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RESPONSE OF DURUM WHEAT (Triticum durum Desf.) CULTIVAR ACSAD 1107 TO SEWAGE SLUDGE AMENDMENT UNDER SEMI ARID CLIMATE

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SUMMARY - The use of sewage sludge on a large scale and at relatively low rates can contribute to the husbandry of urban wastes. This is interesting since this utilization in agriculture appeared to increase crop production. The results of the present investigation, whose objective was to study the response of a rainfed cereal crop to organic amendment with sewage sludge showed an increase in grain yield and yield component, mainly spike fertility and straw production. 30t/ha of sewage sludge dry matter were as efficient as 66 kg /ha of mineral nitrogen.

Key words: Sewage sludge, durum wheat, grain yield, organic mater, mineral fertilization.

RESUME - *L'utilisation des boues résiduaires sur de grandes étendues à des doses relativement faibles permet d'apporter une solution à terme pour la gestion des déchets urbains. Cette solution est d'autant plus intéressante que les boues utilisées dans le domaine agricole se révèlent bénéfiques en terme d'augmentation de la production. Les résultats de la présente contribution dont l'objectif était d'étudier la réponse d'une culture de céréale conduite en pluviale aux amendements organiques à base de boues résiduaires indique une augmentation du rendement en grains et des composantes du rendement notamment la fertilité de l'épi ainsi que la production de paille. Les apports de boue, pour une moyenne de 30 t de ms/ha, s'avèrent aussi efficace que 66 kg d'azote minéral.*

Mots clés: *Boue résiduaire, blé dur, rendement, matière organique, fertilisation minérale.*

INTRODUCTION

Expansion of urban populations and increased coverage of domestic water supply and sewerage give rise to greater quantities of municipal 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 municipal sewage alleviates surface water pollution problems and also takes advantage of its nutrients contain to grow crops.

Sewage sludge can be used to increase crop production, in those situations where the growth conditions due to the unfavorable climate associated to the high production costs don't permit the utilization of chemical fertilizers to overcome cultivated soil fertility problems (Chatha *et al.,* 2002; Pescod, 1992; Ripert *et al.*, 1990).

In fact, soils treated with sewage sludge keep longer their relative humidity and their vegetation develops a deeper rooting system as compared to non treated soils (Tester et *al.*, 1982). Sewage sludge liberates progressively nutritive elements they contain and made them available to the plant along the crop cycle. Nitrogen availability is function of the prevailing climatic growth conditions; the amount of applied sludge and the C/N ration (Pescod, 1992; Barbartik, 1985).

Soils treated with sewage sludge tended to have a neutral pH and a high phosphorus and organic matter content (Mohammad et *al.*, 2004; Gomez et *al.*, 1984). However sewage sludge are often a source of ground water pollution when their content in high in nitrate (Xanthoulis *et al.*, 1998). They are a source of sol salinity (Tasdilas, 1997), heavy metals pollution (Mohammad *et al*, 2004; Bozkurt *et al.*, 2003; Aboudrare *et al.*, 1998) and odors nuisance (Sachon, 1995).

The present study investigates the response of durum wheat (*Triticum durum* Desf.) variety Acsad 1107 to the application of sewage sludge under semi arid climate.

MATERIALS ET METHODS

The experiment was conducted on the experimental site of the Agricultural Farm of the Field Crop Institute of Setif in the Northeastern part of Algeria (5° 24' 51'' E longitude and 36° 11' 21'' N latitude, and 1000 m altitude) during the 2002/03 crop season. Climate is Mediterranean, characterized by mild rainy winter and dry hot summer with average temperature in summer 24.1°C and 7°C in winter and average annual precipitation of 397.0 mm (AFFCI, 2003). Total amount and distribution of rainfall for the period of the study are presented in (*Table 1*). The soil is loamy clay and its chemical characteristics are presented in (*Table 2*).

The trial was laid out in a randomized complete blocks design with three replications. Five treatments were compared: a check without application of sludge nor nitrogen fertilization, a treatment without sludge but fertilized with 33 units ha^{-1} of urea, applied during the tillering stage, and three treatments with respectively 20, 30 et 40 tons dry sludge ha^{-1}. The characteristics of the dry sludge used are reported in (*Table 3*).

The different physico-chemical analyses of the soil and the sludge were carried out at the beginning of the experiment on dry and fine samples (< 2 mm). The determination of the pH and the electrical conductivity were done by Consort C535 Multiparameter on 1:2.5 and 1:5 soil/distilled water respectively, the soil texture by the hydrometer method and the others by standards methods (Chapman and Pratt, 1982).

Acsad 1107, a durum (*Triticum durum* Desf.) genotype, was sown on December 20th 2002 at a 300 seeds m^{-2} rate on plots whose dimensions were 6 rows x 5 m long x 0.20 m space between rows. Emergence was noted on December 28th 2002. Dry sludge was passed through 10x10 mm mech, and applied onto the experiment at the tillering stage. Heading was noted on May 5th 2003 and the crop was harvested on June 16th 2003.

