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Effect of Phosphorus on Growth, Yield and Mineral Composition of Wheat in Different Textured Saline-sodic Soils

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Abstract: A pot experiment was conducted to study the effect of phosphorus rates on growth, yield and mineral composition of wheat in a saline-sodic silty clay loam [EC_e 5.6 dS m^{-1}; SAR 14.02 (mmol $L^{-1})^{½}$] and silt loam [EC_e 12.0 dS m^{-1}; SAR 24.02 (mmol $L^{-1})^{½}$] soils, respectively. Phosphorus was added @ 0, 50, 100, 150 and 200 kg ha^{-1}, respectively along with a basal dose of 150 and 60 kg ha^{-1} nitrogen and potassium. The results revealed that growth and yield of wheat increased significantly with P rates over control in both the soils. However, the increase in growth and yield was more with similar levels of P in the case of silty clay loam than that in the silt loam soils. Results also indicated that maximum grain and straw yields were obtained when P was applied @ 100 kg ha^{-1} in both the soils. Nitrogen and P uptake by straw was recorded maximum at 150 kg P_2O_5 ha^{-1}. The uptake of K^+, Na^+ and Cl^- decreased with P application. It may be concluded that for wheat, phosphorus may be added @ 100 kg ha^{-1}.

Key words: Phosphorus levels, yield, mineral composition, wheat, saline-sodic soils

Introduction

Soil salinity and sodicity threat crop production, particularly in irrigated areas of semi-arid and arid regions. Higher evaporation and lower rainfall are responsible for inadequate leaching and consequently the accumulation of salts in the root zone. The precipitation of calcium and magnesium ions, as calcium carbonate and magnesium silicate, increased the proportion of sodium (Na^+) in soil solution and on the exchange complex (Eaton, 1950).

According to an estimate out of 16 million irrigated land of Pakistan, 6.67 million hectare (m ha) is salt-affected (Khan, 1994). About 56 % (3.73 million hectare) of salt-affected soils are saline-sodic (Muhammed, 1996). Reclamation is a prerequisite for crop economic production in saline sodic/sodic soils, but it requires chemical amendments and plenty of better quality of water, which a common farmer cannot easily afford. Therefore, saline agriculture is the need of today. In this technique, saline sodic/sodic soils are managed in such a way that they can be put under tolerant crops, although with decreased yield. Fertilizers response on these soils is not identical to that normal soils and need special attention.

Wheat (*Triticum aestivum* L.) is a staple food and is grown on an area of 8.13 m ha with production of 18.5 million tones (Anonymous, 2000-2001). Its economic harvest not only brings prosperity but also social stability in the country. Its growth is poor on salt-affected soils. According to an estimate the reduction in yield of wheat is up to 60 % from salt-affected soils (Qayyum and Malik, 1988). Aslam and Muhammed (1972) reported that yield of wheat could be improved by 20 % or more depending upon the gravity of the problem from salt-affected soils by judicious use of plant nutrients. Excessive salts in the root zone usually adversely affect nutrient uptake by plant resulting in some physiological disorders and accumulation of toxic ions in the tissue (Sharma, 1986). Application of phosphorus plays significant role for boosting up wheat yield from salt-affected soils. Literature indicates that yield and yield contributing parameters (such as height, number of tillers, 1000-grain height, etc.) of wheat were increased with the application of phosphorus on salt affected soils (Manchandra *et al.*, 1982 and Bhatti *et al.*, 1983). Very little emphasis has been directed in future on the effect of phosphorus levels on wheat in soils differing in salinity and sodicity levels. Therefore, the present study was designed to evaluate the effect of various levels of phosphorus on wheat yield and mineral concentration on naturally occurring different textured saline-sodic soils.

