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Short Research Article

Phosphorus and Zinc Requirement of Rice under Saline Condition

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Abstract

A green house experiment was conducted for two consecutive years to study the phosphorus and zinc requirement of rice, irrigated with saline water. Three levels of water salinity viz. control (S_0), 8.0 (S_1) and 16.0 (S_2) dSm^{-1} electrical conductivity (EC), three levels of phosphorus 40 (P_1), 80 (P_2) and 120 (P_3) kg ha^{-1} and four levels of zinc sulphate ($ZnSO_4$) viz. control (Zn_0), 25 (Zn_1), 50 (Zn_2) and 75 (Zn_3) kg ha^{-1} were tested in a factorial completely randomized design. Saline water having EC 16 dSm^{-1} decreased the plant height, number of tillers $plant^{-1}$ and grain yield by 18.2, 24.0 and 52.3% during 1st year and 18.73, 22.13 and 51.63%, respectively during 2nd year of experimentation. Phosphorus application @ 80 kg ha^{-1} increased grain yield to extent of 19.12 and 29.02% during1st and 2nd years over 40 kg ha^{-1} dose of phosphorus while $ZnSO_4$ @ 50 kg ha^{-1} increased grain yield by 46.29 and 43.33% during 1st and 2nd year over control, respectively. On the basis of grain yield, positive interaction indicated that 95.10 kg ha^{-1} phosphorus and 60.68 kg ha^{-1} zinc sulphate were found to be optimum doses for getting higher yield of rice under salt stressed condition on sandy loam soils. The N, P, K, Ca, Na and Zn uptake by grain significantly increased up to 50 kg ha^{-1} $ZnSO_4$ application. The electrical conductivity of saturated extract of soil after experimentation remarkably increased but pH was not affected with water salinity levels. Irrigation with saline water adversely affected the growth and yield of rice and nutrient uptake.

1. Introduction

Rice is the one of the most important food crops of India. India is the second largest producer and consumer of rice in world and rice play key role in food security systems of our country as it contributes more than 40% of the total food grain production. In view of increasing pressure on good quality irrigation water for getting more crop yield, saline water is also used for irrigation. High concentration of salts in soil imposes both ionic and osmotic stresses on plant to suppress the normal growth (Sharma and Pal, 2001, Singh et al., 2008). Zinc being the most important nutrient assumes significance in modern agriculture after N and P limiting to growth and yield of rice. Deficiency of Zn is widespread in the Indian soils. On an average 45% soils of Uttar Pradesh are deficient in zinc (Vasuki, 2010). The imbalance between the rate of supply and uptake of nutrients in soil-plant system under salt stress will depend upon the degree of saline-sodic condition and their interactions. The salt induced nutrient imbalance may be reduced by providing essential nutrient to plant for their physiological and metabolic activities through fertilizer application. Thus the present experiment was planned to evaluate the phosphorus and zinc sulphate requirement of rice irrigated with saline water.

2. Materials and Methods

A pot experiment was conducted in the green house of the department of Agricultural Chemistry and Soil Science, R.B.S. College Bichpuri, Agra, during July 1998 and July 1999 on a sandy loamy soil having the following properties electrical conductivity of saturated extract (ECe) 2.3 dSm^{-1}, pH 8.5, exchangeable sodium percentage 3, soluble cation (mel^{-1}) Ca^{2+} 4.2, Mg^{2+} 5.3, Na^+ 12.2 and K^+ 0.2, soluble anions (mel^{-1}) CO_3^{2-} nil, HCO_3^- 7.3, Cl^- 6.8 and SO_4^{2-} 8.1, organic carbon 0.14%, available NPK 178.0, 12.5, 205 kg ha^{-1} ,respectively and DTPA extractable Zn 0.56 mg kg^{-1}. The experiment was laid out in a factorial completely randomized design with three levels of water salinity viz. control (S_0), 8 (S_1) and 16 (S_2) dSm^{-1}, three levels of phosphorus viz. 40 (P_1), 80 (P_2) and 120 (P_3) kg ha^{-1} and four levels of zinc sulphate viz. control (Zn_0), 25 (Zn_1), 50 (Zn_2) and 75 (Zn_3) kg ha^{-1}. Earthen pots of 30 cm diameter were filled with 8.0 kg soil. The salinity levels of irrigation water were prepared by dissolving Na_2SO_4, NaCl, $CaCl_2$. $6H_2O$, $MgCl_2$.$6H_2O$, Na_2CO_3 and $NaHCO_3$ in tub-well water having EC 2.4 dSm^{-1}, Na^+ 14.1, Ca^{2+} 3.1 Mg^{2+} 6.1 and Cl^- 11.8, CO_3^{2-} + HCO_3^- 8.2 and SO_4^{2-} 4.0 mel^{-1}. Recommended doses of N and K @ 120 and 60 kg ha^{-1}, respectively were applied through urea and muriate of potash and phosphorus levels was supplied by single superphosphate. Two seedling of rice (cv Saket-4) were planted on July15 during first year and July18 during second year of experimentation and irrigated with tub-well water just after transplanting and thereafter irrigation was given with treatment water. Seedling was raised by wet bed nursery method with tube well water. Direct dibbling of seeds was avoided because plants could not tolerate high salt stress environment at juvenile stage. Twelve irrigations were given during each year of experimentation and one liter water per pot per irrigation was applied. After 10 days of transplanting crop was thinned to one plant in each pot. The data on growth and yield were recorded. Plant height and tillers were recorded at harvest. The grain sample were processed for nutrient analysis and determined by following standard procedures (Jackson, 1973). Uptake values of nutrient by plant were calculated using the following equation:

