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EFFECT OF SEWAGE WATER, PHOSPHORUS AND POTASSIUM FERTILIZATION ON ALFALFA YIELD

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ABSTRACT

A field experiment was established at the College of Agriculture Experimental and Research Farm at Dirab, south Riyadh, during 1995-1996 season to study the effect of sewage water irrigation, P and K fertilization on yield of alfalfa (*Medicago sativa* L; var. CUF101) and availability of P and K in the soil. Two different soils in textures were used in this study namely; loamy and sandy soils.

The results showed that application of sewage water resulted in a significant increase in alfalfa dry weight under the various levels of P and K. Irrigation with sewage water gave significantly higher yield of alfalfa than that of well water, regardless of P and K treatments in both soils.

Application of 50, 150, and 250 kg P ha^{-1} gave significantly higher yield of alfalfa grown under well water irrigation. The percent increment in alfalfa dry weight were 16.0, 29.5 and 35.0% in loamy soil and 18.1, 24.3 and 37.3% in the sandy soil. In contrast, the rate of increase due to P application was less pronounced under sewage water irrigation. Application of K either at a lower rate (50 kg K ha^{-1}) or at a higher rate (100 kg ha^{-1}) resulted only in a minor increase in alfalfa yield.

The results indicated that the effect of sewage water irrigation was conspicuous on available P content of the soil and resulted in a higher P plant content even if no P fertilizer was applied. Data for available K in the soil indicated a significant decrease in K level regardless of K addition.

Keywords: Sewage water, well water, P and K fertilization, soil texture, alfalfa

INTRODUCTION

Soils of Saudi Arabia are mostly coarse textured, and characterized by high pH values, high amounts of $CaCO_3$ and low organic matter concentration (Bashour *et al*., 1983). This could result in inadequate nutrient supply and could affect the availability of various nutrients especially P and K.

Alfalfa is extensively cultivated in Saudi Arabia and it accounts for about 30% of the total crop production of the Kingdom (El-Hag *et al.*, 1989). Due to the high requirement of alfalfa to P and K, it is expected that continuous production of alfalfa could result in a significant decline in the soil P and K.(Doran *et al*., 1963 and Nuttall *et al*., 1980). Recent fertilizers trials have provided general information regarding the response of alfalfa to P fertilization (Tag El-Din and Assaeed, 1995). While the effects of P fetilizatation have been studied fairly extensively in various parts of the world, K fertilization of alfalfa did not receive similar efforts. This may be due to the wide spread notion that soil is generally have adequate supply of this element. In a study on some soils of Saudi Arabia, Al-Mashhady and Omar (1979) found that there was no response to potassium fertilization although the potassium level in these soils is very low.

Another problem facing agricultural production in the Kingdom is the scarcity of water as a result of aridity, which characterize the whole region. It is suggested that the use of other non-conventional water resources such as treated water could elevate part of this problem (Al-Tarbaq and El-Dewaih, 1996). In addition to that sewage water supplies the plant with some nutrients and enhances the availability of others (Al-Jaloud, *et al*., 1993).

In the Kingdom of Saudi Arabia most farmers tend to apply large amounts of fertilizers than would be needed. This may lead to accumulation of some of the nutrients added such as P and K. The magnitude of accumulation, however, depends on the type of soil, nature and intensity of cropping and the form and amount of fertilizer added (Schwab *et al.*, 1990; McCollum, 1991). On the other hand, the depletion or fixation of the available P and K might take place in certain types of soil if intensive cropping is practiced. Although application of high amounts of P and sometimes K fertilizers to alfalfa is a common practice in the Kingdom of Saudi Arabia, yet diagnostic advice to put forward a sound fertilization programme is practically unavailable.

Fertilizers experiments, using a single fertilizer and under a limited conditions, give only a partial picture of crop and soil responses to the applied nutrient. Therefore, experiments that utilize multiple fertilizers provide an avenue to view the response of crops to multiple factors and obtain a border understanding of the various factors. This could help in modification of the current practices to maximize the fertilizer use efficiency for sustainable crop production. Hence, this study aims to investigate alfalfa response to various P and K applications and irrigation with well water and treated sewage water in two soils.