Materials and Methods

The experiment was conducted during 1995 in the Department of Soil Science, University of Agriculture, Faisalabad to study the effect of phosphorus on wheat under naturally occurring silty clay loam and silt loam soils. Soil samples in bulk were collected from field. The soil samples were separately air-dried, ground, passed through a 2 mm sieve and thoroughly mixed. Physico-chemical properties of these two soils are presented in Table 1. Chemical analysis of data revealed that both the soils are saline sodic. Polythene lined cemented pots were filled with these two soils @ 10 kg pot^{-1}. Ten seed of wheat variety Inqulab-91 were sown in each pot. The plant stand was thinned out to five per pot 15-days after germination. Nitrogen and potassium were added @ 150 and 60 kg ha^{-1}, respectively as urea and sulphate of potash. Five levels of phosphorus, i.e., 0 (control), 50, 100, 150 and 200 kg ha^{-1} were applied as single superphosphate. All the potassium and phosphorus was added at sowing, while nitrogen was split in two three equal doses. Half at the time of sowing while the remaining at tillering at grain initiation stages in to equal splits. The treatments were arranged in Completely Randomized Design. Canal water was used for irrigation through out the growth period of crop. Agronomic data (height, number of tillers, grain and straw yield, 1000-grain weight) were recorded. Wheat straw was analysed chemically for N, P, K^+ Na^+, and Cl^{-1} (Anonymous, 1954; Winkleman *et al.*, 1986). Data were analysed statistically according to methods an described by Steel and Torrie (1980).

Table 1: Physico-chemical properties of soils

Parameters	S1	S2
Sand (%)	19.30	21.30
Sillt (%)	49.3	60.50
Clay (%)	32.40	18.20
Textural class	Silty clay loam	Silt loam
Ph_s	8.0	8.2
EC_e (dS m^{-1})	5.6	12.0
Ca+Mg (mmol L^{-1})	15.0	28.0
Na (mmol L^{-1})	38.4	90.0
SAR (mmol $L^{-1})^{½}$	14.02	24.05
Nitrogen (%)	0.042	0.038
Available P (mg kg^{-1})	6.80	6.10
Available K (mg kg^{-1})	48.0	69.0

S1 = Silty clay loam soil S2 = Silt loam soil

Results and Discussion

Agronomic characteristics

Height of plant (cm): Plant attained maximum height (60.30 and 54.90 cm) in treatment where 100 kg P_2O_5 ha^{-1} was added along with the basal dose of N and K fertilizers in S_1 and S_2 soils, respectively (Table 2). This treatment was followed by T_4 and T_5 and the interaction between these three treatments was

Table 2: Effect of phosphorus on yield components and yield of wheat under saline sodic soils condition

	Height (cm)		No. of tillers (g pot^{-1})		1000-grain weight (g)		Grain yield (g pot^{-1})		Straw yield (g pot^{-1})	
Treatments	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
T_1	51.23c	49.00d	13.0c	11.0c	36.0bc	29.70d	9.13d	7.27d	12.16c	9.99c
T_2	52.93b	51.83c	15.33c	13.0c	37.50b	33.83c	10.10c	8.67c	15.09b	11.12b
T_3	60.30a	54.90a	18.33b	16.0b	44.37a	38.43a	12.14a	11.3a	18.95a	14.9a
T_4	59.27a	53.93ab	20.33ab	19.0a	36.60b	37.47ab	11.87a	9.95b	18.53a	13.01a
T_5	58.77a	52.93b	21.33a	20.0a	34.60c	36.87b	11.05b	9.10c	18.31a	12.91a

Means with same letter (s) are statistically similar at 5 % level of probability

Table 3: Effect of phosphorus on mineral composition of wheat straw under saline sodic soils condition

	N (%)		P (%)		K^+(mmol kg^{-1})		Na^+(mmol kg^{-1})		Cl^- (mmol kg^{-1})	
Treatments	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
T_1	0.302c	0.320c	0.20e	0.24d	282a	324a	160.2a	168.5a	256.8a	257.3a
T_2	0.327c	0.338c	0.28d	0.30c	266ab	298b	157.7ab	158.6b	246.8ab	149.3ab
T_3	0.352b	0.367b	0.42c	0.35c	252bc	284bc	151.8bc	152.1c	241.96bc	244.7ab
T_4	0.356b	0.380b	0.52b	0.50b	238cd	262cd	146.4cd	147.0d	235.8cd	237.4bc
T_5	0.400a	0.437a	0.60a	0.60a	226d	244d	142.1d	145.6d	227.9d	231.8c

Means with same letter (s) are statistically similar at 5 % level of probability S1 = Soil 1 (Silty clay loam) S2 = soil 2 (Silt loam)