Nutrient uptake (mg pot^{-1})=yield (g pot^{-1})×nutrient content (%)×10

Soil sample from each pot was collected after experimentation with the help of *khurpi*. Collected samples from different replications was mixed together treatment wise to getting composite soil sample and analyzed for EC_e and pH using standard methods of analysis as per Jackson (1973).

3. Results and Discussion

3.1. Effect on growth

The plant height and number of tillers $plant^{-1}$ significantly reduced with higher levels of water salinity (Table 1). Each higher levels of salinity caused significant reduction of plant height and tillers $plant^{-1}$ as compared to lower levels of water salinity. The lowest plant height and number of tillers $plant^{-1}$ were recorded at highest level of water salinity (EC16 dSm^{-1}). The S_2 level of salinity reduced the plant height by 18.27 and 18.73% during 1st and 2nd years of study over control, respectively. Higher concentration of salts in irrigation water suppressed the normal growth of the plants might be due to plant nutrient imbalance in the soil solution in the form of higher Na^+ and Cl^- concentration. Due to that leaf water potential and osmotic potential decreased. Predominantly Na^+ and $Cl^–$ contributed to the salt-induced changes in leaf osmotic potential and in such stress conditions the concentrations of the major essential ions (such as Ca, K, Mg and nitrate) transiently decreased (Koyro, 2006). Similar results are also reported by Sharma and Pal (2001). The plant height of rice was affected markedly with P and Zn application. Application of 80 kg phosphorus ha^{-1} significantly increased the plant height of rice than that of 40 kg ha^{-1} during both crop seasons. The 120 kg ha^{-1} level of P also significantly enhanced plant height over 40 kg ha^{-1} during both years of experimentation. Phosphorus application promotes cell division and formation of lateral and fibers roots resulted more absorption of N, K, Ca and Zn by plant which in turn increase growth of the plants. The Zn_2 (50 kg $ZnSO_4$ ha^{-1}) level of zinc significantly enhanced plant height and number of tillers $plant^{-1}$ over Zn_1 and control during both the years. The Zn_1 level of zinc also produced more plant height over Zn_0 during both years. The 50 kg ha^{-1} zinc sulphate application proved more beneficial with respect to plant height. These results are in agreement with those of Singh et al (2013).

3.2. Effect on yield

The grain yield of rice significantly decreased with increasing

Table 1: Effect of water salinity, phosphors and zinc on growth and yield of rice

Treatment	Growth				Grain yield (g pot^{-1})	
	Plant Height (cm)		Number of tillers $plant^{-1}$			
	Ist year	IIst year	Ist year	IIst year	Ist year	IIst year
WS (dSm^{-1})						
Control	90.30	90.08	12.50	12.20	8.31	8.58
8	82.50	82.70	10.80	10.60	6.21	6.42
16	73.80	73.20	9.50	9.50	3.96	4.15
CD (p=0.05)	1.97	1.53	0.76	0.75	0.06	0.14
P (kg ha^{-1})						
40	77.60	76.10	10.60	10.60	5.23	5.41
80	84.10	84.50	11.10	10.90	6.23	6.98
120	84.20	84.80	11.20	10.70	6.18	6.95
CD (p=0.05)	1.97	1.53	NS	NS	0.06	0.14
ZS (kg ha^{-1})						
Control	77.80	78.20	9.90	9.90	4.86	5.10
25	79.90	79.90	10.90	10.20	5.96	6.16
50	85.90	85.90	12.10	11.60	7.11	7.31
75	84.30	84.20	11.10	11.60	6.72	6.36
CD (p=0.05)	2.28	1.77	0.88	0.87	0.07	0.165

