EFFECT OF DIFFERENT QUALITY IRRIGATION WATERS AND SOIL TEXTURE ON THE YIELD AND UPTAKE OF NUTRIENTS BY WHEAT

by A. P. Gandhi,* *Department of Soils, Udaipur University, Udaipur*

and

K. V. Paliwal, *Water Technology Centre, Indian Agricultural Research Institute, New Delhi*-110012

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A greenhouse experiment was conducted on the effect of different quality irrigation waters having 3 levels (14, 28 and 56 meq/l) of salinity and 4 levels (5, 10, 25 and 50) of SAR on the growth, yield and uptake of nutrients by wheat grown on soils (Menar—clay loam; Udaipur—sandy clay loam; Alwar—sandy loam; and Jodhpur—loamy sand) of four textures. It was observed that wheat could be irrigated with waters up to a salinity of 28 meq/l and SAR of 25 corresponding to an EC_e value of 5 to 6.5 mmhos/cm and SAR of 30 to 33 and 30 to 33 ESP of soil with a maximum reduction in yield from 7 to 15 per cent. Salts reduced grain yield more than the dry matter yield. Absorption of Na was increased and those of N, P, Ca, Mg and K was reduced with the increase of salinity and ESP of the soil. Accumulation of salts and adsorption of sodium by the soils, and reduction in crop growth was in the order: Menar > Udaipur > Alwar > Jodhpur, which is the order of their fineness in soil texture.

Introduction

While judging the suitability of an irrigation water, texture of irrigated soil is considered equally important in addition to salinity and sodium adsorption ratio (SAR) of irrigation water (Kanwar 1961; Ramamoorthy 1964; Paliwal 1972). Extensive areas in Rajasthan and other parts of the country are being irrigated with different quality waters, but precise information in relation to the contribution of soil texture on the accumulation of salts, development of soil sodicity and simultaneously the crop growth under similar experimental conditions is lacking.

The objective of this paper is to find out the effect of different quality waters on (*i*) the relative growth of wheat and its mineral nutritional characteristics in soils of different texture; (*ii*) the relative development of salinity and exchangeable sodium status in these soils, and also (*iii*) the inter-relationships of growth and nutrients uptake with the quality of irrigation water and saline-sodic condition of the soils.

Materials and Methods

A greenhouse experiment was conducted in the simple randomized design on four soils (Table I) using 12 different quality waters having 3 levels (14, 28 and 56 meq/l) of salinity and four levels (5, 10, 25 and 50) of SAR.

**Present address*: Asstt. Agricultural Chemist, Regional Agricultural Research Station, Sumerpur, Dist. Pali (Rajasthan).

TABLE I

General properties of soils

Soils	CEC (meq/ 100 g)	*p*H	*O.M.* (%)	Mechanical analysis CaCO$_3$ (%)	Sand (%)	Silt (%)	Clay (%)	Texture
Menar	34.8	8.2	0.80	0.8	36.0	28.0	32.2	Clay loam
Udaipur	15.0	8.2	0.67	1.0	53.8	19.0	22.1	Sandy clay loam
Alwar	9.8	8.3	0.56	0.7	72.5	4.5	18.0	Sandy loam
Jodhpur	8.2	8.3	0.32	1.4	80.5	7.5	11.5	Loamy sand

These soils were pre-salinized in drums with a hole at the bottom for free drainage with these waters by percolating 25 times through the soil till the leachate of the soil was the same as that of the percolating water. A basal dose of 40, 40 and 20 kg/ha of N, P and K was used as ammonium sulphate, super-phosphate and muriate of potash. Half the dose of nitrogen was applied before sowing and the remaining half was applied as top dressing after one month of germination. Wheat (variety RS 31-1) was grown in earthen pots (23 cm diameter × 30 cm height) coated inside with bitumin containing 200 g of washed quartz at the bottom with a hole for free drainage and 6 kg of air dry pre-salinized soil was placed over the sand. The experiment was run in three replicates and a control was also run on each untreated soil by irrigating with tap water (EC = 0.60 mmhos/cm; Ca^{++} = 2.1; Mg^{++} = 3.2; Na^{+}=0.5; Cl^{-}=1.80; HCO_3^{-}=3.4; $SO_4^{=}$=0.2 meq/l). Wheat was sown in November, 1968 and harvested in March, 1969. Irrigations were given to all the pots uniformly when required. Four plants in each pot were kept up to maturity for yield observation. Chemical analysis of the plants and soil was carried out according to Jackson (1962). Statistical analysis was carried out according to Panse and Sukhatme (1957).