Plant height (PHT) was measured at crop maturity; the number of spikes (SN) and total dry matter (BIOM) produced per m^2 of soil were estimated from vegetative samples harvest from

Table 1. Precipitations and temperatures at the experimental site of the Agricultural Farm of the Field Crop Institute (Setif, Algeria) during the period of the study 2002/03

	Rainfall (mm)				Temperature (°C)		
	D1	D2	D3	Total	Min	Max	Mean
September02	1.20	0.30	2.80	4.30	14.67	26.49	20.68
October 02	6.40	6.60	2.90	15.90	11.40	20.63	16.01
November02	59.60	11.80	29.80	101.20	6.29	12.91	9.25
December 02	52.50	11.90	3.00	67.40	3.65	12.18	7.91
January 03	16.40	28.80	71.80	117.00	0.98	6.22	3.80
February 03	19.20	15.00	4.20	38.40	3.58	11.63	4.49
March 03	0.60	5.80	31.20	37.60	4.84	14.66	9.92
April 03	20.02	14.80	3.40	38.22	8.30	16.96	12.63
May 03	18.00	2.40	13.40	43.80	11.22	22.63	19.93
June 03	38.40	20.40	0.60	59.40	17.95	30.32	24.14

D1, D2, D3 : Decades 1, 2 et 3 of the month.

Table 2. Characteristics of the soil (0-20cm) used in the experiment at the experimental site of the Agricultural Farm of the Field Crop Institute (Setif, Algeria)

Parameters	pH_{H2O}	EC	OM	TC	D_b	H_s	H_{fc}	H_{wp}	Texture
Units	-	(mS/m)	(%)	(%)	(g/cm^3)	(%)	(%)	(%)	-
Mean values	8.1	0.23	1.7	19.45	1.33	51.5	36.5	16.5	Loamy clay

EC: Electrical conductivity, OM : Organic Matter, TC : Total Carbone, D_b : Bulk density, H_s : Humidity at saturation, H_{fc} : Humidity at field capacity, H_{wp} : Humidity at wilting point.

Table 3. Characteristics of the sewage sludge originating from the effluents treatment plant of Ain Sfiha (Setif, Algeria).

Parameters	Humidity	$pH(H_2O)$	EC	TN	C	TP	K	C/N
Units	%	-	(mS/cm)	%	%	%	%	-
Mean values	80	7.3	2.61	3.30	33.5	5.7	0.5	10.15

EC : Electrical Conductivity , TN : Total Nitrogen, C : Carbone, TP : Total Phosphorus, K : Potassium

1 row x 1m long area. Grain yield (GY) was measured from the combine harvested trial. Thousand kernel-weight (TKW) was estimated from the count and weight of 250 kernels per replicate. The variables number of kernels produced per m^2 (KNM^2) , per spike (KS), aerial biomass accumulated at heading (BIOH), vegetative growth rate (VGR), kernel filling rate (KFR), harvest index (HI) and amount of straw produced (STR), have been deduced by calculus using the following formulas:

$$KNM^2 = 1000(GY/TKW) \quad (1)$$

Where:

GY: grain yield (g m^{-2})
TKW: thousand kernels weigh (g)
KS: KNM^2 /SN, with
KS: Number of kernels per spike
SN: Spike number. m^{-2}

$$BIOH = BIOM- GY \quad (2)$$

Where:

BIOM: above ground biomass measured at maturity (g m^{-2})

$$VGR = BIOH/DHE \quad (3)$$

Where:

VGR: Vegetative growth rate (g m^{-2} day^{-1})
BIOH: above ground biomass accumulated at heading stage (g m^{-2}),
DHE: number of calendars days from emergence to heading stage (days).

$$KFR = GY/KFP \quad (4)$$

Where:

KFR: rate of filling of the number of kernels produced per m^2 (g m^{-2} $days^{-1}$),
KFP: number of calendar days in the kernel filling period (days).

$$HI = 100 (GY/BIOM) \quad (5)$$

The collected data were subjected to an analysis of variance. Contrast was employed to test the significance of the following treatments effects (1) Check vs N + Sludge, (2) N vs sludge, (3) sludge linear and (4) sludge quadratic (Steel and Torrie, 1980). The relative comparisons between treatments were done according to the following formulas:

$$\text{Amendment effect N + Sludge (\%)} = 100\ [\ (X_{N+S}\ - X_c)/X_c] \quad (6)$$

Where:

X_{N+s}: mean of N+ sludge treatments
X_x: check mean

$$\text{Sewage sludge effect (\%)}\ = 100\ [\ (X_S - X_C)/(X_N - X_T)] \quad (7)$$

Where:

X_S: mean of sludge treatment
X_N: mean of N treatment
X_c: check mean.

