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Effect of Sewage Sludge on Germination, Growth and Biomass Yield of Sorghum in Calcareous Soils

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Abstract

Effect of sewage sludge on germination, growth and biomass yield of sorghum crop was studied utilizing three calcareous soils and the sewage sludge at the rate of 0, 25, 50 and 75 Mg ha^{-1} in a pot experiment. The mean crop germination ranged between 77.5-97.5 percent and there was no significant reduction in germination due to sewage sludge application. Mean plant height ranged between 33.98-77.60 cm and the mean biomass ranged bgtween 0.075-0.525 kg per pot in different sewage sludge treatments. The plant height and the biomass yield increased significantly with an increase in sewage sludge application. There was an increasing trend in plant height and total biomass yield in heavy textured soil than other soils. There was no significant effect of varying $CaCO_3$ contents of soils on crop germination, plant height and biomass yield receiving different rates of sewage sludge. In conclusion, there exists an excellent potential for the use of sewage sludge not only as organic matter but also a promising source of plant nutrition for increasing the productivity of sandy calcareous soils in an arid environment. The research findings also highlighted the usefulness of sewage sludge and sewage waste for its utilization as organic matter for reasonable forage production as well as to minimize the expected environmental hazards from land disposal of these sewage wastes.

Introduction

Land disposal of liquid and solid sewage waste is a common phenomenon in the modern societies. Generally, sewage waste disposal is carried out for landfill or discharged into the rivers or canals or oceans depending upon the situation. In Saudi Arabia, the production of wastewater and sewage waste is on the increase due to rural and urban expansion specially in some of the major cities like Riyadh, Jeddah, Dammam and Jubail etc. These waste waters are also being treated to varying degrees for reuse and recycling in the development of agriculture. This process has resulted in the production of huge quantities of sewage sludge.

Application of sewage sludge as a source of organic matter decreased the pH of soil than control treatment (Bevacqua and Mellano, 1994; Tester, 1990; Del Castilho *et al.*, 1993; Shiha, 1990). Recent research showed that soil salinity increased with an increase in the application rate of sewage sludge in calcareous sandy soils (Shiha, 1990; Del Castilho *et al.*, 1993; Bevacqua and Mellano, 1994). It is well known that sewage sludge contains heavy metals to a varying degree and its application to soils, as a source of plant nutrients, might cause bio-accumulation of some heavy metals such as Ni, Cd, Cu, Co, Fe and Cr in soils and plants. Al-Nahidh (1991) reported that an increase in sludge application rate considerably increased the available N, P and K in soil. Shiha (1990) concluded that addition of sewage sludge caused significant increase in the concentration of Fe, Zn, Ni, Cu, Pb and Cd in the calcareous loamy soil.

A marked increase in dry matter production upon sludge application to soil has been reported by many investigators (Hinesly *et al.*, 1972; Dowdy and Ham, 1977; Topper and Sabey, 1986). Al-Nahidh (1991) found considerable increase in dry weight with an increase in the sludge application under greenhouse conditions. Kumar and Wahid (1994) reported a substantial increase in growth and biomass production in vines treated with organic materials as compared to the control. A reduced plant growth due to high salt concentration in slugged soil was reported by Cunningham *et al*. (1975). Tedious and Bogale (1995) reported that application of cow dung gave similar mean grain yield as with 60 kg N ha^{-1} (4.42 vs 4.93 Mg ha^{-1}). The application of 60 kg N ha plus cow dung gave the highest yield of 6.22 Mg ha^{-1}.

Presently, the information regarding the status of sewage sludge production, its disposal and effect on soils and crops is inadequate. Therefore, this research was carried out to determine the effect of sewage sludge application on soils and crops in calcareous soils under an arid environment in Saudi Arabia.

Materials and Methods

The experiment was carried at Experimental Research Station, Al-Muzahmiyah, King Abdulaziz City for Science and Technology, Riyadh, Saudi Arabia.

