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The Effect of Sewage Sludge Application on Durum Wheat (*Triticum durum*)

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ABSTRACT

Under semi arid cropping conditions, soil degradation is a rapid process, which could be alleviated through sewage sludge application, as continuous production of these wastes increased the awareness of their safe disposal. A field experiment was conducted to study the effects of sewage sludge application on the growth and yield components of durum wheat (*Triticum durum* Desf.). Treatments were mineral fertilization with 33 kg ha^{-1} N as urea, 20, 30 and 40 tons dry sludge ha^{-1}, applied at the tillering stage and an un-amended control. The results showed an increase in grain yield and yield components, mainly spike fertility and straw yield. 30 tons ha^{-1} of sewage sludge dry matter were as efficient as 66 kg ha^{-1} of mineral nitrogen. Results suggested that sewage sludge application could be used as a mean to increase and stabilize durum wheat yield under semi arid conditions and as a safe disposal mean of these wastes.

Key Words. Sewage sludge; Durum wheat; Organic matter; Mineral fertilization

INTRODUCTION

Most of the Algerian agricultural soils are carbonate-rich soils, with low organic matter content (Kribaa *et al.,* 2001). Semi arid climate-type favours rapid soil organic matter mineralisation because of high summer temperature. Mining agricultural practices based on wheat - fallow system decreased overtime soil fertility (Kribaa *et al.,* 2001). Expansion of urban populations and increased coverage of domestic water supply and sewerage give rise to greater quantities of wastewater. With the current emphasis on environmental health and water pollution issues, there is an increasing awareness of the need to dispose of these wastewaters safely and beneficially. Properly planned use of sewage wastewater and its by products alleviates many environmental problems (Pescod, 1992). The use of these wastes in agriculture is seen as an important issue for both soil conservation and residual disposal. In fact, most sewage wastes contain valuable nutrients that improve soil fertility and crop production (Kara *et al.,* 2003; Mohammad & Athamneh, 2004; Ahmad *et al.,* 2006). Sewage sludge can be used to increase crop production, in those situations, where the growth conditions due to the un-favorable climate associated to the high production costs do not permit the utilization of chemical fertilizers to improve soil fertility (Ripert *et al.,* 1990; Pescod, 1992; Chatha *et al.,* 2002). In fact, soils amended with sewage sludge keep longer their relative humidity and their vegetation develops a deeper rooting system than non-treated soils (Tester *et al.,* 1982). Sewage sludge releases the nutritive elements slowly, which remain available to the plant along the crop cycle. Nitrogen availability is function of the prevailing climatic growth conditions; the amount of applied sludge and its C/N ratio (Barbartik *et al.,* 1985; Pescod, 1992).

Soils amended with sewage sludge tended to have a neutral pH and a high phosphorus and organic matter content (Gomez *et al.,* 1984; Mohammad & Athamneh, 2004). However, sewage sludge is often a source of ground water pollution, when their content is high in nitrate, a source of sol salinity (Tasdilas, 1997), heavy metals pollution (Aboudrare *et al.,* 1998; Bozkurt & Yarilgaç, 2003; Mohammad & Athamneh, 2004) and odors nuisance (Sachon, 1995). Rapid urbanization of the Setif area (Eastern Algeria) generates a great volume of wastewater. Beneficial disposal of the resulting treated bio solids is sought to avoid its accumulation around the treatment plant. The objective of this study is to report on the response of durum wheat (*Triticum turgidum* var *durum* L.) to sewage sludge application in comparison with and without mineral nitrogen fertilisation under semi arid conditions.

MATERIALS AND METHODS

The experiment was conducted on the experimental site of the Agricultural Farm of the Field Crop Institute,

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Setif, Algeria (5 24’ 51’’ E longitude, 36 11’ 21’’ N latitude & 1000 m altitude) during the 2002-2003 crop season. The climate is semi-arid Mediterranean with an average annual rainfall of 397 mm, occurring mostly in autumn and spring and a monthly mean temperature ranging from 7°C in winter to 24.1°C in summer (Fig. 1). The soil was silty clay, whose chemical characteristics are given in Table I.