RESULTS AND DISCUSSION

The analysis of variance showed a significant treatment effect for the whole variables measured but not for the number of spikes (*Table 4*). The non significant treatment effect for the number of spikes could explained by the fact the amendment (sludge and N) was applied later on, at the tillering stage, when this yield component was partially expressed.

The amount of sludge applied remains below the nutriments requirement of the plant 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, the number of kernels per spike and the harvest index (*Table 4*). The comparison between the check 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 the number of spikes produced per unit square of land (*Table 5*).

Table 4. Means squares of the analysis of variance of the measured variables

Source	Treatment	S+N vs C	S vs N	S lin	S qua	error
dll	4	1	1	1	1	8
GY	20939.4**	62489.5**	17398.1**	3310.7**	559.5ns	301.2
SN	1067.2ns	411.2ns	458.8ns	3398.6*	0.00ns	389.1
KNM^2	3201164**	1848504**	9054255**	792289**	11198ns	156915.8
TKW	20.35*	72.6**	4.84ns	3.23ns	0.72ns	2.92
KS	76.55**	225.2**	78.8**	1.25ns	1.01ns	1.96
BIOH	66006.7**	177055**	39190.7**	43146.3**	4634.8ns	1967.6
VGR	4.22**	11.33**	2.51**	2.76**	0.30ns	0.13
KFR	21.7**	64.79**	18.04**	3.43*	0.58ns	0.31
BIOM	45893.0**	449916**	108812**	70360**	1973.9ns	833.9
HI	85.46**	293.7**	8.06ns	0.43ns	39.6ns	8.01
STR	61169**	196459**	27749**	19728**	738.3ns	763.6
PHT	406.9**	1316.1**	164.7**	140.2**	6.72ns	4.9

C= Check, 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, BIOH= above ground biomass accumulated at heading stage (gm^{-2}), VGR = vegetative growth rate (g m^{-2} day^{-1}), GFR = filling rate of the KNM^{-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.

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 the 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 check treatment. This could be explained by the fact that the nitrogen or the sludge applied had a more pronounced effect on the accumulated above ground biomass than on gain yield (*Table 4*, Fig. 1).

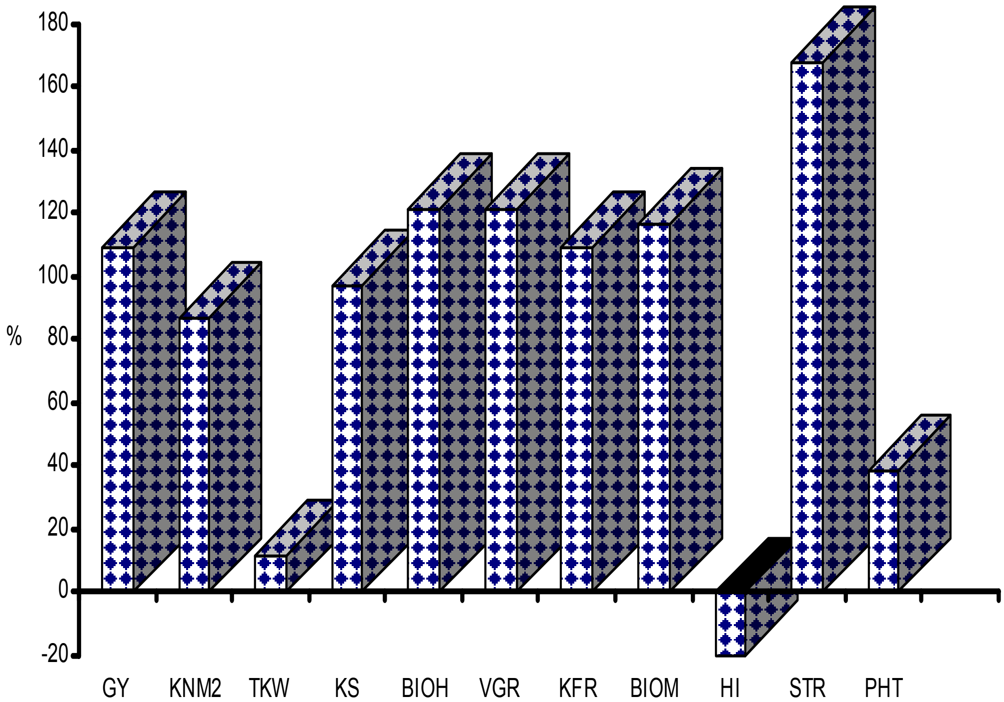

Fig. 1. Contribution of the applied amendment (N+ S) to the increase in the mean values of the measured traits relatively to the mean values of the check.