Procedure: The experiment was carried out in plastic pots with a mean diameter of 30 cm and a height 45 cm. Three soils namely sandy, sandy-loam and sand having 5.37 percent, 24.0 percent and 45 percent calcium carbonate were selected. The soils were collected from three different agricultural farms in the vicinity of Al-Muzahmiyah Research station. The soils were air-dried, passed through 2-mm sieve and stored for experiment. The field capacity of soils ranged between 8-10 percent. The physico-chemical analyses of soils is given in Table 1. Each pot was filled with 18 kg of soil up to 40 cm depth leaving the upper 5 cm for irrigation water. The sewage sludge was applied at the rate of 0, 25, 50 and 75 Mg ha to each pot. It came to 0, 30, 60 and 90 gram per pot for T_1 (0 kg ha^{-1}),

T_2 (25 kg ha^{-1} T_3 (50 kg ha^{-1}) and T_4 (75 kg ha^{-1}) treatments. A Complete Randomized Statistical Design was followed with each treatment having four replications. The sewage sludge used in the experiment was prepared by Al-Bustan Company, Riyadh Kingdom of Saudi Arabia. The chemical composition of sewage sludge as given by the manufacturer is N (1.7%), P_2O_5 (1.6%), K (0.2%), Fe (1.1%), Zn (0.1%), Cu (0.02%), Mn (0.01%), O.C.(46.5%) and pH of 7.0. The sewage sludge was mixed in the upper 5 cm of soil before crop cultivation. The pots were irrigated after sludge application and left for two days to attain equilibrium. There was no application of inorganic source of fertilizer.

Table 1: Physico-Chemical Properties of Experimental Soils

Sr. No	S_1(Sandy)	S_2(Sandy-Loam)	S_3(Sandy)
pH	7.68	8.00	8.25
ECe (dS m^{-1})	0.56	2.90	0.73
CaCO3 (%)	5.37	23.88	45.00
Sand (%)	97.00	72.00	90.00
Silt (%)	0.00	10.00	4.00
Clay Textural	3.00	16.00	6.00

A local sorghum cultivar (*Sorghum vulgare* L.) was planted as a test crop. The groundwater available at the research station having an average total salinity of 1292 mg L^{-1} (TDS) and sodium-adsorption-ratio (SAR) of 2.5 was used for crop irrigation (US Salinity Staff, 1954). A pre-soaking irrigation was applied to each pot to the level of field capacity of soil. The irrigation water was applied at the rate of 1.45 liter per pot per irrigation with the help of a graduated beaker on one side of the pot. Twenty seeds of sorghum were planted in each pot on May 2nd, 1998. The crop germination was completed within a week. The plants were not thinned after germination in order to measure the total biomass yield for use as animal forage. The pots were irrigated with an interval of 3-days between irrigation when the soil moisture reached around half of the field capacity on a predetermined level for the experimental soils with the groundwater from Al-Muzahmiyah Research Stetion. The pots received a total of 39 liters of irrigation water during the growth period.

Plant growth measurements include germination, fresh weight, dry matter yield and mineral composition of plants. The crop was harvested on July 17th, 1998 after 70 days of plantation. Fresh weight was taken immediately after harvesting. Plants were washed thoroughly with 0.1 percent HCi and then rinsed with distilled water properly before putting in the oven for drying. The plants were dried in an oven at 48°C for 48 hours to a constant weight and later on ground in Willy Mill and stored for analysis.

The soil samples were collected from 0-15 and 15-30 cm depth after harvesting the crop. The soil samples were air-dried and stored for chemical analyses.

The data were analyzed by Analysis of Variance Techniques for evaluating the treatment effects (Snedecor and Cochran, 1973).

Results and Discussion

Crop Germination

Sandy Soil (S_1): Mean crop germination ranged between 87.5-97.5 percent in various sewage sludge treatments (Table 2). The crop germination did not increase significantly with an increase in sewage sludge application than the control treatment. Although the crop germination showed a decreasing trend with an increase in sewage sludge application than the control treatment but overall the crop germination did not differ significantly among various treatments ($L50_{0.05}$ = 13.061).

Sandy-Loam Soil (S_2): Depending upon various sewage sludge treatments, the mean crop germination came to 77.5 percent in all the treatments (Table 2). The crop germination did not increase significantly with an increase in sewage sludge application than the control treatment. The difference in per cent germination was not significant among various treatments ($LSD_{0.05}$ = 26.392). This suggests that application of sewage sludge did not affect crop germination irrespective of its amount of application in different sandy calcareous soils.

Sandy Soil (S_3): Mean crop germination ranged between 87.5-92.5 percent in different sewage sludge treatments (Table 2). The crop germination did not increase significantly with an increase in sewage sludge application than the control treatment. The difference in crop germination was not significant among various rate of sewage sludge application ($LSD_{0.05}$ = 14.107). The results indicated that different rates of sewage sludge application did not affect crop germination in a sandy calcarious soil.