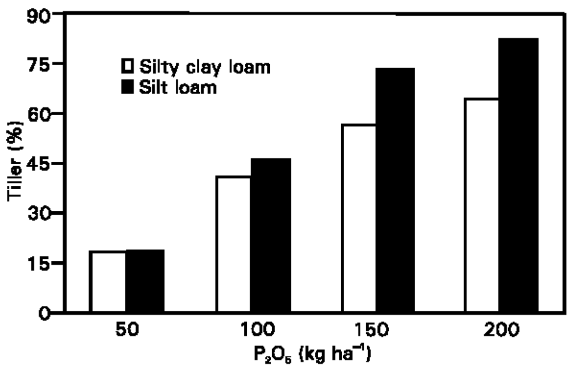

Fig. 1: Effect of phosphorus on tillers of wheat

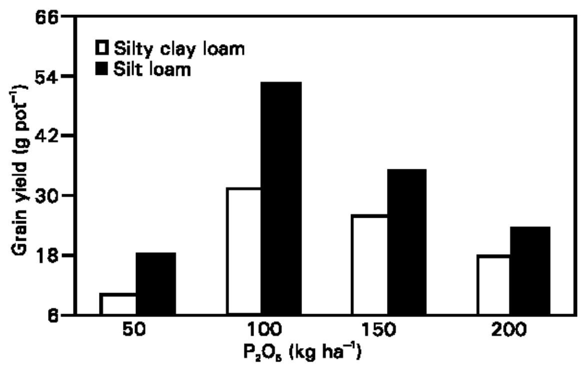

Fig. 2: Effect of phosphorus on grain yield of wheat

statistically non-significant. Minimum height was recorded in the case of control in both the soils (51.23 and 49.00 cm, respectively). At given levels of phosphorus, more height of plant was observed from S1 than that of S2. Less height of plant from S2 soil might be due to the presence of high salinity (EC_e 12 dS m^{-1}) and sodicity (SAR 24.05). Inhibited vegetative growth in highly saline media might be due to reduced cell division, cell enlargement and cell wall expansion (Greenway, 1973).

Number of tillers pot^{-1}: Results shows that number of tillers increased significantly with the application of phosphorus in both the soils (Table 2). Less number of tillers pot^{-1} were noted in the case of control in both the soils (13 and 11 tillers pot^{-1}), respectively. This might be due to inadequate fertility levels under these conditions, which restricted the growth. Maximum number of tillers was recorded in T_4 (150 kg P_2O_5 ha^{-1}) and T_5 (200 kg P_2O_5 ha^{-1}) in both the soils, respectively. At similar P levels, less number of tillers was produced from soil S2 than that S1. Overall, there was a significant increase in number of tillers pot^{-1} in both the soils over control. It is interesting to note that percent tillers were more with phosphorus application from silt loam than that from silty clay loam soils (Fig. 1). For instance, there was 18.18; 17.92, 45.45; 41.00, 72.70; 56.39 and 81.82; 64.01%, respectively increase in tillers at 50, 100, 150 and 200 kg P_2O_5 ha^{-1} in silt loam and silty clay loam soils. The increase in tillering could be attributed to better nutrition even on adverse soil environment. Results are in line with Brown *et al*. (1961) and Bhatti *et al*. (1983).

1000-grain weight (g): Different levels of phosphorus significantly affected the 1000-grain weight (Table 2). Results indicated that highest 1000-grain weight was recorded in T_3 (100 kg P_2O_5 ha^{-1}) in both the soils, respectively, which was statistically significant over all other treatments. At 100 kg P_2O_5 ha^{-1}, more 1000-grain weight was noted in the case of soil S1 that of S2. It indicated that phosphorus application helped in grain filling, resulting in an increased grain weight and consequently higher grain yield. Brown *et al*. (1961) observed the similar results and reported that 1000-grain weight of wheat increased significantly with phosphorus application on salt affected soils.

Grain yield (g pot^{-1}): The grain yield is a function of the combined contribution of various yield components, which have direct relationship to the growing conditions and practices adopted to manage the crop. Yield obtained at 0 and 50 kg P_2O_5 ha^{-1} were significantly lower than those at 100, 150 and 200 kg P_2O_5 ha^{-1} (Table 2). At same level of phosphorus, more yields were noted in silty clay loam than that from silt loam soils. Reduction in yield at higher salinity (12.0 dS m^{-1}) was attributed almost entirely to the reduction in seed weight per spike. Reduction in both seed weight per spike (data not shown) and 1000-grain weight were the main contributing factors to the grain yield in the case of silt loam soils. Francois *et al*. (1986) observed the similar results and reported that soil salinity greatly reduced the seed weight per spike and 1000-grain weight, which consequently lowered the yield of wheat. There was 10.62, 32.96, 27.4 and 19.2 % increase in yield at 50, 100, 150 and 200 kg P_2O_5 ha^{-1} over control in silty clay loam soil (Fig. 2). Similarly the yield was 19.3, 55.4, 36.9 and 25.2% in silt loam at 50, 100, 150 and 200 kg P_2O_5 ha^{-1} over control, respectively, depicting that P played a significant role in increasing yield by providing favourable growth conditions.

