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Impact of Ca/Mg Ratios of Irrigation Water on Soil Properties and Crop Yields

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Abstract: A pot experiment was conducted to investigate the impact of different Ca/Mg ratios (1:1, 2:1, 3:1 1:2, 1:3 1:4 in addition to canal water as standard) on soil properties and maize and wheat yields. A normal soil was taken in lysimeters, these crops were grown in sequence and irrigated with synthetic water of variable Ca/Mg ratios consistently for three years. It was observed that fodder yield of maize and grain yield of wheat was significantly decreased when irrigation with higher Mg content compared to Ca was adopted. The impact was more pronounced with wider ratios and in the later two years. Harmful effect on soil properties was also noticed because EC, pH and SAR in these treatments was recorded to be on higher side. Thus, irrigation waters having comparatively more Mg than Ca proved deleterious not only for cops but also impaired the soil conditions.

Key words: Irrigation water, Ca/Mg ratio, maize, wheat, and soil properties

Introduction

Scarcity of irrigation water is a major factor of low yield in Pakistan and as a result sub-soil water has to be used for supplementing water supply. The persistent dry spell of 1999-2000 further aggravated this problem and the alternative sources of irrigation water got prime importance. Unluckily, major part of the ground water is not directly usable and has to be managed scientifically to ensure its safe usage so that it may not threat the soil properties, crop yields and the environment. Different irrigation waters have to be classified for management purposes as well as predicting their probable harmful effects. In present classification criteria of irrigation water, Ca/Mg ratio is not taken into account rather these cations are pooled together for calculating SAR.

According to recent research if Mg content exceeds the Ca content, they prove equally toxic for soil properties and crop growth as the Na. Many workers have studied the effect of brackish ground waters on soil physical and chemical characteristics and plant growth but they too added up these two cations. However, It has been reported that at equal or lower Mg concentration, Mg behaves like Ca (Bohn *et al*., 1985) and if Mg becomes more than Ca it behaves like Na resulting in soil dispersion and decreased infiltration rate. Chaudhry *et al*. (1986) reported increase in EC, SAR and pHs of a normal soil and decrease in rice and wheat grain yield with the irrigation water when Mg was more than Ca. This hidden loss to soils and crop yields is being unknowingly ignored. There was a dire need that such probabilities be investigated to generate scientific information on the subject. The study was thus planned to ascertain the effect of varying Ca/Mg ratios of irrigation water on soil properties and crop growth under prevailing conditions.

Materials and Methods

This lysimeter study was conducted at Soil Salinity Research Instituted, Pindi Bhattian, Pakistan over a period of three years (1997-2000). A bulk soil sample from the depth of o-15 cms was obtained from a normal medium textured field and was brought to the laboratory. After processing, the soil was passed through 2 mm sieve and 20 kg of it was filled in each lysimeter. Physical and chemical characteristics of the soil were determined (Table 1). Maize and wheat crops were sown in the sequence as test crops in these lysimeters. Recommended dose of N and P at the rate of 150 and 100 Kg ha^{-1} respectively was applied to each crop. Both the crops were irrigated with synthetic water having EC one dS m^{-1}, SAR 10 (m mol L^{-1}) ^{½} and Cl^- to SO_4^{-2} ratio as 1: 1. Seven Ca/Mg ratios were developed in irrigation water using NaCl, Na_2SO_4, $CaCl_2.2H_2O$ and $MgSO_4.7H_2O$ salts. The developed ratios were:

T_1 , Control (Canal water), T_2, 1:1; T_3, 2: 1; T_4, 3:1; T_5, 1: 2; T_6, 1: 3; $_{TO}$, 1: 4; Crops were irrigated according to their requirement. Fodder maize was harvested after eight weeks whereas wheat was harvested at maturity and biomass and grain weights were recorded. Lysimeters were sampled after the harvest of last crop and soil analysis was completed for the parameters of ECe, pH and SAR. The data were also analyzed statistically (Steel and Torrie, 1984)

Table 1: Physical and chemical analysis of pre-treated soil

Property	Value
ECe	0.90dS m^{-1}
pH	7.97
$CO3^{-2}$	Nil
HCO_3^{-1}	0.8me L^{-1}
Cl^{-1}	1.2me L^{-1}
SO_4^{-2}	7.0me L^{-1}
$Ca^{+2} + Mg^{+2}$	6.4me L^{-1}
Na^{+1}	2.8me L^{-1}
SAR	1.45(m mol L^{-1}) ^{½}
Textural class	Sandy clay loam

Results and Discussion

Maize Effect of Ca/Mg ratio of irrigation water on crop yields: Effect of irrigation water having different Ca/Mg ratios on maize yield was recorded separately for each year, but it has been presented in pooled form (Table 2). Results indicated that treatment as well as year effect on dry matter yield proved significant. Highest yield of 6.31 gms lysimeter^{-1} was receded in case of T_2 (Ca/Mg = 1:1), which was significantly higher than all other treatments except T_4 (Ca/Mg = 3:1). Yield in T_4 was recorded as 5.86 gms biomass lysimeter. In general, it was observed that the yield decreased with increase of Mg contents in irrigation water. During the first year, comparatively higher yield was obtained than the later two years, which can be attributed to the deterioration of soil properties due to high Mg irrigation water.