The trial was laid out in a randomized complete blocks design with three replications. Five treatments were compared: a control without application of sludge nor nitrogen fertilization, a treatment without sludge, but fertilized with 33 kg ha^{-1} N as urea, applied at the tillering stage and three treatments where, respectively 20, 30 et and 40 tons dry sludge ha^{-1}. The sewage sludge, produced through the activated sludge treatment process was collected at Setif wastewater plant. Its physico-chemical analyses were done following Cottonie (1980) and INRA (1996) and are given in Table II. Acsad 1107, a durum wheat (*Triticum durum* Desf.) genotype, was sown on December 20, 2002 at 120 kg ha^{-1} seeding rate in plots 5 m long by 1.20 m wide and an inter row spacing of 0.20 m. Emergence was noted on December 28, 2002. Dry sludge was passed through 10 x 10 mm mech and applied onto the experiment at the tillering stage. Heading was noted on 5th May 2003 and the crop was harvested on 16th June 2003.

Plant height was measured at physiological maturity. Grain dry weight, spikes m^{-2}, kernels per spike and weight per kernel were measured, when plants ripened. Plants were hand-harvested by cutting them at ground level from a single row 1 m long. Above ground biomass was determined by weighting the vegetative dry sample. Spikes were counted, threshed with a single-spike thresher and the grain was weighted to get the sample grain mass. Harvest index was calculated as the grain mass divided by the above ground biomass. 250 kernels were counted with an electronic counter and weighted to obtain the weight per kernel. Kernels per spike were derived as the ratio of the grain mass divided by the product of spikes x weight per kernel. Straw yield was derived as the difference between the above ground biomass and the vegetative sample grain mass. Grain yield was also determined from the combine-harvested trial. Vegetative growth rate and kernel filling rate were calculated following the method described by Hunt (1982). The collected data were subjected to an analysis of variance using STATITCF software package (Beaux *et al.*, 1999). Contrast was employed to test the significance of the following treatments effects (1) Control vs. N + Sludge, (2) N vs. sludge, (3) sludge linear and (4) sludge quadratic (Steel & Torrie, 1980). The relative comparisons between treatments were done according to the following formulae:

$$\text{Amendment effect (N + Sludge) (\%)} = 100\,[(X_{N+S} - X_c)/X_c]$$

Where, X_{N+S} = mean of (N + Sludge) treatments.
Xc = control mean.

$$\text{Sewage sludge effect (\%)} = 100\,[(X_S-X_C)/(X_N-X_c)]$$

Where, X_S = mean of sludge treatment.
X_N = mean of N treatment.
Xc = control mean.

RESULTS

The analysis of variance showed a significant treatment effect for the whole variables measured except spikes m^{-2} (Table III). The non-significant treatment effect for spikes m^{-2} could be explained by the fact that the amendment (sludge & N) was applied later on, at the tillering stage, when this yield component was partially expressed. The amount of sludge applied remains below the nutrients requirement of the crop since the quadratic effect was not significant for the measured traits. The linear effect of the applied sludge was not significant for the thousand-kernel weight, kernels per spike and harvest index (Table III). The comparison between the control and amendment (N+S) means indicated that mineral as well as organic fertilization were beneficial to the expression of the measured variables of the crop except spikes m^{-2} (Table IV). Under the growth conditions of the present experiment, the relative contribution of the amendment (N+S) to the increase in the means of the measured variables ranged from 12% for thousand-kernel weight to 168% for straw yield. The amendment effect was negative for the harvest index, which is reduced by 20.0% relatively to the mean expressed by the control treatment. This could be explained by the fact that mineral nitrogen or the sludge applied had a more pronounced effect on the accumulated above ground biomass than on gain yield (Table IV & Fig. 2). The relative increase in the mean values of the yield component was smaller compared to the grain yield increase. Grain yield improvement resulted from the multiplicative effects of the improvement obtained in the yield components. Thousand-kernel weight was less sensitive to the amendment effect, because it is formed under low rainfall and high temperature conditions prevailing during the grain-filling period (Fig. 1). The increase in the mean value of straw after application of sludge or mineral nitrogen indicated that organic or mineral amendment induced a better expression of the above ground biomass compared to the grain yield, which had a negative effect on harvest index as explained above.

The comparison between organic amendment and mineral fertilization treatments showed that the mean values of these treatments did not differed significantly for the number of spikes, thousand kernel weight and harvest index (Tables III & IV). For these traits the effect of sewage sludge application was similar to the effect of nitrogen mineral fertilization. Organic amendment induced a relative increase of 128.1% for plant height and 213.5% for the number of kernels per spike. Grain yield showed a 192.7% increase relatively to the control mean yield (Table IV & Fig. 3).

