Effect of Water Qualities and Fertilizer Levels on Nutrient Uptake by Wheat

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The addition of higher doses of fertilizers has been suggested as one approach for having satisfactory growth under saline conditions (Ravikovitch and Porath [7]). Lal [5] reported that fertilization tended to mitigate the adverse effect of higher levels of EC and SAR of waters on crop growth and yield to some extent. However, at the highest level of EC or SAR of waters no response was observed.

Many experiments have been conducted to study the effect of fertilizers on plant composition and nutrient uptake but only a few references are available regarding the interactive effects of soil salinity and fertility on plant composition and nutrient uptake by the crops. Since the use of fertilizers has been suggested for facilitating crop growth on saline soils or with saline waters, it becomes all the more important to have the information on the uptake of nutrients as affected by salinity-fertility interactions.

As the same type of water does not have identical effects on various soil types it was also thought desirable to investigate nutrient uptake on 4 different light textured soils which cover the larger area of the arid and semi-arid parts of Rajasthan.

Experimental

Four texturally different soils i.e. sandy soil (S_1), loamy sand (S_2), sandy loam (S_3) and loam (S_4) were selected for the pot experiment. Their physical and chemical properties are given in Table 1. An equal amount (9.0 kg) of soil was filled in each pot according to the plan of the experiment. The experiment was conducted under drained condition.

By taking the combinations of three salt concentrations (E_1 — 6.0, E_2 — 21.0, E_3 — 48.0 me/l, approximate EC being 0.6, 2.1 and 4.8 mmhos/cm, respectively) and three SAR levels (R_1 — 8.0, R_2 — 20.0 and R_3 — 32.0), nine types of waters were prepared. The 10th water having EC 0.2 mmhos/cm and SAR 2.13 was taken as control. The chlorides of sodium, calcium and magnesium were used to have the desired level of EC and SAR of the waters. The composition of these waters is given in Table 2.

Ten seeds of wheat variety RS 31—1 were sown in each pot but only five plants were maintained after their germination. The fertilizer application was done at two levels viz. lower dose (F_1 — 30, 30 and 15 kg/ha nitrogen, P_2O_5 and K_2O respectively) and higher dose (F_2 — 60, 60 and 30 kg/ha nitrogen,

P_2O_5 and K_2O respectively). Ammonium sulphate, superphosphate and muriate of potash were used as carriers of nitrogen, phosphorus and potassium, respectively.

All in all nine irrigations were given to the crop, and 50 mm of water was applied in each irrigation. Thus, altogether 450 mm water was used in each case.

After harvesting, grain and straw samples were analysed for nitrogen (KJELDAHL's method), phosphorus (Method No. 61 of USDA Handbook No. 60 [9]), calcium plus magnesium (CHENG and BRAY's method [3]), sodium and potassium (flame photometer). The data for the uptake of each nutrient were statistically analysed by using the analysis of variance.

Table 1

Physical and chemical characteristics of the soil

Soil characteristics	Soil types			
	S_1	S_2	S_3	S_4
1. Textural class	Sandy soil	Loamy sand	Sandy loam	Loam
2. Hydraulic conductivity (cm/hr)	8.48	6.69	2.98	1.55
3. Calcium carbonate (%)	0.75	1.00	1.50	2.00
4. pH (1 : 2.5)	8.10	8.30	8.35	8.40
5. Total nitrogen (%)	0.03	0.03	0.03	0.04
6. Total P_2O_5 (%)	0.08	0.10	0.10	0.11
7. Available P_2O_5 (mg/100 g)	1.68	1.58	1.75	1.84
8. Total K_2O (%)	0.32	0.33	0.35	0.38
9. Available K_2O (mg/100 g)	4.76	5.72	6.02	6.25
10. Organic carbon (%)	0.24	0.25	0.28	0.32
11. EC of saturation extract (mmhos/cm)	2.20	2.50	3.12	3.35
12. SAR	8.80	11.35	11.95	14.37
13. ESP	9.30	13.70	15.00	18.00