RESULTS AND DISCUSSION

The average data (Table II) on dry matter and grain yield of wheat irrigated with different quality waters on Alwar, Jodhpur, Udaipur and Menar soils show that yield decreased with the increase of salinity, SAR or both as compared to the control. At the highest level of salinity, the reduction in dry matter yield was 18.0, 19.4, 23.4 and 30.7 per cent, and in grain it was 32.9, 29.7, 29.4 and 44.0 per cent as compared to controls in Jodhpur, Alwar, Udaipur and Menar soils, respectively. Thus, reduction in grain yield was more than in dry matter yield. Similarly, the reduction in dry matter yield, at the highest SAR of irrigation water, was 19.6, 20.6, 20.6 and 25.3 per cent and in grain yield it was 34.5, 33.7, 32.4 and 34.5 per cent in Jodhpur, Alwar, Udaipur and Menar soils, respectively. It appears that both salinity and SAR of irrigation water contribute to some extent in adversely affecting the crop growth. However, their combined effect was always less than their individual contribution due to their interaction.

Statistical analysis shows (Table II) that treatments of salinity and SAR are significant on crop growth, and their interaction was significant only in Jodhpur

TABLE II

Effect of salinity and SAR on the yield (g/pot) of wheat crop grown in different soils

SAR	Dry matter: Salinity (meq/l) 14	28	56	Average	Grain: Salinity (meq/l) 14	28	56	Average
				Jodhpur				
	Control yield 7.10				Control yield 4.20			
5	7.26	7.27	6.53	7.02	4.43	4.20	3.25	3.96
10	7.31	7.08	6.47	6.95	4.15	4.20	3.20	3.85
25	7.18	7.20	6.25	6.87	4.05	3.93	2.65	3.54
50	6.59	6.56	4.02	5.71	3.06	2.90	2.18	2.75
Avg.	7.34	7.03	5.82		3.93	3.81	2.82	
	Salinity	SAR	Salinity × SAR		Salinity	SAR		
S Em ±	0.113	0.131	0.227		0.100	0.118		
CD 1%	0.490	0.580	0.990		0.440	0.520		
				Alwar				
	Control yield 7.64				Control yield 4.21			
5	7.98	7.64	6.55	7.39	4.35	4.10	3.40	3.95
10	7.82	7.68	6.70	7.60	4.15	4.16	3.43	3.91
25	7.81	7.39	6.32	7.18	3.97	4.00	2.66	3.54
50	6.54	6.55	5.34	6.14	3.12	2.90	2.34	2.79
Avg.	7.54	7.32	6.23		3.90	3.79	2.96	
	Salinity	SAR			Salinity	SAR		
S Em ±	0.177	0.204			0.128	0.162		
CD 1%	0.780	0.890			0.620	0.710		
				Udaipur				
	Control yield 7.51				Control yield 4.32			
5	7.54	7.40	6.38	7.11	4.35	4.11	3.26	3.91
10	7.50	7.30	6.40	7.06	4.29	4.10	3.20	3.86
25	7.42	7.35	5.93	6.92	4.20	4.05	3.05	3.76
50	6.97	6.66	4.25	5.96	3.07	2.98	2.70	2.92
Avg.	7.36	7.20	5.75		3.98	3.81	3.05	
	Salinity	SAR			Salinity	SAR		
S Em ±	0.154	0.177			0.102	0.118		
CD 1%	0.680	0.780			0.320	0.520		
				Menar				
	Control yield 5.86				Control yield 3.36			
5	6.14	6.09	4.43	5.55	3.44	3.35	2.33	3.04
10	6.10	6.05	4.29	5.48	3.49	3.30	1.87	2.88
25	5.96	5.72	3.93	5.21	3.28	3.05	1.87	2.73
50	5.02	4.70	3.41	4.38	2.64	2.49	1.46	2.20
Avg.	5.81	5.63	4.06		3.21	3.05	1.88	
	Salinity	SAR			Salinity	SAR		
S Em ±	0.082	0.102			0.083	0.092		
CD 1%	0.360	0.650			0.370	0.490		