Table I. Physico-chemical characteristics of the experimental soil

Parameters	pH (H_2O)	EC	OM	D_b	$CaCO_3$	H_s	H_{fc}	H_{wp}	Texture
Units	-	mS cm^{-1}	%	g cm^{-3}	%	%	%	%	-
Mean values	8.1	0.23	1.7	1.33	19.45	51.5	36.5	16.5	Silty clay

EC: electrical conductivity (mS cm^{-1}), OM: organic matter (%), TC: total carbone (%), Db: bulk density (g cm^{-3}), Hs: humidity at saturation (%), Hfc: humidity at field capacity (%), Hwp: humidity at wilting point (%)

Table II. Characteristics of the sewage sludge (Wastewater treatment plant of Ain Sfiha, Setif, Algeria)

Parameter	Humidity	$pH_{(H2O)}$	EC	TN	OM	TP	K	C/N
Units	%	-	mS cm^{-1}	%	%	%	%	-
Mean val.	80	7.3	2.61	3.30	57.62	5.7	0.5	10.15

EC: electrical conductivity (mS cm^{-1}), TN: total nitrogen (%), C: carbone (%), TP: total phosphorus (%), K: potassium (%)

Table III. Means squares of the analysis of variance of the measured variables

Source	Treatment	S+N vs C	S vs N	S lin	S qua
	*4	1	1	1	1
GY	20939.4**	62489.5**	17398.1**	3310.7**	559.5ns
SN	1067.2ns	411.2ns	458.8ns	3398.6*	0.00ns
KNM^2	3201164**	1848504**	9054255**	792289**	11198ns
TKW	20.35*	72.6**	4.84ns	3.23ns	0.72ns
KS	76.55**	225.2**	78.8**	1.25ns	1.01ns
BIOH	66006.7**	177055**	39190.7**	43146.3**	4634.8ns
VGR	4.22**	11.33**	2.51**	2.76**	0.30ns
KFR	21.7**	64.79**	18.04**	3.43*	0.58ns
BIOM	45893.0**	449916**	108812**	70360**	1973.9ns
HI	85.46**	293.7**	8.06ns	0.43ns	39.6ns
STR	61169**	196459**	27749**	19728**	738.3ns
PHT	406.9**	1316.1**	164.7**	140.2**	6.72ns

C= control, N= nitrogen, S= Sludge, GY= grain yield (g m^{-2}), SN= number of spikes m^{-2}, KNM^2= number of kernels m^{-2}, TKW= 1000 kernel weight (g), KS= number of kernels $spike^{-1}$, BIOH= above ground biomass accumulated at heading stage (g m^{-2}), VGR= vegetative growth rate (g m^{-2} day^{-1}), GFR = filling rate of the KN M^{-2} (g m^{-2} day^{-1}), BIOM= above ground biomass measured at maturity (g m^{-2}), HI= harvest index (%), STR= straw yield (g m^{-2}), PHT= plant height (cm); ns,*,** = effect non-significant and significant at 5% and 1% probability level, respectively. * = degree of freedom

Table IV. Mean values of the different treatments

Source	C	N+S	N	S	20	30	40
SN	318.9	305.8	316.5	302.3	278.5	302.3	326.1
GY	147.5	308.9	242.9	330.9	301.8	342.0	348.7
KNM^2	3159.2	5933.7	4769.1	6321.9	5879.6	6479.6	6606.4
TKW	46.53	52.03	50.93	52.40	51.5	52.8	52.9
KS	9.9	19.6	15.1	21.0	21.3	21.5	20.4
BIOH	223.3	494.9	395.9	527.9	459.1	495.8	628.7
VGR	1.79	3.96	3.17	4.22	3.67	3.97	5.03
KFR	4.75	9.95	7.82	10.65	9.72	11.01	11.23
BIOM	370.8	803.7	638.8	858.7	760.9	837.8	977.5
HI	54.2	43.2	41.7	43.6	44.9	40.6	45.4
STR	169.5	455.6	372.3	483.4	419.6	496.2	534.3
PHT	58.7	82.1	75.6	84.2	80.0	83.0	89.7