Table 2

Composition of irrigation waters

Waters	Symbol	EC	SAR	Na	Ca	Mg	Class (USSL 1954)
				me/l			
1. E_1R_1	W_1	0.6	8.02	5.17	0.62	0.21	C_2S_2
2. E_1R_2	W_2	0.6	19.91	5.83	0.13	0.04	C_2S_4
3. E_1R_3	W_3	0.6	31.80	5.93	0.05	0.02	C_2S_4
4. E_2R_1	W_4	2.1	8.04	14.50	4.90	1.60	C_3S_2
5. E_2R_2	W_5	2.1	19.85	19.14	1.40	0.46	C_3S_4
6. E_2R_3	W_6	2.1	31.90	20.20	0.60	0.20	C_3S_4
7. E_3R_1	W_7	4.8	8.03	26.40	16.20	5.40	C_4S_3
8. E_3R_2	W_8	4.8	19.93	39.96	6.03	2.01	C_4S_4
9. E_3R_3	W_9	4.8	31.86	44.16	2.90	0.96	C_4S_4
10. Good water	W_{10}	0.2	2.13	1.28	0.54	0.18	C_1S_1

Table 3

Effect of different qualities of irrigation water, ECiw, SARiw, fertilizer levels and soil types on the uptake of nitrogen, phosphorus, potassium, calcium, magnesium and sodium (mg/pot)

Treatment	N	P	K	Ca	Mg	Na
W_1	336.0	70.3	371.5	37.5	32.3	33.1
W_2	288.5	60.3	298.2	28.2	25.2	63.9
W_3	250.2	49.7	248.8	21.0	21.7	96.7
W_4	298.0	56.5	300.1	34.6	30.9	56.8
W_5	254.5	48.7	231.7	25.4	24.3	70.8
W_6	219.6	39.8	181.0	19.0	19.1	99.1
W_7	258.7	46.3	223.2	30.0	28.3	73.0
W_8	229.1	38.1	182.2	22.4	22.6	87.3
W_9	201.5	30.6	142.9	15.6	17.9	103.2
W_{10}	325.6	67.8	348.0	35.1	30.1	15.0
S.Em.±	6.888	5.024	10.490	0.942	0.974	3.302
C.D. at 5%	19.414	14.160	29.566	2.655	2.746	9.307
E_1	291.6	60.1	306.2	28.9	26.4	64.6
E_2	257.4	48.4	237.6	26.3	24.8	75.6
E_3	229.7	38.3	182.8	22.7	22.9	87.8
S.Em.±	3.976	2.901	6.057	0.544	0.562	1.906
C.D. at 5%	11.206	8.176	17.072	1.532	1.585	5.372
R_1	297.6	57.7	298.3	34.0	30.5	54.3
R_2	257.4	49.0	237.4	25.4	24.1	74.0
R_3	223.8	40.0	190.9	18.5	19.6	99.7
S.Em.±	3.976	2.901	6.057	0.544	0.562	1.906
C.D. at 5%	11.206	8.176	17.072	1.532	1.585	5.372
F_1	237.6	43.7	222.4	23.7	22.5	73.0
F_2	294.7	57.9	283.1	30.0	28.0	66.8
S.Em.±	3.080	2.247	4.691	0.421	0.436	1.476
C.D. at 5%	8.681	6.333	13.221	1.187	1.227	4.160
S_1	273.2	53.9	273.8	27.8	26.9	57.0
S_2	279.3	54.6	266.7	28.5	27.4	58.4
S_3	264.1	50.2	247.0	27.0	23.9	78.5
S_4	248.0	44.5	223.5	24.2	22.7	85.4
S.Em.±	4.355	3.178	6.327	0.596	0.616	2.088
C.D. at 5%	12.274	N.S.	17.833	1.679	1.736	5.885
Significant interactions (at 5%)	EF, RF, WF, ES, WS	—	EF, RF, WF, ES, RS, WS	EF, RF, WF, ES, RS, WS	ES, WS	ER

Results and discussion

The effect of different qualities of irrigation water, ECiw (EC of irrigation water), SARiw (SAR of irrigation water), fertilizer levels and soil types on nutrient uptake and percentage combination is summarized in Tables 3 and 4.