MATERIALS AND METHODS

A field experiment was conducted at the College of Agriculture Experimental and Research Farm at Dirab, south Riyadh. The climate is sub-tropical hyper-arid type. Average annual precipitation is about 100 mm. The experiment was initiated during 1995/1996 season, to determine the effects of two sources of water (Treated sewage water (TW) and well water (WW), four P rates applied as diammonium phosphate (DAP) (0, 50, 150, 250 Kg P ha^{-1}) and three K rates (0, 50, 100 kg K ha^{-1}) applied as K_2SO_4 on yield of alfalfa (*Medicage sativa* L; var CUF 101) and availability of P and K in the soil.

Two soils were used for this study namely; loamy and sandy soils. Some chemical and physical properties are given in Table (1). The experimental design was a split-split plot design with four replicates. The plot area was 3x3m , the water source represented the main plots, the P fertilization was assigned to the sub plots and K fertilization was assigned to the sub-sub plots. (DAP, 46% P_2O_5) and potassium in the form of potassium sulphate at the previously mentioned rates were added as one dose before the cultivation. Nitrogen in the form of urea (46%N) was added at a rate of 20 kg ha^{-1} after each cut. Irrigation system with two water types (treated water (T.W) and well water (W.W) was performed by using the surface irrigation system for each treatment. The chemical composition of the two irrigation waters is given in Table 2. The volume of water varied with each irrigation time due to the variation in the season temperature. Cuts were taken monthly, and a total of ten cuts were taken by the end of the experiment. Each plot was harvested with a mower at a height of approximately 5 cm. The forage fresh yield for each plot was collected and weighted and a sub-sample weighing about 200-300 gm was taken from fresh forage, oven dried at 70ºC and weighted to estimate dry matter %. Forage dry yield was calculated on dry weight basis. Surface soil samples (0-30 cm) before sowing and after harvesting were prepared and analyzed for available P and K according to the procedure described by Soltanpour and Schwab (1977). P was determined colorimetrically and K was determined by a flame photometer. The data obtained were subjected to statistical analysis using Statistical Analysis System-Analysis of Variance (SASI, 1982).

Table 1: Some physical and chemical characteristics of the experimental soils.

	Clay	Silt	Sand	Texture	$CaCO_3$ %	pH (Paste)	EC* dSm^{-1}	Available nutrients mg kg^{-1}		
								N	P	K
Soil 1 (Loamy)	21	46	33	Loamy	37.6	7.5	8.26	54	6.35	296
Soil 2 (Sandy)	4	5	91	Sandy	24.6	7.8	0.85	28.5	9.15	128

*** In paste extract**

Table 2: Chemical composition of irrigation water.

Parameters	T.W[a]	WW[b]
P mg L^{-1}	7	Tr
K mg L^{-1}	14	22
EC (dSm^{-1})	1.3	6.2

T.W[a] = Treated waste water W.W.[b]= Well water Tr.= Traces

RESULTS AND DISCUSSION

Effect of treatments on alfalfa dry weight

The effect of irrigation with treated municipal waste water, P, K fertilization and soil texture on alfalfa (*Medicago sativa* L. var. CUF 101) dry weights are presented in Table 3. The data demonstrated that total dry yield of 10 cuts in the loamy soil, under treated sewage irrigation water varies between 36.85-44.66 tons ha^{-1} and between 26.34-41.76 tons ha^{-1} under well water. The corresponding yield data for the sandy soil were 42.45-47.11 tons ha^{-1} and 23.13-42.04 tons ha^{-1}, respectively.

Table 3: Effect of irrigation water quality, P , K fertilization and soil texture on Alfalfa dry yield tons ha^{-1}