Table 5. Mean values of the different treatments

	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= Check, 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, BIOH= above ground biomass accumulated at heading stage (gm^{-2}), VGR = vegetative growth rate (g m^{-2} day^{-1}), GFR = filling rate of the KNM^{-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).

The relative increase in the mean values of the yield component was smaller compared to the increase noted in grain yield. Grain yield increase resulted from the multiplicative effects of the increase obtained in the yield components. The thousand kernel weight was the yield component which was the less sensitive to the amendment effect; because this trait is formed when climatic growth conditions become less favorable.

The increase noted 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 4* and *5*). 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 check mean yield (*Table 5*, Fig. 2).

On average 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.

These results indicated that applying sewage sludge to cultivated soils induced an increase in crop grain yield and contributed to disposal of and recycling of this waste material (Ripert et *al.*, 1990). The increases noted in grain yield and in the yield associated variables are due to the high concentrations of nitrogen, phosphorus and organic matter of the sewage sludge applied.

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.

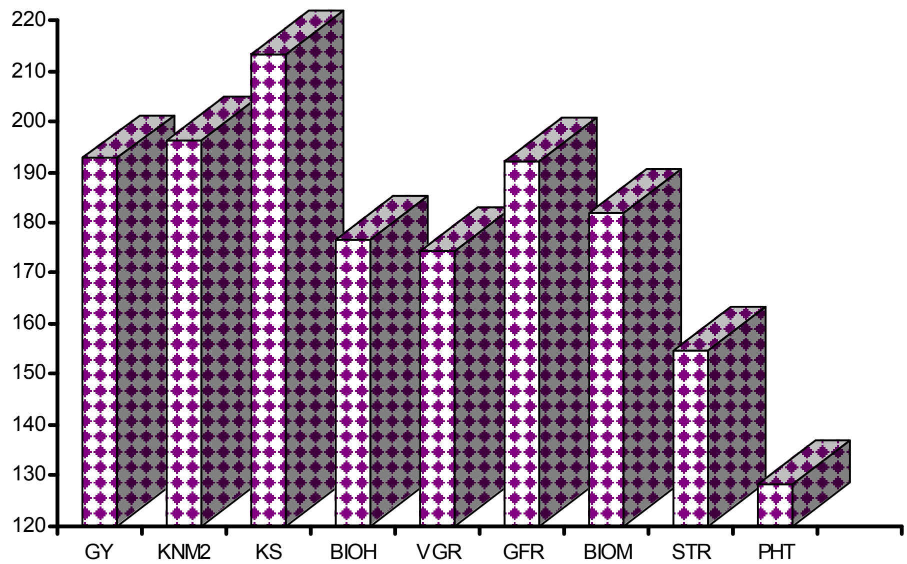

Fig. 2. Relative increase in the mean values of the measured traits due to the effect of applied sewage sludge as % of the mineral nitrogen fertilization effect

In the present study yield increase originated from the increase noted in the number of kernels produced per unit square of soil ($r_{GY/KNM^{-2}} = 0.98^{*}$) and to the number of kernels per spike ($r_{GY/KS} = 0.92^{*}$) but not from the fertile tillering ability of the crop ($r_{GY/SN} = 0.21^{ns}$). During the course of the experiment the check treatment was somewhat earlier and senesce more rapidly than the amended treatments. Application of sewage sludge acted as a seal, it reduced from the soil evaporation, and helped to keep soil more moist because of its high organic matter content.

Sewage sludge is considered as a substrate which is susceptible to contribute to maintain soil organic matter and to improve soil structural stability, cationic exchange and water retention capacities (Gomez et *al.*, 1984). Barbartik *et al.* (1985) noted that application of sewage sludge during 4 consecutive cropping seasons increased the upper the organic matter content of the upper 15 cm soil horizon from 1.2 to 2.4%.

Tester *et al.* (1982) studied the response of tall fescue (F*estuca arundinacea* L) to sewage sludge; they observed that soil amendment with sewage sludge improve tall fescue nitrogen nutrition, stimulated root growth and increase forage production comparatively to the non amended check. 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) noted an improvement of the tillering capacity of oat (*Avena sativa* L.) grown under sewage sludge amended soil.

According to Sachon (1995) incubated sewage sludge develops aerobic and anaerobic chemical reactions which, in 6 to 7 weeks, reduced the organic matter to the form of compost which is similar to the humus. The mineralization of organic nitrogen is dependent on the C/N ratio, higher this ratio is the lower the mineralization will be (Barbartik *et al.,* 1985; Sachon, 1995).

CONCLUSION

Use of wastewater in agriculture could be an important consideration when its disposal is being planned in arid and semi-arid regions. Treated sludge can be applied to growing cereal crops without constraint. Land application of raw or 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. Sludge application resulted in significantly increased crop yields, attributed to the beneficial effects on soil structure and to the nutrients contain.

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