The uptake of nitrogen, phosphorus, potassium, calcium and magnesium decreased significantly with an increase in the EC and SAR level of irrigation waters while the reverse trend was observed in the case of sodium (Table 3). With increasing levels of salinity of waters the phosphorus and potassium con-

Table 4

Effect of different qualities of irrigation water, ECiw, SARiw, fertilizer levels calcium and sodium in grain and straw of wheat (per cent), on grain and

Nutrients		W_1	W_2	W_3	W_4	W_5	W_6	W_7	W_8	W_9
Nitrogen	Grain	2.43	2.45	2.48	2.47	2.49	2.53	2.56	2.57	2.59
	Straw	0.55	0.56	0.57	0.57	0.59	0.60	0.60	0.62	0.63
Phosphorus	Grain	0.52	0.52	0.49	0.49	0.49	0.47	0.47	0.45	0.42
	Straw	0.11	0.12	0.11	0.10	0.10	0.10	0.10	0.09	0.08
Potassium	Grain	0.55	0.52	0.45	0.52	0.45	0.39	0.41	0.38	0.34
	Straw	1.63	1.53	1.43	1.55	1.42	1.31	1.41	1.30	1.14
Calcium	Grain	0.04	0.04	0.03	0.05	0.04	0.04	0.05	0.04	0.03
	Straw	0.17	0.15	0.14	0.18	0.16	0.14	0.19	0.17	0.13
Magnesium	Grain	0.17	0.17	0.16	0.19	0.18	0.17	0.19	0.18	0.17
	Straw	0.09	0.08	0.07	0.09	0.09	0.08	0.11	0.09	0.08
Sodium	Grain	0.03	0.06	0.10	0.06	0.09	0.13	0.11	0.16	0.18
	Straw	0.16	0.37	0.68	0.32	0.48	0.83	0.50	0.70	1.00
Grain yield (g/pot)		9.36	7.95	6.86	8.09	6.94	5.88	6.90	6.09	5.34
Straw yield (g/pot)		19.64	16.54	13.75	16.72	13.89	11.82	13.66	11.95	10.09
EC of saturation extract (mmhos/cm)		1.90	2.03	2.28	2.99	3.20	3.61	5.22	6.28	6.46
ESP		16.61	29.43	39.04	19.67	31.52	42.57	19.97	33.01	44.44
pH (1 : 2.5)		8.43	8.88	9.21	8.28	8.74	9.02	8.13	8.56	8.32

tents of grain and straw decreased while the nitrogen, calcium, magnesium and sodium contents tended to increase. With a rise in the SAR of waters the nitrogen and sodium contents of grain and straw increased while others, viz. phosphorus, potassium, calcium and magnesium decreased. Since a marked reduction in the grain and straw yields of wheat was observed with increasing level of the EC or SAR of irrigation waters (Table 4), the decrease in the uptake of nitrogen, phosphorus, potassium, calcium and magnesium was the natural outcome. Sodium uptake increased in spite of the reduction in yields due to high EC and SAR of irrigation waters. This led to the marked increase in the sodium content of grain and straw.

The increase in the nitrogen content of grain and straw is due to the accumulation of proteins under saline conditions (Strogonov & Oknina [8]). These accumulated proteins are not readily available for the growth of the plants due to restricted movement. A minor change in the nitrogen content with a possible trend of higher nitrogen content at higher salinity and alkalinity levels shows that nitrogen was not a limiting factor in the growth of the plants. Abdel Salam and El Nour [1] also reported an increase in the nitrogen content in corn stalks to the extent of 50 per cent if salinity was raised from 1 to 3 atmosphere osmotic pressure (EC 2.8 to 8.3 mmhos/cm), while increase in the nitrogen content on raising the SAR from 2.3 to 19.3 was 39.5 per cent at a salinity level of 1 atmosphere osmotic pressure.

