Grain yield of cv. Genc-99 significantly varied along the locations and treatments (Table-4). The highest grain yield was obtained in MKU-99 while the lowest was in MKU-98 (Table-5). There was also significant location × treatment interaction for grain yield and the highest grain yield was obtained in A8 treatment in MKU-99 location while the lowest one was in C0 in MKU-98 (Table-5). The lowest yield difference was obtained in G treatment despite that it had the lowest grain yield in MKU-99 while it had one of the highest in DK-97 (Table-5). However, A8 had the highest yield difference (3175 kg ha^{-1}) among locations since it had the highest yield in MKU-99 although it had one of the lowest in MKU-98 (Table-5). Almost all the compost dosages and animal manure treatments resulted in comparatively higher grain yield than chemical fertilizer and control treatment in most cases (Table-5). In addition, in the low yielding environment of MKU-98, C2 and C4 had the highest grain yield (Table-5).

In previous experiments, compost treatments resulted in significantly higher yield than that of other treatments including animal manure[25,26]. Additionally, combination of chemical fertilizer with mature compost might even yield better[27]. In present study, C2 and C4 treatments yielded more in low yielding environments than others suggesting that low or moderate levels of compost treatment may provide more grain yield even in the low yielding environments. A8 had the highest yield in the high yielding environment and its yield was comparably higher in other environments.

In the low yielding environment of MKU-98, C2 and C4 resulted in 70.4 and 59.3 % more grain yield over the control treatment, respectively. This indicated that in low yielding environments moderate level compost treatment may be a better alternative. Addition of 15 ton ha^{-1} composted baggase in a semi-arid condition resulted in the highest wheat grain yield and using 15 ton ha^{-1} compost resulted in a substantial net benefit of US $ 600 per hectare[28]. Application of compost was reported to increase the aggregate stability of soil through the formation of cationic bridges thereby, improving the soil structure[29]. In Eastern Mediterranean region, which is considered as a typical semi-arid region, moderate levels of compost treatment may improve both soil properties and wheat production, as well as decrease the fertilizer costs. However, further experiments combining the solid waste composts with farmyard manure and chemical fertilizers might increase wheat yield and improve different properties of yield components. Additionally, due to large treatment × environment interaction, more locations should increase the precision and more conclusive evidence in terms of stability for the traits of interest.

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