TABLE III

Effect of different quality waters on the development of salinity, SAR and exchangeable sodium percentage of irrigated soils

Water quality: Salinity meq/l	Water quality: SAR	EC_e (mmhos/cm)	SAR	ESP	EC_e (mmhos/cm)	SAR	ESP
			Jodhpur			*Alwar*	
14	5	1.9	8.6	12.1	2.3	8.5	10.2
,,	10	1.9	15.8	18.1	2.5	16.0	18.4
,,	25	2.1	30.0	33.7	2.4	32.0	34.7
,,	50	2.2	49.0	46.9	2.6	51.2	48.9
28	5	4.8	9.7	13.3	5.3	10.6	11.3
,,	10	4.7	16.2	19.1	5.5	15.4	17.4
,,	25	4.8	30.8	32.5	5.8	31.6	33.7
,,	50	5.0	52.4	45.8	5.5	53.8	49.9
56	5	9.5	9.5	12.1	9.8	11.5	12.3
,,	10	9.8	16.8	20.5	10.0	18.8	18.4
,,	25	10.5	31.6	33.7	10.5	32.6	33.7
,,	50	10.5	56.4	48.2	10.5	56.4	52.1
			Udaipur			*Menar*	
14	5	3.2	9.3	9.9	3.0	9.2	10.1
,,	10	3.1	15.3	16.7	3.4	15.3	14.9
,,	25	3.3	29.6	31.3	3.4	34.6	28.7
,,	50	3.4	50.3	42.7	3.3	41.0	36.2
28	5	6.0	10.0	11.9	6.3	11.4	10.6
,,	10	6.3	14.0	15.9	6.4	15.7	14.9
,,	25	6.0	32.2	31.9	6.5	32.5	28.2
,,	50	6.3	52.5	43.9	6.8	57.4	36.7
56	5	11.0	11.5	12.6	13.5	11.0	10.4
,,	10	11.5	16.7	15.9	13.0	16.0	16.9
,,	25	11.8	34.8	32.6	13.5	33.0	29.3
,,	50	11.3	55.0	44.6	12.5	58.0	38.2

EC_e = EC of the saturation extract of the soil.

soil; and wheat can be grown with a maximum reduction of 7 to 15 per cent on irrigating with waters having salinity up to 28 meq/l and SAR of 25 in all these soils corresponding to an EC value of the saturation extract as 4.8, 5.5, 6.1 and 6.5 mmhos/cm and SAR value as 30.1, 30.2, 33.0 and 33.6 for Jodhpur, Alwar, Udaipur and Menar soils, respectively. The corresponding ESP value of these soils was 33.7, 32.6, 30.8 and 29.5, respectively. These limits of salinity and SAR both of irrigation water and the saturation extract of soil for satisfactory growth of wheat are in conformity with those of Ravikovitch and Muravsky (1958), Luken (1962), Bhumbla *et al.* (1964), Maliwal and Paliwal (1972), and Lal and Singh (1973) with minor variation due to soil texture. Thus, both dry matter and grain yield almost regularly decreased with the increase of EC and SAR of the irrigation water and the saturation extract of the soil and also of the ESP of soil. It is evident from the significant negative coefficient of correlation between salinity and ESP of the soil with dry matter or grain yield for all the soils except in a few cases in relation to ESP (Table III). It may be concluded that yield of wheat would decrease with the increase of salinity or ESP or both beyond the above limits. The depressing effect of salinity was found more than that of ESP of the soil as evident from its higher negative regression coefficient each of dry matter and grain yield.