Table 2: Effect of Sewage Sludge on Growth Parameters of Sorghum Crop

	Sewage Sludge (Mg ha^{-1})			
	0	25	50	100
Plant Height (cm)				
S_1	33.98b	56.38c	69.88b	77.60a
S_2	49.68c	70.70b	75.13ab	77.23a
S_3	46.55c	68.00b	70.03b	76.25a
Germination (%)				
S_1	97.50a	95.00a	90.00a	87.50a
S_2	77.50a	77.05a	77.50a	77.50a
S_3	90.00a	90.00a	87.50a	92.50a
Biomass Yield (Mg ha^{-1})				
S_1	00.07c	00.22b	00.37a	00.44a
S_2	00.19c	00.40b	00.49a	00.53a
S_3	00.15d	00.32c	00.40b	00.50a

Figures in a column with the same letter are not significantly different by $LSD_{0.05}$

Plant Height

Sandy Soil (S_1): Mean plant height ranged between 33.98-77.60 cm in various sewage sludge treatments (Table 2). Plant height increased significantly with an increase in sewage sludge application than the control treatment ($LSD_{0.05}$ = 6.943). The difference in plant height was significant among four treatments. This could be due to the nutrients present in sewage sludge which might have enhanced plant growth even without the application of inorganic fertilizer as a source of plant nutrition.

Sandy-Loam Soil (S_2): The mean plant height ranged between 49.68-77.23 cm in various sewage sludge treatments (Table 2). The plant height increased significantly with an increase in sewage sludge application than the control treatment ($LSD_{0.05}$ = 4.607). The difference in plant height was not significant between T_2 and T_3 as well as between T_3 and T_4 sludge treatments.

Sandy Soil (S_3): sMean plant height ranged between 46.55-76.25 cm in different sewage sludge treatments (Table 2). The plant height increased significantly with an increase in the application rate of sewage sludge than the control treatment ($LSD_{0.05}$ = 5.286). The difference in plant height was significantly more in T_4 than all other treatments except T_2 and T_3 where it was not significant. The increase in plant height due to sewage sludge may be attributed to the presence of appreciable amount of plant growth elements in this organic material.

Total Biomass Yield

Sandy Soil (S_1): Depending upon various sewage sludge treatments, the mean biomass yield ranged between 0.075-0.438 kg per pot (Table 2). The biomass yield increased significantly with an increase in sewage sludge application than the control treatment($LSD_{0.05}$ = 0.078). The difference in yield was significant among treatments T_1, T_2 and T_3 but it was not significant between T_3 (50 Mg ha^{-1}) and T_4 (Mg ha ^{1}). This significant increase in biomass yield might be attributed to the nutrients present in the sewage sludge thus enhancing the crop growth.

Sandy-Loam Soil (S_2): The mean biomass yield ranged between 0.188-0.525 kg per pot in various sewage sludge treatments (Table 2). The biomass yield increased significantly with an increase in the application of sewage sludge than the control treatment ($LSD_{0.05}$ = 0.070). The difference in yield was significant among T_1, T_2 and T_3 but it was not significant between T_3 and T_4 treatments. This increase in biomass yield with an increase in sewage sludge application could be attributed to the nutrients present in sewage sludge which enhanced plant growth as compared to the control treatments. It was also noticed that biomass yield showed continuous increases with the increased amount of sewage sludge application. This suggest that the pots with higher dose of sewage sludge might have received more nutrients thus resulting in higher plant growth and the biomass yield. It was also found that application of sewage sludge, containing appreciable amount of plant growth nutrient elements, might result in saving of inorganic fertilizer such as urea etc for higher crop production. In conclusion, application of sewage sludge, containing appreciable amount plant growth elements, to sandy calcareous soils could prove a good preposition not only for its economical disposal but also for increasing the productivity of sandy calcareous soils. However, further investigations are required to study in detail about the rate of application and its detrimental effects on soil and plant composition if planned for use as animal forage to avoid health hazards and environmental pollution.

Sandy Soil (S_3): Mean biomass yield ranged between 0.15-0.50 kg per pot in different sewage sludge treatments (Table 2). The biomass increased significantly with the application of sewage sludge than the control treatment ($LSD_{0.05}$ = 0.055). The difference in biomass yield was significantly more in pots receiving higher dose of sewage sludge than low doses treatments. This significant increase in biomass yield could be due to the nutrients present in sewage sludge which were more with higher dose of sewage sludge as compared to lower levels. It is worth mentioning that no additional inorganic fertilizer in the form of urea or phosphorus or potassium was applied to supplement the nutrients from sewage sludge to the crop during its growth period. It can be tentatively concluded from this piece of information that a considerable amount of saving in the application of inorganic fertilizer could be achieved if sewage sludge containing appreciable amount of plant nutrient elements is applied as a potential source of organic material for the improvement of sandy calcareous soils in an arid environment.