Treatments		K	Cut 1-5	Cut 6-10	Cut 1-10	Cut 1-5	Cut 6-10	Cut 1-10
Water	P		Sandy soil				Loamy soil	
T.W	P0	K0	24.80	17.74	42.54	21.86	14.99	36.85
		K1	25.15	17.57	42.72	23.90	16.11	40.01
		K2	24.55	18.09	42.64	25.04	16.87	41.91
	P1	K0	24.52	18.59	43.11	23.14	16.36	39.50
		K1	26.62	17.48	44.10	23.88	16.52	40.40
		K2	26.08	19.51	45.59	24.63	16.09	40.72
	P2	K0	27.86	19.25	47.11	25.13	15.91	41.04
		K1	26.85	19.08	45.93	25.97	15.34	41.31
		K2	24.94	19.67	44.61	26.61	15.52	42.13
	P3	K0	26.11	18.93	45.04	27.03	15.26	42.29
		K1	26.91	19.98	46.89	26.05	14.67	40.72
		K2	27.62	19.44	47.06	28.54	16.12	44.66
W.W	P0	K0	15.59	12.51	28.10	16.45	9.89	26.34
		K1	16.99	15.14	23.13	19.42	10.76	30.18
		K2	16.43	14.17	30.60	20.84	13.28	34.12
	P1	K0	18.01	15.22	33.23	22.55	12.17	34.72
		K1	18.28	17.13	35.41	22.53	12.57	35.10
		K2	20.96	17.38	38.34	22.63	12.66	35.29
	P2	K0	19.63	16.61	36.24	23.66	14.82	38.48
		K1	20.59	16.63	37.22	24.10	15.37	39.47
		K2	21.92	17.49	39.41	24.40	14.98	39.38
	P3	K0	22.37	18.28	40.65	23.55	15.70	39.25
		K1	22.94	19.10	42.04	24.82	16.82	41.64
		K2	23.57	18.41	41.98	25.38	16.38	41.76
L.SD (0.05)			1.07	1.35	1.79	1.09	1.31	1.98

T.W: Treated Water; W.W: Well Water

The yield obtained is comparatively higher than that recorded for other local varieties of alfalfa grown on some soils of Saudi Arabia (Tag El-Din and Assaeed, 1995). This diversity may be attributed to the differences in the cultivated varieties. Alfalfa (CUF 101) as a hybrid has been proved to produce higher yields.

The yield was significantly higher in the treated sewage water irrigated plots. (Table 4). The increases in alfalfa dry yield were 12.8% in the loamy soil and 23.4% in the sandy soil. Irrigation with sewage water gave significantly higher yield of alfalfa than that of well water regardless of P and K treatments. This indicated that nutrients present in the treated sewage water improved dry matter yield of alfalfa even though various level of PK were applied to meet crop nutrients needs. Similar results were reported by Sollenbergs (1981), Saenz (1987) and Al-Jaloud *et al*. (1993). Also, This may be attributed to the low salinity of treated sewage water.

The data in Table 5 indicated that application of 50, 150, and 250 kg P ha^{-1} gave significantly higher yield of alfalfa grown under well water irrigation. The percent increment in alfalfa dry weight were 16.0, 29.5 and 35.3% in loamy soil and 18.1, 24.3, and 37.1% in the sandy soil. In contrast, the rate of increase due to P application was less pronounced under sewage water irrigation and amounted only to (1.5, 4.8, 7.4%) and (3.8, 7.6, 8.6%) in the sandy and loamy soils, respectively. The increase in dry matter yield with

P application under well water irrigation may be attributed to the lack of available forms of P in the well water (Table 2) as compared to sewage water. The usefulness of P and its effectiveness in increasing the yield of alfalfa were reported by El-Hag *et al.* (1989); Tag El-Din and Assaeed, (1995).Their results demonstrated that application of P fertilizer increased dry weight of alfalfa significantly. It should be noted here that no significant differences in alfalfa yield was obtained by P addition under sewage water irrigation.

Table 4: Effect of irrigation water on Alfalfa dry yield tons ha^{-1}

Soil	Treatments	Cuts		
		1-5	6-10	1-10
Loamy Soil	T.W	25.15	15.81	40.96
	W.W	22.52	13.78	36.31
	LSD(0.05)	1.21	0.68	1.15
Sandy Soil	T.W	26.00	18.78	44.78
	W.W	19.77	16.53	36.30
	LSD(0.05)	0.53	0.84	1.18

Table 5: Effect of P fertilization on Alfalfa dry yield tons ha^{-1}

Treatments		P	Cuts		
Soil	Water		1-5	6-10	1-10
Loamy soil	T.W	P0	23.60	15.99	39.59
		P1	23.88	16.32	40.20
		P2	25.90	15.59	41.49
		P3	27.20	15.35	42.52
	W.W	P0	18.90	17.48	30.21
		P1	22.57	19.51	35.04
		P2	24.05	19.25	39.11
		P3	24.58	19.08	40.88
		L.S.D(0.05)	0.69	0.85	1.09
Sandy Soil	T.W	P0	24.83	19.67	42.63
		P1	25.74	18.93	44.26
		P2	26.55	19.98	45.88
		P3	26.88	19.44	46.32
	W.W	P0	16.33	13.94	30.27
		P1	19.08	16.68	35.76
		P2	20.71	16.91	37.62
		P3	22.96	18.60	41.50
		L.S.D(0.05)	0.63	0.72	1.06