Soil texture

Data on the effect of increasing levels of salinity independent of SAR of irrigation water on the relative grain yield (Fig. 1) show that yield was reduced in the

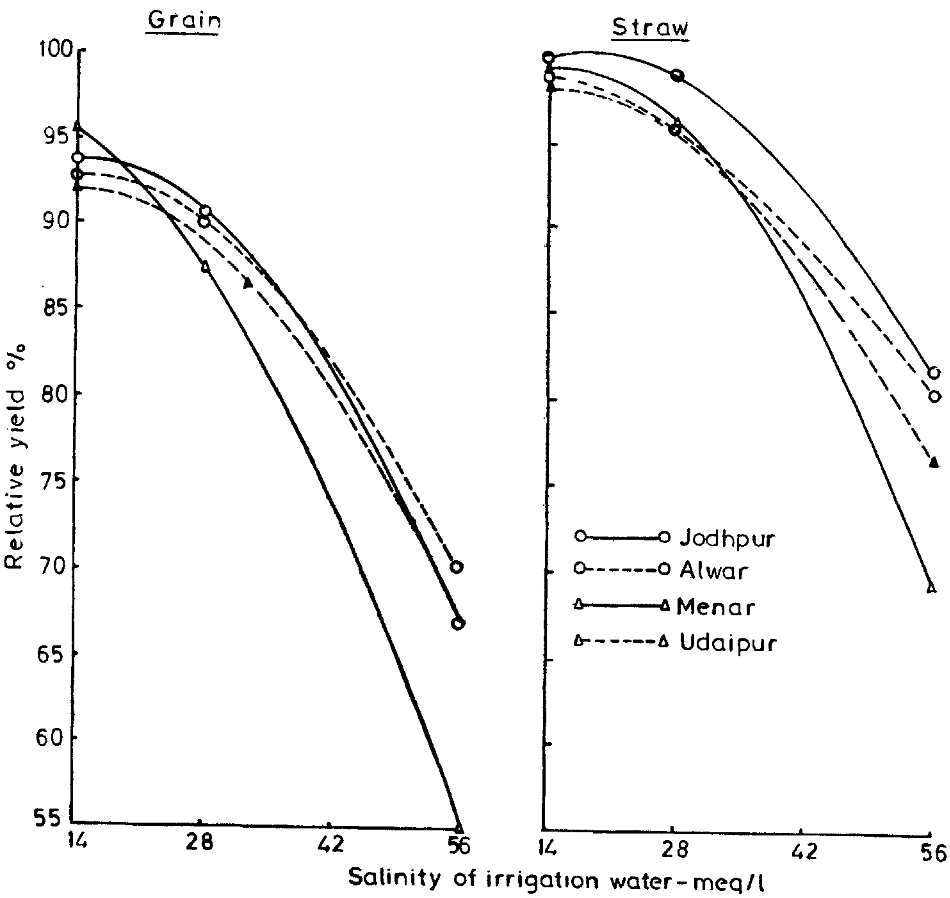

FIG. 1. Effect of salinity of irrigation water and soil texture on the relative dry matter and grain yield of wheat.

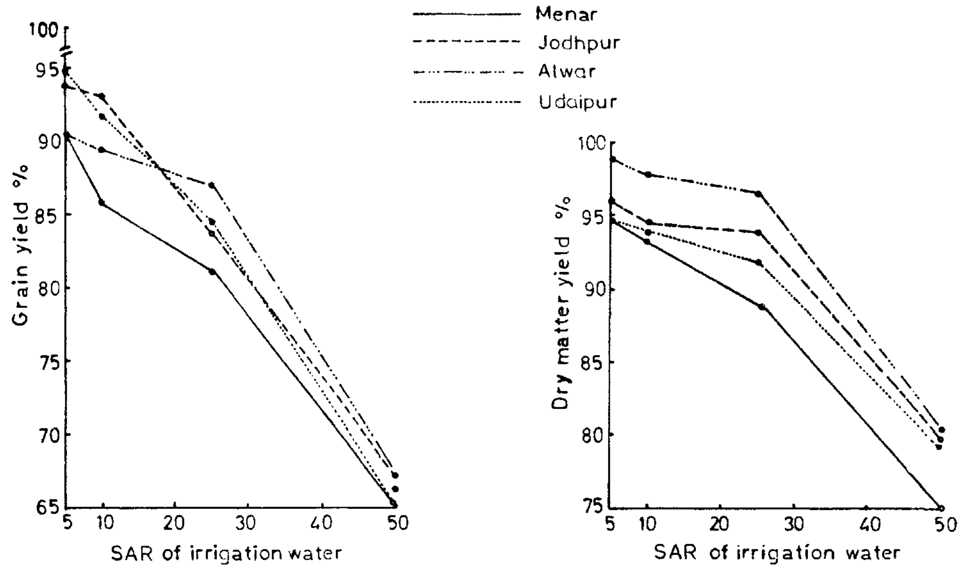

FIG. 2. Effect of SAR of irrigation water and soil texture on the relative dry matter and grain yield of wheat.