Comparison of Soils vs Plant Growth Parameters

Crop Germination: The analysis of data show that there is no significant difference among the three soil types varying in the total $CaCO_3$ contents and receiving different doses of sewage sludge (Table 3). The Least Significant difference (LSD) was 14.984 (T_1), 18.465 (T_2), 17.060 (T_3) and 25.140 (T_4) at 5 percent level of significance. It shows that application of sewage sludge did not adversely affect the crop germination in soils varying in texture and $CaCO_3$ contents.

Plant Height: Mean Plant height ranged between 33.98 cm and 77.60 cm in different sewage sludge treatments (Table 3). There was no significant difference in plant height in various sewage sludge treatments except control and T_1 sewage sludge application) in sandy soil (SO with low $CaCO_3$ contents (5.37%) where plant height was significantly less than other soils with higher $CaCO_3$ contents [$LSD_{0.05}$ of 5.881 (control), 5.950 (T_2), 8.052 (T_3) and 5.146 (T_4)]. The difference in plant height was not significant between S_2 and S3 soils in all the sewage sludge treatments.

Biomass (Fresh Weight) Yield: Mean biomass (fresh weight yield ranged between 0.075-0.525 kg per pot in different sewage sludge treatments (Table 3). The biomass yield was significantly less in S_1 than S_2 and S_3 in all treatment except T-3 receiving 50 Mg ha^{-1} sewage sludge. The results show that higher contents of $CaCO_3$ might hay stimulated plant growth by providing more nutritional elements upon dissolution by reaction with sewage sludge other than those already present in sewage sludge [$LSD_{0.05}$ of 0.077 (T_1), 0.095 (T_2), 0.142 (T_3) and 0.066 (T_4)] However, there was an increasing trend in biomass yield in the heavy textured soil (S_2) than the light textured soils (S_1 and S_3). Overall, it can be concluded from the limited research findings that there is a possibility for obtaining higher biomass yield of sorghum crop in heavy textured oils with sewage sludge when applied as a source of organic matter for the improvement of sandy calcareous oils in an arid environment.

Table 3: Effect of Soils on Plant Growth under Different Rates of Sewage Sludge Application

Oil Type	0 (Control)	25	50	75
	----------kg ha^{-1}----------			
Crop Germination				
Sandy (S_1)	92.5a	95.0a	90.0a	87.5a
Sandy-loam (S_2)	77.5b	77.5a	77.5a	77.5a
Sandy (S_3)	90.0a	90.0a	87.5a	92.5a
Plant Height				
Sandy (S_1)	33.98b	56.38b	69.53a	77.60a
Sandy-loam (S_2)	49.68a	73.20a	69.87a	77.23a
Sandy (S_3)	46.55a	68.00a	75.13a	76.25a
Bioamass Yield (Fresh Weight)				
Sandy (S_1)	0.07b	0.22b	0.37a	0.44b
Sandy-loam (S_2)	0.19a	0.40a	0.49a	0.52a
Sandy (S_3)	0.15ab	0.32a	0.40a	0.50a

Figures in a column followed by the same letter do no differ significantly by $LSD_{0.05}$

Discussion

In considerable research has been accomplished elsewhere higher than the Kingdom of Saudi Arabia on the use of swage sludge on soils and crop. Many investigators have reported a substantial increase in plant growth and biomass production upon sewage sludge application (Hinesly *et al*., 1972; Dowdy and Ham, 1977; Topper and Sabey, 1986; Al-Nahidh, 1991; Kumar and Wahid, 1994). It was found in the present study that there was no adverse effect on crop germination upon sewage sludge application. There was a significant increase in plant height and biomass production an increase in sewage sludge application (ranging from 75 Mg ha^{-1}) than the control treatment. The results are similar to those of Kumar and Wahid (1994), Al-Nahidh (1991), Hinesly *et al*. (1972), Dowdy and Ham (1977) and Topper and Sabey (1986) who reported an increase in plant with and biomass production with the application of sewage sludge.

The study has highlighted the potential use of sewage sludge as a source of organic matter for the improvement productivity of sandy calcareous soils and for a reasonable production of forage crop like sorghum without addition of inorganic fertilizers. However, further stigations are needed to work out the nutritional distribution of sewage sludge for crop production, acumulation of heavy toxic metals in soils and plants and economical dose for application to soils.

Conclusion, there exits a lot of potential for the use of sewage sludge for improving the productivity of sandy soils to minimize the potential environmental hazards reacted from land disposal of sewage sludge and sewage wastes.

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