The reduction in the phosphorus content with increasing levels of SAR may be attributed to the higher pH values of the soils caused by irrigation

and soil types on the contents of nitrogen, phosphorus, potassium, straw yield and on EC, ESP and pH of soil (after harvest samples)

W_{10}	E_1	E_2	E_3	R_1	R_2	R_3	F_1	F_2	S_1	S_2	S_3	S_4
2.45	2.45	2.50	2.57	2.48	2.50	2.53	2.48	2.52	2.48	2.48	2.50	2.55
0.58	0.56	0.59	0.62	0.57	0.59	0.60	0.56	0.61	0.56	0.57	0.59	0.62
0.52	0.51	0.48	0.45	0.49	0.48	0.46	0.47	0.50	049	0.49	0.48	0.47
0.11	0.11	0.10	0.09	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.10	0.09
0.69	0.51	0.45	0.38	0.49	0.45	0.39	0.42	0.48	0.46	0.45	0.46	0.43
1.61	1.53	1.43	1.28	1.53	1.42	1.29	1.38	1.48	1.49	1.47	1.40	1.36
0.05	0.04	0.04	0.04	0.05	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04
0.17	0.15	0.16	0.16	0.18	0.16	0.14	0.16	0.16	0.16	0.16	0.16	0.16
0.18	0.17	0.18	0.18	0.18	0.18	0.17	0.17	0.18	0.18	0.18	0.17	0.17
0.08	0.08	0.09	0.09	0.10	0.09	0.08	0.08	0.09	0.09	0.09	0.09	0.08
0.03	0.06	0.10	0.15	0.07	0.10	0.14	0.10	0.09	0.07	0.07	0.11	0.14
0.07	0.40	0.54	0.73	0.33	0.52	0.83	0.57	0.45	0.37	0.38	0.54	0.73
8.85	8.06	6.97	6.11	8.12	6.99	6.03	6.60	7.86	7.57	7.61	7.12	6.60
18.62	16.64	14.15	11.90	16.68	14.13	11.89	13.34	16.00	15.24	15.59	14.69	13.16
1.50	2.07	3.26	5.99	3.37	3.83	4.12	3.45	3.65	2.10	2.54	4.14	5.42
8.04	38.36	31.25	32.47	18.75	31.37	42.01	28.00	28.85	23.82	28.62	29.34	31.93
7.32	8.84	8.68	8.54	8.28	8.73	9.05	8.58	8.52	8.40	8.57	8.60	8.62

with waters having higher SAR values (Table 4). It is well known that the availability of phosphorus is adversely affected by higher pH values. The decrease in the potassium content of grain and straw caused by irrigation with waters of high EC and SAR is due to the increase in the concentration of sodium in the soil solution or on the adsorbing complex (Table 4). The high concentration of sodium restricts the absorption of potassium. HEIMAN [4] stated that sodium-potassium relationship may be synergistic or antagonistic depending upon the ratio between them. Under saline conditions, antagonism is predominant. In this study at higher SAR values, the sodium/potassium ratio was excessively high resulting in a regular decrease in potassium uptake and content with increasing SAR of water. A decrease in the calcium and magnesium contents in straw and grain with increasing SAR is due to the depression in their absorption. The increase in the sodium content of grain and straw with increasing EC and SAR of irrigation waters may be attributed to an increase in the sodium concentration and its proportion in the soil solution and on the adsorbing complex which result in the increased absorption of sodium by plants. ABDEL SALAM and OSMAN [2] also observed a reduction in the potassium content and an increase in the sodium content of barley stalk with rising SAR of irrigation water.