order: Menar (clay loam) > Udaipur (sandy clay loam) > Alwar (sandy loam) > Jodhpur (loamy sand). The same trend was observed for the effect of SAR of irrigation water, independent of its salinity (Fig. 2). However, up to the salt tolerance limits (EC = 28 meq/l ; SAR = 25) of this crop variety, there was a little difference in maximum yield reduction due to texture. On combining the maximum adverse effect of salinity and SAR on the crop growth on these soils, the relative order can be expressed as : Menar > Udaipur > Alwar > Jodhpur, and this is the relative order of the fineness of their soil texture.

Soil salinity and sodicity

Data (Table IV) show that salinity of the saturation extract (EC_e) of soils increased with the salinity of irrigation water as well as the fineness of the texture. There was little difference in soil salinity on increasing the SAR at a particular salinity of irrigation water. In spite of irrigating with the same quality water, the ratio of EC_e extract to EC of irrigation water (EC_e/EC_{irr}) increased with the fineness of the soil texture. The average EC_e/EC_{irr} ratio, irrespective of SAR of irrigation water, was found out to be 2.33, 2.18, 1.86 and 1.64 for Menar, Udaipur, Alwar and Jodhpur soils, respectively. Consequently about 40 per cent more salts were accumulated in the clay loam soil of Menar as compared to the sandy soil of Jodhpur. Such an increase in salinity with the fineness of texture has been reported for Rajasthan (Paliwal and Maliwal 1971; Paliwal and Gandhi 1972), Gujarat (Talati 1969) and Punjab soils (Singh and Bhumbla 1968). The values of EC_e/EC_{irr} ratios were in the order of the fineness of the soil texture.

Similarly, the exchangeable sodium status of the soils slightly increased with the increase of salinity and more so with the SAR of irrigation water. In spite of irrigating with the same quality water, the total adsorption of sodium was maximum by the Menar soil having highest cation exchange capacity (CEC) and the relative order was: Menar>Udaipur>Alwar>Jodhpur. But on the basis of exchangeable sodium percentage (ESP) the trend was reverse, i.e. in relation to CEC, the soil of lowest CEC showed the maximum ESP values. Such a trend is quite reasonable according to Mattson's inverse relationship (Babcock 1963; Paliwal and Maliwal 1970, 1971; Paliwal 1972).

TABLE IV

Coefficient of correlation (r) between soil properties and yield (g/pot) of wheat in different soils

Variables	'r'	Regression equation	'r'	Regression equation
	Alwar soil		*Jodhpur soil*	
EC × dry matter	−0.741**	Y = −0.18x + 8.12	−0.678*	Y = −0.18x + 7.64
EC × grain	−0.664*	Y = −0.14x + 4.36	−0.721**	Y = −0.15x + 4.37
ESP × dry matter	−0.722**	Y = −0.03x + 4.42	−0.564	—
ESP × grain	−0.632*	Y = −0.03x + 7.95	−0.685*	Y = −0.04x + 4.53
	Udaipur soil		*Menar soil*	
EC × dry matter	−0.770**	Y = −0.21x + 8.20	−0.836**	Y = −0.19x + 6.61
EC × grain	−0.685*	Y = −0.12x + 4.44	−0.847**	Y = −0.14x + 3.78
ESP × dry matter	−0.624*	Y = −0.03x + 4.35	−0.500	—
ESP × grain	−0.490	—	−0.486	—

*Significant at 5% level; **Significant at 1% level.

Crop growth vs. salinity and ESP

The growth of crop is more closely related with the effective salinity and ESP of the soil near the root zone throughout the cropping period than the salinity and SAR of irrigation water alone. The relative data on dry matter and grain yield of wheat expressed in relation to EC_e (Fig. 3) and ESP (Fig. 4) of each soil reveal that the yield decreased with the increase of salinity and sodicity of the soil, and more so beyond an EC_e value of 5 to 6.5 mmhos/cm and ESP of 30 to 35. Generally, irrespective of soil type, reduction in grain yield was more than in dry matter yield. It is interesting to note that maximum reduction was in Menar soil which also showed development of maximum salinity with about 30 to 40 per cent more salt accumulation than other soils in spite of irrigating with the same quality water.