C= control, N= nitrogen, S= Sludge, GY= grain yield (g m^{-2}), SN= number of spikes m^{-2}, KNM^2= number of kernels m^{-2}, TKW= 1000 kernel weight (g), KS= number of kernels $spike^{-1}$, BIOH= above ground biomass accumulated at heading stage (g m^{-2}), VGR= vegetative growth rate (g m^{-2} day^{-1}), GFR= filling rate of the KN M^{-2} (g m^{-2} day^{-1}), BIOM= above ground biomass measured at maturity (g m^{-2}), HI= harvest index (%), STR= straw yield (g m^{-2}), PHT= plant height (cm)

DISCUSSION

Considerable research has been accomplished worldwide on the use of sewage sludge on soil and crop. Many investigators have reported a substantial increase in plant growth and biomass production upon sewage sludge application (Azam & Lodhi, 2001; Chatha *et al.,* 2002; Mohammad & Athamneh, 2004; Dursan *et al.,* 2005; Casado-Vela *et al.,* 2006 & 2007; Jamil *et al.,* 2006). It was found in the present study that application of sewage sludge appeared to be more beneficial for the crop than mineral nitrogen fertilization. The effect of the applied sewage sludge was significant and more apparent on spike fertility, above ground biomass accumulated at heading and maturity, on vegetative growth rate and grain filling rate. Jamil *et al.* (2006) reported that sewage sludge increased the grain yield and straw production of wheat. They mentioned that the maximum yields in both grain and straw were obtained at 40 t ha^{-1} of sewage sludge application. The increases noted in grain yield and in the yield associated variables are due to the high concentrations of nitrogen, phosphorus and micronutrients of the sewage sludge applied (El Neggar & El Ghamry, 2001). Azam and Lodhi (2001) indicated that benefits of sewage sludge amendments are derived mainly from a net release of nitrogen from decomposing organic matter with high nitrogen concentration and narrow C/N ratio. Bouzerzour *et al.* (2002) reported that the application of sewage sludge increased leaves dimensions, leaf area index, accumulated above ground dry matter, tillering capacity and plant height of barley (*Hordeum vulgare* L.) and oat (*Avena sativa* L.) genotypes, evaluated in pots experiment. They noted also that the response of the measured variables to the applied sewage sludge was linear, which corroborated the results of the present study. The maximum amount of 40 t ha^{-1} of applied sewage sludge did not show any harmful effect on the expression the measured parameters. In the present study grain yield increase was correlated with the increase noted in the number of kernels produced per unit area (r=0.98, P<0.05) and the number of kernels per spike (r=0.92, P<0.05), but not with the fertile tillering ability of the crop (r=0.21, P>0.05).

Application of sewage sludge acted as a seal, it reduced the soil evaporation and helped to keep soil more moist because of its high organic matter content. In fact, Gomez *et al.* (1984) mentioned that sewage sludge acted as

Fig. 1. Precipitations and temperatures at the experimental site during the period of the study 2002-2003

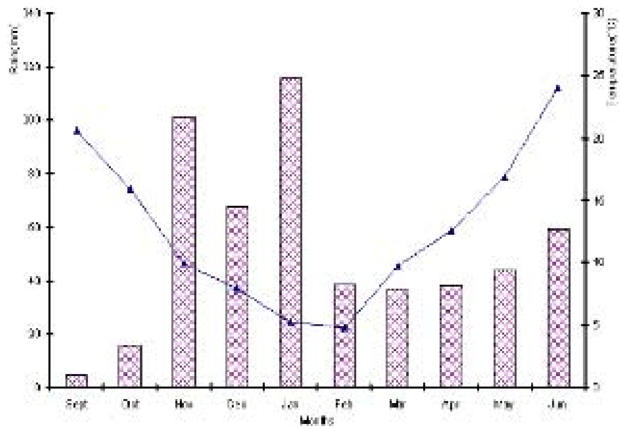
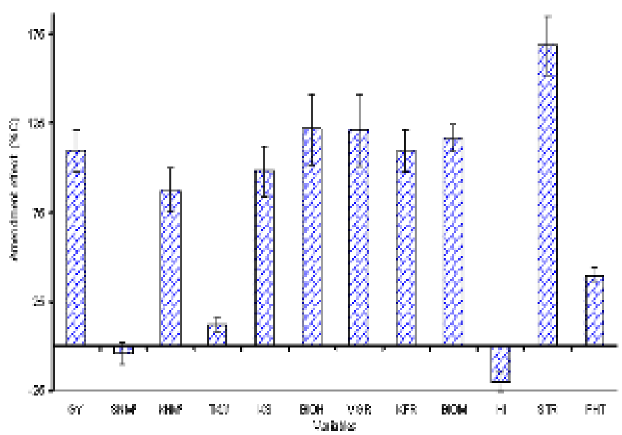