WS: water salinity; P: phosphorus; ZS: $ZnSO_4$

levels of salinity. Each increasing level of salinity caused significant reduction in grain yield as compared to lower level of salinity and resulted in yield reduction to the extent of 52.34 and 51.63% during 1st and 2nd years at 16 dSm^{-1} water salinity over control. Less plant growth might be cause of low grain yield at higher level of water salinity. A similar harmful effect of salinity was also noted by Parida and Das (2005). Grain yield of rice increased significantly with phosphorus and zinc application up to 80 kg ha^{-1} and 50 kg ha^{-1}, respectively during both the years. These levels of phosphorus and zinc increased grain yield of rice to the extent of 19.1 and 29.0% and 46.2 and 43.3% over 40 kg ha^{-1} and control, respectively during 1st and 2nd years. Similar observation was also noted by Swarup and Yaduvanshi (2000).

3.3. *Response of rice to phosphorus and zinc*

The response of rice to phosphorus and zinc was calculated on the basis of average grain yield of two years (Table 2). Regression equation was calculated to phosphorus and zinc application and regression equation for phosphorus and zinc were Y=2.046+0.10385X-0.00055×2 and Y=4.910+.07021X-0.00058 x 2, respectively. Per kg phosphorus application in the range of 40 to 80 kg P ha^{-1} increased 0.038 g grain yield per pot. While in the range of 80 to 120 kg P ha^{-1}, one kg phosphorus increased 0.016 g grain yield per pot. The optimum dose of phosphorus was found 95.10 kg ha^{-1} and at this level one kg of phosphorus increased 0.030 g yield of rice. The optimum level of zinc sulphate was calculated 60.68 kg ha^{-1}. At this level one kg $ZnSO_4$ application increased 0.035 g yield per pot. Therefore, 95.10 kg ha^{-1} phosphorus with 60.68 kg ha^{-1} $ZnSO_4$ were statistically proved optimum doses for getting maximum yield of rice in present set of experimentation.

3.4. *Interaction effect*

Each increasing level of salinity of irrigation water reduced significantly the grain yield of rice as compared to lower levels of salinity under each level of phosphorus during both years of experimentation (Table 3). Further, 80 kg ha^{-1} level of phosphorus significantly enhanced the grain yield of rice over 40 kg ha^{-1} level under each level of water salinity. The highest and lowest yield was noted at S_0P_2 and S_2P_1 combinations of water salinity and phosphorus, respectively. Interaction effect between salinity and zinc with respect to grain yield indicated that each increasing level of salinity decreased significantly the grain yield of rice in comparison to lower levels of salinity under each level of zinc. The 25 kg ha^{-1} and 50 kg ha^{-1} levels of zinc sulphate significantly enhanced the grain yield over control and 25 kg ha^{-1} levels of zinc sulphate under each level of salinity during both the years of study. These interactions showed that adverse effects of salinity can be mitigated by phosphorus and Zn application. Interaction effect between phosphorus and zinc revealed that the grain yield of rice increased significantly with 80 kg ha^{-1} phosphorus application over 40 kg ha^{-1} level of phosphorus under each level of zinc sulphate (Table 4). The difference between P_2 and P_3 level of phosphorus was insignificant under each level of zinc, but the P_3 level increased grain yield significantly over P_2 level under Zn_3 level during 1st year. Zn_1 and Zn_2 levels of zinc sulphate enhanced significantly the grain yield of rice over lower levels of zinc under each level of phosphorus. It means combine application of P and Zn is more beneficial than single application of P or Zn. A similar interaction effect was also noted by Sayed (2011). Interaction effect between water salinity, phosphorus and zinc indicate that the each increasing level of salinity of irrigation water reduced significantly the grain yield in comparison to lower levels of salinity under each level of P and Zn during both the years of experimentation (Table 5). The P_2 level of phosphorus enhanced significantly the grain yield of rice over P_1 level of phosphorus under each level of salinity and zinc. The Zn_2 level of zinc enhanced significantly grain yield over Zn_1 and Zn_0 levels of zinc under each level of salinity and phosphorus.