The effect of K applications on alfalfa yield are shown in Table (6). The results indicated that application of K either at lower rate (50 kg K ha^{-1}) or at higher rate (100 kg K ha^{-1}), resulted only in a trifle increase in alfalfa yield. The high K treatment in the sandy soils gave only 1.2% increases whereas the lower rate gave only 1.04% increases under sewage irrigation water. As for the loamy soil, the percent increases were 1.7 and 6.1%. The corresponding values for the well water irrigation were 8.5 and 5.5% for the high and low K rates, respectively. The lack of response to K fertilization may relate to the higher amount of K being added with irrigation water, particularly in the sandy soil. Furthermore, it should be noted that the K content in the studied soils is fairly adequate (Table 1). In this respect some investigators have demonstrated that addition of K fertilizers might not give a favorable response if the K content in the soil exceeded 330 kg ha^{-1} (Lanyon and Smith, 1985). The present results are also in agreement with those obtained by Jones *et al.* (1974).

Table 6: Effect of K fertilization on Alfalfa dry yield tons ha^{-1}

Treatments			**Cuts**		
Soil	**Water**	**K**	**1-5**	**6-10**	**1-10**
Loamy Soil		K0	24.29	15.63	39.92
	T.W	K1	24.95	15.66	40.61
		K2	26.21	16.15	42.36
		K0	21.55	13.14	34.69
	W.W	K1	22.72	13.88	36.60
		K2	23.31	14.33	37.64
		L.S.D(0.05)	0.55	0.66	0.99
Sandy Soil		K0	25.82	16.63	44.45
	T.W	K1	26.38	18.53	44.91
		K2	25.80	19.18	44.98
		K0	18.90	15.74	34.64
		K1	19.70	16.99	36.69
	W.W	K2	20.72	16.86	37.58
		L.S.D(0.05)	0.54	0.68	0.89

The data presented in Table (7) gave the stepwise regression for the various factors under study. These results indicated that dry yields of alfalfa were significantly affected by the various treatments. The data show that P addition contributed 37.8% of the total effect for the loamy soil. This value was further increased to 69.8% via the irrigation water treatment. However, the K treatments contributed only 7.1% increment. On the other hand, the values obtained for the sandy soil were 62.4% increase due to irrigation treatment; it increased to 86.4% when P was added. Application of K resulted in only a minor increase in alfalfa yield and amounted only to 1.8%. In general, our results clearly show that addition of sewage water caused overwhelming beneficial effect on alfalfa yield especially in sandy soils.

Table 7: Stepwise regression for the various treatments

Dependent	Independent variables	R^2	Δ R^2%
	Water	32.0	
Loamy Soil	Water+Phosphorus	69.8	37.8
	Water+Phosphorus +Potassium	76.9	7.1
	Water	62.4	
Sandy Soil	Water+Phosphorus	86.4	24.0
	Water+Phosphorus +Potassium	88.2	1.8

Effect of treatments on available P and K in soil

The results (Fig. 1) demonstrated that the initial level of available P in the surface soil (0-30cm), under well water irrigation, markedly declined in the control plots as well as in the P treated plots in both soils. The soil test P declined from 6.4 to 1.11, 1.77, 2.36 and 3.36 mg P kg^{-1} in the control and treatments P1. P2, and P3 respectively, in the loamy soil. The corresponding decrease in the sandy soil was from 9.2 to 2.23, 3.2, 4.9 and 7.9 mg P kg^{-1}. Earlier, Sample et al. (1980) mentioned that $CaCO_3$ content in the soil may lead to great fixation of the added P. The presence of high $CaCO_3$ in these soils may explain the great decline of P content in the tested soil. Also, Al-Sewailem (1999) reflected this in his study on some calcareous soils in Saudi Arabia.