Fig. 2. Contribution of the applied amendment (N+S) to the increase in the mean values of the measured traits relatively to the mean values of the control

GY= grain yield (g m^{-2}), SN= number of spikes m^{-2}, KNM^2= number of kernels m^{-2}, TKW=1000 kernel weight (g), KS=number of kernels $spike^{-1}$, BIOH=above ground biomass accumulated at heading stage (g m^{-2}), VGR=vegetative growth rate (g m^{-2} day^{-1}), GFR=filling rate of the KN M^{-2} (g m^{-2} day^{-1}), BIOM=above ground biomass measured at maturity (g m^{-2}), HI=harvest index (%), STR=straw yield (g m^{-2}), PHT=plant height (cm)

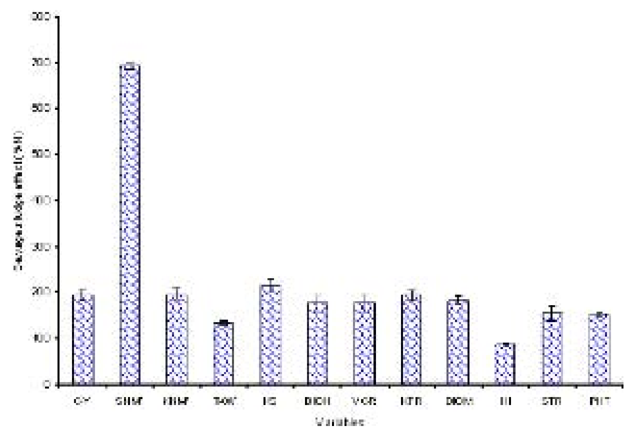


substrate, which maintained soil organic matter and improved soil structural stability, cationic exchange and water retention capacities. Barbartik *et al.* (1985) noted that application of sewage sludge during four consecutive cropping seasons increased the upper organic matter content of the upper 15 cm soil horizon from 1.2 to 2.4%.

The results of this study corroborated results from others investigations. Tester *et al.* (1982) reported that soil amendment with sewage sludge improved tall fescue (*Festuca arundinacea* L.) nitrogen nutrition, stimulated root growth and increase forage production comparatively to the non-amended control plot. With ray grass (*Lolium perenne* L.), Guiraud *et al.* (1977) observed an improvement of nitrogen concentration of tissue of plants grown in sewage sludge amended soils. Cherak (1999) reported an

Fig. 3. Relative increase in the mean values of the measured traits due to the effect of applied sewage sludge as percentage of the mineral nitrogen fertilization effect

GY=grain yield (g m^{-2}), SN=number of spikes m^{-2}, KNM^2=number of kernels m^{-2}, TKW=1000 kernel weight (g), KS=number of kernels $spike^{-1}$, BIOH=above ground biomass accumulated at heading stage (g m^{-2}), VGR=vegetative growth rate (g m^{-2} day^{-1}), GFR=filling rate of the KN M^{-2} (g m^{-2} day^{-1}), BIOM=above ground biomass measured at maturity (g m^{-2}), HI=harvest index (%), STR=straw yield (g m^{-2}), PHT=plant height (cm)



improvement of the tillering capacity of oat (*Avena sativa* L.) grown under sewage sludge amended soil, compared to the control. Antolın *et al.* (2005) reported that application of sewage sludge increased barley grain yield because the soil amended had improved microbiological properties, which promoted the recycling of nutrients for the crop.

CONCLUSION

Land application of treated sewage sludge can reduce significantly the sludge disposal cost component of sewage treatment as well as providing a large part of the nitrogen and phosphorus requirements of many crops. The organic matter in sludge can improve the water retaining capacity and structure of soils especially, when applied in the form of dewatered sludge cake. Application of sewage sludge to durum wheat crop increased grain yield, improved crop growth and accumulated above ground biomass. The results of this study indicate that sewage sludge applications in the semi-arid zones on durum wheat might be an attractive option to increase crop yields, to reduce cost of production because crop amended this way need less inorganic nutrients and mainly less applied mineral nitrogen and to manage wastes disposal.

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