3.5. *Effect on nutrient uptake*

Nitrogen, phosphorus, potassium, calcium and zinc uptake in rice grain was reduced significantly with each higher levels of water salinity over control (Table 6). The 16 dSm^{-1} level of EC proved more harmful with respect to uptake of nitrogen, phosphorus, potassium, calcium and zinc. Possible reason of nutrient uptake reduction might be reduction of grain yield. But Na uptake was increased markedly under S_1 level of water salinity over control. The P_2 (80 kg ha^{-1}) and P_3 (120 kg ha^{-1}) levels of phosphorus enhanced significantly the N, P, K, Ca, Na and Zn uptake by grain over to P_1 (40 kg ha^{-1}) level of P_2O_5. Zinc sulphate application @ 50 kg ha^{-1} and 75 kg ha^{-1}

Table 2: Response of rice to phosphorus and zinc regarding grain yield

	Value of P and $ZnSO_4$ (X) (kg ha^{-1})	Y=yield (g pot^{-1})	Response of Y to X (g kg^{-1})	Regression equation
Levels	Phosphorus			
P_1	40	5.33	-	Y=2.046+
P_2	80	6.86	0.038	0.10385X-
P_3	120	6.65	0.016	0.00055×2
Optimum	95.10	6.98	0.030	
$ZnSO_4$	Zinc			
Zn_0	0	4.91	-	
Zn_1	25	6.30	0.056	Y=4.910+
Zn_2	50	6.97	0.041	0.07021X-
Zn_3	75	6.92	0.027	0.00058×2
Optimum	60.68	7.04	0.035	

Table 3: Interaction effect of water salinity and phosphorus and water salinity and zinc on grain yield of rice (g pot^{-1})

Water salinity (dSm^{-1})	Phosphorus levels (kg ha^{-1})						Zinc sulphate (kg ha^{-1})							
	1st year			2nd year			1st year				2nd year			
	40	80	120	40	80	120	Control	25	50	75	Control	25	50	75
Control	6.92	9.07	8.95	7.05	9.30	9.40	6.90	8.06	9.38	8.96	7.26	8.30	9.60	9.16
8	5.43	6.82	6.40	5.77	7.08	6.42	4.93	6.03	7.30	6.61	5.14	6.00	7.56	7.00
16	3.35	4.30	4.25	3.42	4.57	4.45	2.76 0	3.80	4.70	4.60	2.90	4.20	4.76	4.73
CD (*p*=0.05)		0.11			0.24				0.12				0.28	

Table 4: Interaction effect phosphorus and zinc on grain yield (g pot^{-1})

Phosphorus levels (kg ha^{-1})	Zinc sulphate (kg ha^{-1})							
	1st year				2nd year			
	Control	25	50	75	Control	25	50	75
40	4.10	5.00	6.00	5.84	4.16	5.26	6.06	6.16
80	5.26	6.46	7.66	7.53	5.64	6.73	7.83	7.73
120	5.23	6.48	7.66	6.80	5.50	6.50	8.00	7.00
CD (*p*=0.05)		0.12				0.28		

Table 5: Interaction effect of salinity, phosphorus and zinc on grain yield of rice (g pot^{-1})

Treatment		Water salinity (dSm^{-1})					
		1st year			2nd year		
Phosphorus (kg ha^{-1})	Zinc sulphate (kg ha^{-1})	Control	8	16	Control	8	16
40	Control	5.80	4.30	2.20	6.00	4.20	2.30
	25	6.40	5.60	3.00	7.00	5.70	3.40
	50	7.80	6.00	4.20	8.00	6.20	4.00
	75	7.77	5.83	4.00	7.50	7.00	4.00
80	Control	7.50	5.20	3.10	7.60	5.93	3.40
	25	8.90	6.30	4.20	9.20	6.30	4.70
	50	10.20	7.90	4.90	10.40	8.10	5.00
	75	9.70	7.90	5.00	10.00	8.00	5.20
120	Control	7.40	5.30	3.00	8.20	5.30	3.00
	25	8.90	6.20	4.20	9.00	6.00	4.50
	50	10.00	8.00	5.00	10.40	8.40	5.30
	75	9.50	6.10	4.80	10.00	6.00	5.00
CD (*p*=0.05)			0.22			0.49	

increased significantly N, P, K, Ca, Na and Zn uptake by grain as compared to 25 kg ha^{-1} and control. The 25 kg ha^{-1} of $ZnSO_4$ also increased significantly uptake of these nutrients by grain over control. Enhancement of grain yield might be cause of increase of nutrient uptake. Similar results were also reported by Sharma and Pal (2001).