Though the crop growth decreased with the increase of total exchangeable Na of the soil in each case, but the contribution of soil texture was such that soils of finer texture having higher CEC showed higher reduction in crop growth even at a lower ESP value. On the other hand, Jodhpur and Alwar soils of lighter texture showed less adverse effect even at a higher ESP level. But on examining the yield

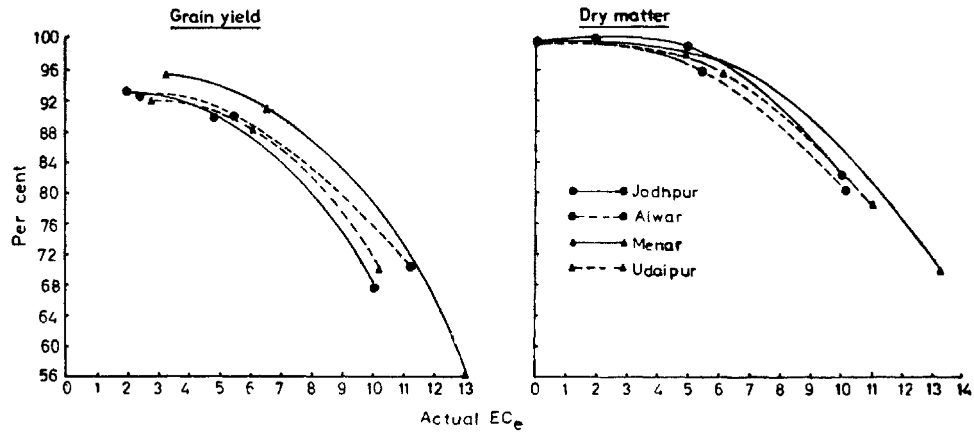

FIG. 3. Effect of soil salinity and soil texture on the relative dry matter and grain yield of wheat.

data in relation to total exchangeable sodium, the crop reduction was found linear to the exchangeable sodium status. Amongst these soils, those of Alwar and Jodhpur of lighter texture showed a narrow range of exchangeable sodium of 2 meq/100 g soil for maximum yield reduction, while the range was widened with the increase of CEC; and in case of Menar, the yield reduction was gradual with the increase of exchangeable sodium. This seems to be related with the reduced availability of Ca in respect of the soil type, and the exchangeable sodium status of the order of 3.0, 3.4, 4.5 and 8.0 meq/100 g may be taken as critical for Jodhpur, Alwar, Udaipur and Menar soils for wheat crop.

These limits of salinity and SAR of irrigation, salinity of the saturation extract and exchangeable sodium of the soil can reasonably be applicable to similar type of soils in conditions of low water table in areas of arid and semi-arid regions. However, a fair consideration has to be given to soil physical conditions, particularly, in case of the heavy soils where air-water relationships, due to swelling and shrinking characteristics of the soil, are more adversely influenced even up to the above limits having less exchangeable sodium.

Mineral nutrition

It would be quite useful to examine reduced crop growth in relation to mineral nutrition of plants in addition to judge the salt tolerance behaviour of the plant on the basis of growth observations. The data (Table V) on the uptake of the nutrients viz., N, P, Na, K, Ca and Mg in wheat plants, at maturity, reveal that generally irrespective of the soil type, except Na, absorption of all the nutrients decreased with the increase of salinity and SAR.

Nitrogen—Generally, nitrogen content decreased with the increase of salinity and SAR of irrigation water in all the soils except a little increase at lower levels of salinity and SAR. The uptake of nitrogen was more from Menar followed by Udaipur, Jodhpur and Alwar soils irrespective of salinity and SAR. Wheat plant appears to show a slight increase in N uptake up to SAR of 10 and salinity of 28 meq/l of irrigation water corresponding to EC_e of 5.0 to 6.4 mmhos/cm. The