The uptake of nitrogen, phosphorus, potassium, calcium and magnesium and their contents in grain and straw were higher with the higher dose than the lower dose of fertilizers while the sodium content of grain and straw was decreased by application of fertilizers (Tables 3 and 4). With increasing level

Table 5

Interactive effect of EC levels of irrigation water and fertilizer levels (EF) and SAR levels of irrigation water and fertilizer levels on the uptake of nitrogen, potassium and calcium (mg/pot)

Fertilizer levels	EC levels of irrigation water			SAR levels of irrigation water		
	E_1	E_2	E_3	R_1	R_2	R_3
Nitrogen uptake						
F_1	250.6	233.0	217.6	262.1	233.0	206.2
F_2	332.6	281.8	241.8	333.1	281.8	241.3
S.Em.±	5.623			5.623		
C.D. at 5%	15.848			15.848		
Potassium uptake						
F_1	265.8	208.3	172.3	255.6	210.3	180.6
F_2	346.5	266.9	193.3	341.0	264.4	201.2
S.Em.±	8.567			8.567		
C.D. at 5%	24.146			24.146		
Calcium uptake						
F_1	24.6	23.3	21.3	29.5	22.8	16.9
F_2	33.3	29.4	24.0	38.6	28.0	20.1
S.Em.±	0.769			0.769		
C.D. at 5%	2.168			2.168		

Table 6

Interactive effect of qualities of irrigation water and fertilizer levels (WF) on the uptake of nitrogen, potassium and calcium (mg/pot)

Irrigation waters	Nitrogen uptake		Potassium uptake		Calcium uptake	
	F_1	F_2	F_1	F_2	F_1	F_2
W_1	279.8	392.2	303.8	439.3	30.8	44.2
W_2	248.6	328.5	254.4	341.9	24.4	32.1
W_3	223.4	277.0	239.3	258.3	18.5	23.5
W_4	263.5	332.6	258.9	341.3	29.9	39.3
W_5	233.5	275.6	205.0	258.3	22.8	28.1
W_6	202.1	237.2	161.0	201.0	17.1	20.8
W_7	243.0	274.4	204.1	242.4	27.8	32.3
W_8	216.9	241.2	171.4	193.1	21.1	23.6
W_9	193.0	209.9	141.4	144.3	15.1	16.1
W_{10}	272.8	378.5	285.1	411.0	29.8	40.3
S.Em.±	9.741		14.838		1.332	
C.D. at 5%	27.455		41.821		3.754	

of salinity or alkalinity of waters, the nitrogen, potassium and calcium uptake decreased but at every level of either EC or SAR, their uptake was higher with the higher dose of fertilizers (Tables 5 and 6). However, the higher dose of fertilizers could not improve significantly the uptake of nitrogen and potassium at the highest level of EC or SAR of irrigation water. The results indicate that the higher dose of fertilizers tended to counteract the adverse effect

Table 7

Interactive effect of EC of irrigation water and soil types (ES) and SAR of irrigation water and soil types (RS) on the uptake of nitrogen, potassium, calcium and magnesium (mg/pot)

Soil types	EC levels of irrigation water			SAR levels of irrigation water		
	E_1	E_2	E_3	R_1	R_2	R_3
Nitrogen uptake						
S_1	285.5	267.6	256.2	Not significant		
S_2	300.7	274.1	250.6			
S_3	292.3	256.0	222.9			
S_4	287.7	232.0	189.2			
S.Em.±	7.953					
C.D. at 5%	22.416					
Potassium uptake						
S_1	319.6	260.0	226.8	305.8	259.1	241.6
S_2	301.3	263.4	216.9	304.1	263.7	213.8
S_3	306.7	234.8	165.0	300.0	233.9	172.6
S_4	297.1	192.1	122.5	283.2	192.8	135.6
S.Em.±	12.110			12.110		
C.D. at 5%	34.132			34.132		
Calcium uptake						
S_1	27.7	27.8	26.7	34.0	26.9	21.2
S_2	29.1	28.9	26.2	34.5	28.1	21.6
S_3	30.0	26.5	21.8	34.3	25.6	18.3
S_4	28.9	22.2	16.0	33.3	20.8	13.0
S. Em.±	1.087			1.087		
C.D. at 5%	3.064			3.064		
Magnesium uptake						
S_1	25.9	26.6	27.9	Not significant		
S_2	27.4	27.4	26.8			
S_3	24.8	24.1	21.1			
S_4	27.5	21.0	16.0			
S.Em.±	1.124					
C.D. at 5%	3.168					

of salinity or SAR of water on their uptake only up to the medium levels. At their highest levels the beneficial results of fertilization may be negated.