3.6. *Effect on soil properties*

Water salinity considerably increased electrical conductivity of saturation extract (ECe) of experimental soil after crop harvest during both the years of experimentation (Table-6). The S_1 and S_2 levels of water salinity markedly enhanced the ECe of soil over control. Highest ECe value of soil was noted at highest level of salinity during both the years. The ECe value of the soil was nearly 3.5 times than that of EC of applied irrigation water under S_1 and S_2 levels of water salinity. It might be due to accumulation of added salts in the soil because bottom hole of the pots was closed to restrict the leaching of salts. The ECe value of soil was not affected markedly with phosphorus and zinc application. The pH values of experimental soil were not affected markedly with water salinity, phosphorus and zinc levels. A minute increase in pH was noted with enhancing levels of salinity during both the years of experimentation. Similar results have been also reported by Singh (2013).

Table 6: Effect of water salinity, phosphors and zinc on nutrient uptake of rice and soil properties

Treatment	Nutrient uptake in grain												Soil properties			
	N (mg pot^{-1})		P (mg pot^{-1})		K (mg pot^{-1})		Ca (mg pot^{-1})		Na (mg pot^{-1})		Zn (μg pot^{-1})		ECe (dSm^{-1})		pH	
	Ist year	IIst year	Ist year	IIst year	Ist year	IIst year	Ist year	IIst year	Ist year	IIst year	Ist year	IIst year	Ist year	IIst year	Ist year	IIst year
WS (dSm^{-1})																
Control	101.4	104.1	17.2	17.7	50.6	52.8	28.0	27.5	11.5	12.4	275.1	284.1	2.42	2.60	8.71	8.71
8	78.7	81.8	10.8	11.3	33.3	33.1	17.1	18.0	13.0	13.9	180.0	191.2	30.	30.34	8.79	8.88
16	53.5	55.0	5.60	5.8	15.2	16.6	9.47	9.9	9.8	9.9	76.8	77.9	42	54.51	8.90	8.93
CD (p=0.05)	1.11	1.95	0.23	0.36	1.47	1.36	0.62	0.83	0.41	0.57	5.36	9.08	54.04			
P (kg ha^{-1})																
40	63.7	65.2	8.9	9.3	26.1	26.6	13.3	13.4	11.7	11.9	162.0	170.8	28.95	28.86	8.82	8.85
80	85.2	87.3	12.3	12.7	36.2	37.6	19.9	20.1	12.6	12.7	194.3	201.8	29.06	28.15	8.84	8.82
120	84.7	87.8	12.4	12.8	36.8	38.3	21.3	22.0	10.1	11.6	175.9	182.5	28.91	28.90	8.83	8.82
CD at 5%	1.11	1.95	0.23	0.36	1.47	1.36	0.62	0.83	0.41	0.57	5.36	9.08				
$ZnSO_4$ (kg ha^{-1})																
Control	60.2	62.31	9.2	9.7	25.3	27.0	13.4	13.4	10.0	10.2	132.0	139.7	28.74	28.80	8.82	8.78
25	75.2	77.1	10.9	11.3	31.4	32.2	17.2	16.8	11.3	12.2	168.4	173.4	29.00	29.20	8.82	8.80
50	90.9	92.2	12.7	13.2	38.5	39.7	21.5	21.9	12.7	13.5	207.4	216.0	29.10	29.15	8.83	8.85
75	85.2	88.7	11.8	12.2	36.8	37.8	20.7	21.8	11.9	12.4	201.7	211.7	29.16	29.05	8.67	8.60
CD (p=0.05)	1.28	2.23	0.27	0.42	1.66	1.57	0.71	0.96	0.47	0.66	6.19	10.48				

WS: water salinity; P: Phosphorus

4. Conclusion

Saline water having EC 16 dSm^{-1} decreased grain yield. On the basis of grain yield, positive interaction indicated that 95.10 kg ha^{-1} phosphorus and 60.68 kg ha^{-1} zinc sulphate were found to be optimum doses for getting higher yield of rice under salt stressed condition. The N, P, K, Ca, Na and Zn uptake by grain significantly increased up to 50 kg ha^{-1} $ZnSO_4$ application. The EC of saturated extract of soil remarkably increased but pH was not affected.

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