Table 2: Effect of Ca/Mg ratio of irrigation water on maize fodder yield (Oven dry weight in grams lysimeter^{-1})

		1997-1999 (Pooled data)				
Treatments	Ca: Mg	1997	1998	1999	Treatment means	Mean increase/ decrease over control (%)
T_1	Control	6.98	1.22	1.48	3.22C	-
T_2	1: 1	15.61	1.62	1.70	6.31A	+95.72
T_3	2: 1	5.79	0.81	0.85	2.49C	-22.54
T_4	3: 1	10.82	3.26	3.51	5.86AB	+81.74
T_5	1: 2	6.45	1.43	1.46	3.11C	-3.35
T_6	1: 3	10.46	1.84	1.25	4.71B	+46.19
T_7	1: 4	5.46	1.25	1.42	2.71C	-15.96
Year means		8.79A	1.63B	1.75B		

Wheat: All the treatments had a significant effect on wheat biomass yield (Table 3). However, highest yield of 16.94gms biomass lysimeter^{-1}was obtained in T_4 (Ca/Mg 3:1), which proved significantly

Table 3: Effect of Ca/Mg ratio of irrigation water on biomass of wheat in grams lysimeter^{-1})

		1997-2000 (Pooled dated)				
Treatments	Ca: Mg	1997-1998	1998-1999	1999-2000	Treatment means	Mean increase/ decrease over control (%)
T_1	Control	9.96	20.88	12.70	14.52b	-
T_2	1:1	13.33	14.61	13.10	13.60b	-5.78
T_3	2:1	12.40	16.351	10.24	12.94b	-10.88
T_4	3:1	15.57	17.53	17.72	16.94a	+6.66
T_5	1:2	14.90	9.52	5.82	10.08c	-30.57
T_6	1:3	14.98	8.27	5.33	9.53c	-34.36
T_o	1:4	14.56	6.80	3.33	8.23c	-43.31
Year means		13.67A	13.40 A	9.75B		

Table 4: Effect of Ca/Mg ratio of irrigation water on wheat grain yield (gms lysimeter^{-1})

Treatments	Ca: Mg	1997-98	1998-99	1999-2000	Treatment means
T_1	Control	3.98	8.35	5.08	5.80B
T_2	1:1	5.33	5.84	5.24	5.47B
T_3	2:1	4.96	6.47	4.09	5.17B
T_4	3:1	6.22	7.01	7.08	6.77A
T_5	1:2	5.95	3.80	2.33	4.03C
T_6	1:3	5.99	3.31	2.13	3.81cd
T_o	1:4	5.83	2.72	1.34	3.29d
Year means		5.46A	5.36A	3.90	

Table 5: Effect of Ca / Mg ratio of irrigation water on soil ECe, pH and SAR (0-15 cm) at the end of experiment (2000)

Treatments	Ca:Mg	ECe (dS m^{-1})	pH	SAR (m mol L^{-1}) ^{½}
T_1	Control	2.563D	7.297B	3.040B
T_2	1: 1	7.433C	7.273B	4.073AB
T_3	2: 1	10.010B	7.451B	4.717A
T_4	3: 1	9.653BC	7.480B	2.567B
T_5	1: 2	10.430AB	8.267A	5.473A
T_6	1: 3	11.310AB	8.117A	3.653B
T_7	1: 1	2.550A	8.327A	4.870AB

higher than all the other treatments. It was observed that yield decreased from 30.57 to 43.31% as the Ca/Mg ratio narrowed. As for as the effect of time was concerned, it was noted that the yield was unaffected in the 2nd year of experiment, but decreased significantly in the 3rd year, which may be due to adverse effect of narrow Ca/Mg ratio. Similar results were also noted by Chaudhry *et al*. (1986).

Grain yield: Data of Table 4 indicated that grain yield of wheat also followed the same pattern of variation as noticed for biomass. Mean yields were statistically similar for canal water and wider Ca: Mg ratio (T_1, T_2 and T_3). Grain yield was found as the maximum where Ca was with the highest ratio (3:1, T_4). The wheat yield decreased as Mg ratio in irrigation water increased progressively (T_5, T_6 and T_o). Difference among the first two years was non-significant while yield in the third year decreased significantly indicating a progressive deleterious effect of poor quality water.

Effect of Ca/Mg ratio on irrigation water on soil properties: After the completion of study period the soil was sampled and analyzed for ECe, pHs, and SAR so that the impact of different treatments on these properties may be determined. The data is given in table 5. All the treatments had a significant effect on soil ECe which was more pronounced in the treatments where high Mg ratio water was used continuously for irrigation. It was the highest in T_o (Ca/Mg, 1:4) and its recorded value was 12.55 dS m^{-1} as against 6.53 in control. However, the difference was found to be non- significant compared with T_5 and T_6. The soil pHs also increased with lowering of Ca, Mg ratio. Although pHs of the soil increased due to increase of Mg in irrigation water but it was within the permissible limits of 8.5. Similar behavior of soil SAR was observed.

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