An increase in the straw and grain yields and in the contents of nitrogen, phosphorus, potassium, calcium and magnesium with increasing dose of fertilizers resulted in a higher uptake of these elements. The increase in the contents of nitrogen, phosphorus, potassium and calcium of straw and grain is caused by the rise in their concentrations in the soil solution due to the application of fertilizers. At higher fertility level, the sodium content of straw and grain decreased due to the increased concentration of potassium in the soil solution caused by the addition of potassic fertilizers. LUNIN and GALLATIN [6] reported an increase in the contents of phosphorus, potassium, calcium and magnesium to the extent of 17.6, 30.2, 38.6 and 15.2 per cent respectively and a decrease in the sodium content of bean leaves to the extent of 8.3 per cent by the application of phosphorus and potassium at the EC level of 6.5 mmhos/cm as compared to those where no fertilizer was added. These findings are also supported by RAVIKOVITCH and PORATH [7] who observed an increase in the uptake of nitrogen and phosphorus with the application of higher quantities of fertilizers on salinized soils.

The effect of interactions-ES on the uptake of nitrogen, potassium, calcium and magnesium and RS on the uptake of potassium and calcium was significant (Table 7). In general the nitrogen uptake decreased with an increase in the clay percentage of soils, i.e. from sandy and loamy sand soil to sandy loam and sandy loam to loam. Generally on all soils the uptake decreased with increasing salinity of irrigation water but the effect of the salinity of water lessened as the percentage of sand in the soil increased. The reason lies in the fact that the accumulation of salts in the soil increases with an increase in the clay percentage of the soil if the same quality of irrigation water is used (Table 4).

The magnesium uptake was not affected by the increasing levels of EC on sandy and loamy sand soils. Only the highest level of EC reduced it on sandy loam, while it was drastically reduced on loam soils due to the increased concentration of salts in the water.

Although the uptake of potassium on all the soils decreased with increasing levels of either EC or SAR of irrigation waters but the extent of decrease in potassium uptake grew as the clay percentage of the soil increased. On sandy and loamy sand soils, the uptake of calcium was not affected by the increasing levels of the EC of waters but on sandy loam and loam soils it decreased regularly. On all soils the uptake decreased with increasing SAR of waters but it was affected less on sandy and loamy sand soils than on sandy loam and loam soils. As already pointed out, the permeable sandy and loamy sand soils are less affected by the use of poor quality waters, i.e. they have less salt accumulation, low SAR and ESP. Due to this differential effect of irrigation water on the properties of soils, uptake on sandy and loamy soils was not much affected.

Summary

A pot experiment — by taking four different soils, ten waters and two fertilizer levels as variables — was conducted during the Rabi Season of 1966 – 67 to study the effect of salinity-fertility interactions on the nutrient uptake by wheat crop. The uptake of nitrogen, phosphorus, potassium, calcium and magnesium decreased while that of sodium increased with an increase in the EC and SAR level of the irrigation water. The phosphorus and potassium content of grain and straw decreased while that of nitrogen, calcium, magnesium and sodium tended to increase with increasing level of salinity of water. With a rise in the SAR of water, the contents of phosphorus, potassium, calcium and magnesium in grain and straw decreased while the contents of nitrogen and sodium increased. The contents in grain and straw and the total uptake of nitrogen, phosphorus, potassium, calcium and mag-

nesium increased with increased fertilization. The sodium content in grain and straw was appreciably reduced by the higher dose of fertilizer. With increasing level of salinity or alkalinity of the water the uptake of nitrogen, potassium and calcium decreased but at every level of either EC or SAR, their uptake was higher with the higher dose of fertilizer. Although the uptake of nutrients like nitrogen, phosphorus, potassium, calcium and magnesium decreased by the use of irrigation water of poor quality, it was affected less on permeable light textured soils.

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