Another factor that can play an important role in fixation of added P is the method of application (Murphy and Dibb, 1986). In this connection Sample *et al.* (1980) demonstrated that banding P application was more efficient than broadcasting. Because banding will reduce soil fertilizer contact and ultimately raise the fertilizer P efficiency. It is postulated that organic P in the sewage water is readily available and does not tend to be fixed in these calcareous soils as compared to mineral P fertilizers. Fardeau (1996) in his study on the dynamics of phosphate in soils stated that the P contained in biological wastes is as available as P of water-soluble fertilizer. The results indicated clearly that sewage water irrigation resulted in the accumulation of extractable P in the surface soil which increased from the initially low status to high and very high levels as indicated by the soil test data even if no fertilizer was applied. The magnitude of accumulation was commensurate with the volume of treated water applied. The amount of fertilizer required to maintain the initial soil test can be determined graphically by plotting soil test level as a function of the applied fertilizer rate (Fixen and Ludwick, 1983). In the present work, the amount of the fertilizer required to maintain the soil P test at its initial level in the studied soils was estimated to be 607 and 319 kg P ha^{-1} in the loamy and sandy soil, respectively. Such rate is much higher than the previously recommended by Al-Mustafa *et al*. (1995) for some calcareous soils in Saudi Arabia. Such difference may be related to higher P fixation in the studied location, than other areas.

fig1

On the other hand, this study revealed a very interesting phenomenon with respect to sewage water irrigation, which resulted in higher P content. On the basis of the present results, it is not possible to establish the cause of this effect. However two possibilities can be suggested. First, addition of treated sewage water could have served as a readily available source of phosphorus. Second, the addition of sewage water may enhance some chemical and physical properties of the soil and ultimately increase the release of phosphate ions into soil and hence improved the availability of P to plants.

Soil data for available K (Fig 2), again indicated a marked decrease in K levels regardless of K addition. Such decrease in K content despite large amounts of added K in the treated plot is attributable to its large removal by the crop during the 10 cuts. Similar observations were recorded by Al-Mustafa *et al.* (1995).

In conclusion it may be stated that:

1-Alfalfa yield increased significantly by sewage water irrigation and addition of P fertilizer, addition of P was more pronounced under well water irrigation.

2-Nutrients present in treated sewage water proved to be useful in increasing the dry matter yield of alfalfa.

3-Phosphorus present in sewage water results in the accumulation of available P in the soil, the magnitude of which depends on the volume of added water

4-The use of sewage water for irrigation can help to reduce P fertilizer dose as it results in greater build up of available P in the soil.

5-Although alfalfa yield was not significantly affected by K additions, yet it is important to add K fertilizers to compensate for K depletion

fig2

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تأثير مياه الصرف الصحي والتسميد الفوسفاتي والبوتاسي على إنتاجية البرسيم الحجازي

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تم اجراء تجربة حقلية في محطة الأبحاث والتجارب الزراعية بديراب جنوب مدينة الرياض خلال عام ١٩٩٦/١٩٩٥ وذلك لدراسة تأثير الري بمياه الصرف الصحي والتسميد الفوسفاتي والبوتاسي على إنتاجية محصول البرسيم الحجازي (صنف كاف ١٠١)، وعلى تيسر عنصري الفوسفور والبوتاسيوم في التربة.تمت الدراسة في تربتين مختلفتي القوام (طميية ورملية).

أوضحت النتائج أن إضافات مياه الصرف الصحي أدت إلى زيادة معنوية في إنتاجية البرسيم الحجازي لكلا التربتين مقارنةً بمياه الآبارعند كل معدلات الإضافة من الفوسفور والبوتاسيوم. أدت إضافات الفوسفور بمعدلاته المختلفة (٥٠، ١٥٠، ٢٥٠ كجم P/هكتار) تحت نظام الري بمياه الآبار إلى زيادة معنوية في المادة الجافة لمحصول البرسيم الحجازي. وكانت النسبة المئوية للزيادة ١٦,٠، ٢٩,٥، ٣٥% في التربة الطميية و ١٨,١، ٢٤,٣، ٣٧,٣% في التربة الرملية. وبالمقارنة نجد أن تأثير إضافات الفوسفور كان أقل وضوحاً تحت نظام الري بمياه الصرف الصحي.

وأوضحت النتائج أن إضافة البوتاسيوم بمعدليه (٥٠، ١٠٠ كجم K /هكتار)، أدى إلى حدوث زيادة طفيفة في محصول البرسيم الحجازي في كلا التربتين وتحت نوعي مياه الري.

أشارت النتائج إلى أن استخدام مياه الصرف الصحي في الرى أدى إلى زيادة كبيرة في محتوى التربة من الفوسفور الميسر حتى بدون إضافة أسمدة فوسفاتية، بينما حدث انخفاض معنوى في مستوى البوتاسيوم فى كلا التربتين بغض النظر عن إضافة أسمدة بوتاسية.