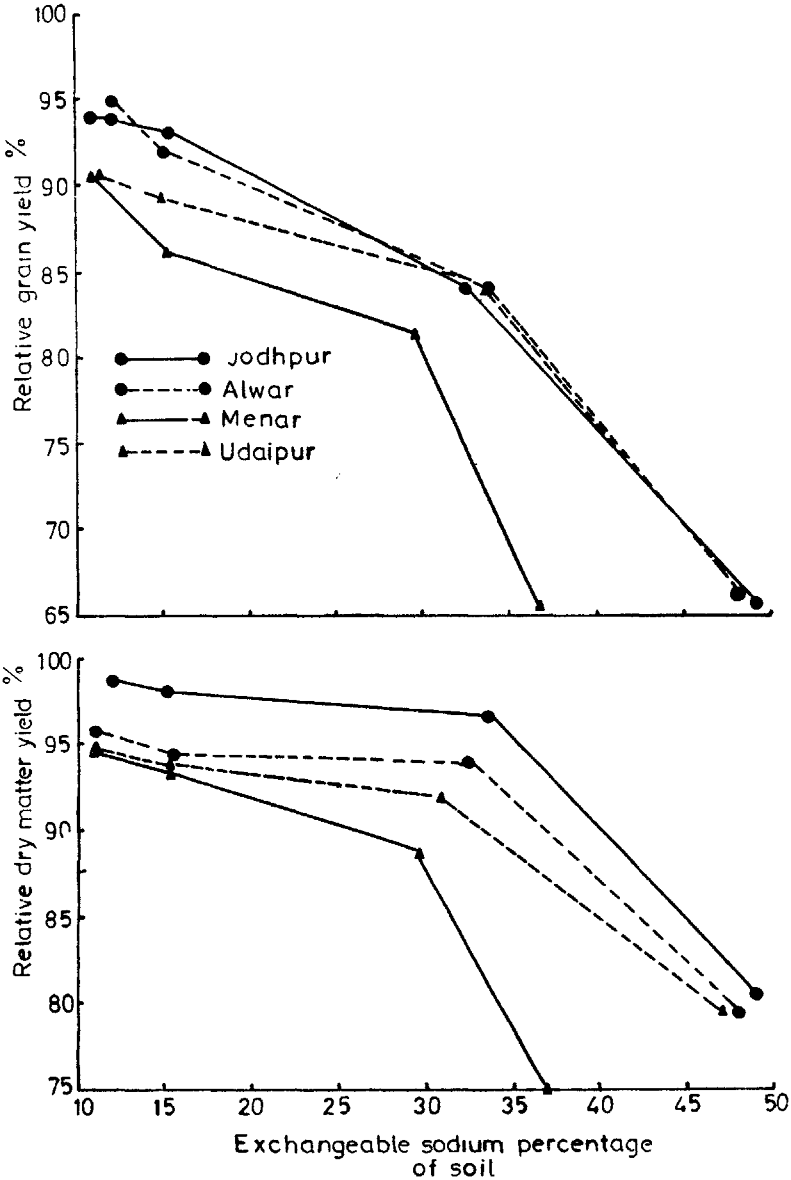

FIG. 4. Effect of exchangeable sodium percentage and texture of soil on the. relative dry matter and grain yield of wheat.

increase in N content of plant tissue may be due to the tendency of the proteins to accumulate in the plant part because of restricted movement (Strogonov and Oknina 1961) as has been reported earlier (Gauch and Eaton 1942; Bains and Fireman 1964; Udovenko *et al.* 1970). But at the highest level of salinity and ESP, the N uptake was decreased as reported earlier (Burdygina and Kuzin 1965; Maliwal and Paliwal 1972; Paliwal 1972).

TABLE V

Range and average of nutrients absorbed by wheat plant irrigated with different quality waters

Soil	Limits	N (%)	P (%)	Na	Ca (meq/100 g)	Mg (meq/100 g)	K
Jodhpur	Range	0.62-0.80	.095-0.137	25.0-62.0	8.0-22.4	4.2-10.4	26.6-35.2
	Average	0.71	0.123	38.8	16.7	7.8	31.0
Alwar	Range	0.55-0.82	.092-0.130	27.0-62.0	9.6-24.6	4.8-11.2	26.4-35.2
	Average	0.71	0.114	39.4	17.3	7.7	32.4
Udaipur	Range	0.62-0.98	0.107-0.136	30.0-64.0	8.4-25.0	4.0-10.2	24.0-34.0
	Average	0.81	0.122	42.4	16.7	6.8	28.5
Menar	Range	0.74-1.05	0.105-0.137	32.0-61.0	8.0-23.0	4.0-8.0	24.0-33.6
	Average	0.87	0.124	43.0	14.3	6.1	26.8

TABLE VI

Coefficient of correlation (r) *between soil properties and uptake of nutrients in wheat* (RS 31–1) *plant*

Variables	Different soils: Jodhpur (loamy sand)	Alwar (sandy loam)	Udaipur (sandy clay loam)	Menar (clay loam)
EC × N	−0.367	−0.374	−0.776**	−0.653*
EC × P	−0.736**	−0.485	−0.022	−0.281
EC × Na	+0.784**	+0.810**	+0.796**	+0.770**
EC × Ca	−0.271	−0.458	−0.116	−0.090
EC × Mg	−0.726**	−0.515	−0.219	−0.039
EC × K	−0.433	−0.371	−0.625*	−0.523
ESP × N	−0.798**	−0.144	−0.396	−0.693*
ESP × P	−0.375	−0.073	−0.478	−0.469
ESP × Na	+0.640*	+0.607*	+0.598*	+0.608*
ESP × Ca	−0.920**	−0.870**	−0.937**	−0.398
ESP × Mg	−0.650*	−0.814**	−0.824**	−0.796**
ESP × K	−0.861**	−0.865**	−0.779**	−0.694

*Significant at 5% level; **Significant at 1% level.

Phosphorus—Phosphorus in wheat plant increased up to a SAR value of 25 both at low and moderate levels of salinity in Alwar, while the same increased up to 25 SAR only at a low (14 meq/l) salinity in the rest of soils, and then decreased at higher levels of salinity and SAR in all the soils. Again P uptake was maximum from Menar soil. The uptake of phosphorus was also slightly increased up to moderate level of salinity and ESP, while it was reduced at the highest level of salinity and ESP as was reported earlier for wheat and other crops (Scharrer and Schropp 1953; Ravikovitch and Porath 1967; Deo and Kanwar 1968; Maliwal and Paliwal 1972; Paliwal 1972; Lal and Singh 1973).

Cations—Amongst the major cations, Na content, irrespective of the salinity and soil texture, increased with the increase of SAR, but the increase was not in proportion to the increase of salinity, SAR or both. On the other hand, Ca, Mg and K contents of the plant were decreased with the increase of salinity and SAR of irrigation water or soil solution and ESP of the soil.

Relationships—In order to examine whether there is any relationship between absorption of nutrients in the plant, with the salinity and ESP of the soils, coefficient of correlations were worked out. Statistical analysis revealed (Table VI) that uptake of Na, was positively correlated with the salinity and ESP of these soils irrespective of the soil texture. Though the uptake of N, P, Ca, Mg and K was decreased with the increase of EC_e and ESP of the soil, but the relationship only of K, Ca and Mg was significant with ESP in all the soils except that of Ca in Menar soil. The correlation of P uptake was significant with EC_e in Jodhpur soil and only that of N both with EC_e and ESP in Menar soil, with EC_e in Udaipur and with ESP in Jodhpur soil.

The low uptake of N at high levels of salinity and ESP appears to be related with the low degree of mineralization of N and its availability (Paliwal and Maliwal 1972; Nitant 1974). Besides this, these results suggest that some physiological functions in relation to N and P are stimulated at low and moderate levels of salinity and ESP, and the same are adversely affected at higher salinity levels. Nitrogen uptake seems to be related with maintenance and stabilisation of hydrophylic colloid system of a plant (Shakhov 1956). The relation between P absorption and plant growth seems to be more related with the effect of salts on the physiology of the plant rather than its solubilization in salts.

Regarding the cations, the regulatory mechanism of the wheat plant appears to be such that it is not influenced by salinity and different proportions of Na, K, Ca and Mg up to a saturation extract of 5 to 6.4 and ESP of about 30. The sum of these cations remains fairly constant with a maximum variation from 5.3 to 6.7 per cent for all these soils. This supports the view that law of equivalent constancy of cations holds good in spite of the wide variation in soil type and quality of irrigation water. Sodium appears to play an antagonistic role in relation to the uptake of K, Ca and Mg, and such an effect is more evident from the negative correlation of the uptake of these cations with the ESP of these soils.

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