Manchandra *et al*. (1982), Chaudhry *et al*. (1992) and Azam, (1993) reported that grain yield increased with phosphorus application from saline-sodic soils.

Straw yield (g pot^{-1}): The data of straw yield (Table 2) depicts that straw yield of wheat was affected significantly in both the soils with phosphorus levels. Maximum straw yield was 18.95 and 14.09 g pot^{-1}, respectively in the case of silty clay loam and silt loam soils in T_3, which was followed by T_4 and T_5. Straw yield was increased by 24.09, 55.84, 52.38 and 50.57; 11.31, 49.15, 30.23 and 29.23 % at 50, 100, 150 and 200 kg P_2O_5 ha^{-1} over control in silty clay loam and silt loam soils, respectively. Like grain yield, the treatment where 100 kg P_2O_5 ha^{-1} was applied has resulted higher straw yield in both the soils over all other treatments. Results indicated that less straw yield was resulted with the same levels of phosphorus from silty clay loam than that from silt loam soils. Increased in straw yield of wheat with phosphorus application from salt-affected soils was also reported by Manchandra *et al*. (1982) and Niazi *et al*. (1993).

At given levels of phosphorus, the reduction in growth and yields of wheat was more in the case of silt loam (EC_e 12.0 dS m^{-1} and SAR 24.05) than that in silty clay loam (EC_e 5.6 dS m^{-1} and SAR 14.02) soils, respectively at similar levels of phosphorus. This might be due to osmotic effect of salts (Greenway and Munns, 1980), antagonistic/synergistic effect of Na^+, Ca^{+2}, Mg^+, CO_3^{-2}, HCO_3^{-2}, Cl^- and SO_4^{-2} ions (Staple and Toenniessen, 1984) or specific ion toxicity (Ayres and Westcot, 1985). The osmotic potential caused by salts reduces the ability of plant roots to extract water. Water availability in the soil is related to the sum of the matric and osmotic potential. Water taken up by plant is relatively free of salts thus the plant must expend extra metabolic energy to extract its water from more saline solution from silt loam than that from silty clay loam soils, respectively. As a results of which plant could not maintain turgor (Arif, 1990) due to which more reduction in yield was occurred in silt loam than that in the silty clay loam soils. A decrease in yield may also be due to accumulation of exchangeable Na^+ (Pearson, 1960), which may cause mechanical impedance to root penetration due to poor soil structure prevailing in the root zone of silt loam (SAR 24.04) soil and/or sodium may be directly toxic to wheat plant (Rhoades, 1972). Thus nutritional imbalance due to high Na^+ in soil solution and/or on exchange sites may result in poor crop yield from silt loam that from silty clay loam soils.

Mineral concentration of wheat straw

Nitrogen and phosphorus concentration (%): The nitrogen and phosphorus content of wheat straw was affected significantly with phosphorus levels over control in both the soils (Table 3). Maximum nitrogen content (0.4 %) was noted in T_5 where 200 kg P_2O_5 ha^{-1} was added followed by T_4, T_3 and T_2, while minimum was in T_1 (0.302 %) in silty clay loam soil. Similarly, maximum N was 0.437 % in straw resulted from T_5 in the case of silt loam soil. The increase in N content of straw might be due to the reason that phosphorus application had improved the root growth and other physical properties of the soils, due to which N availability to plant was increased. Low nitrogen content in straw yielded in the case of control was associated with poor growth of the plant under saline-sodic soil.

It is evident (Table 3) that phosphorus levels significantly increased the P content of straw over control under both the soil conditions. Maximum P content was recorded in T_5 (0.60 and 0.60%) while minimum in control (0.20 and 0.24 %), respectively in both the soils. The increased P content at higher P rates might be due to the better supply of phosphorus in growing medium. Rabie *et al*. (1985) and Niazi *et al*. (1992) observed the similar results and reported that P uptake by straw was more at higher P levels than that at lower P rates.

Potassium, sodium and chloride content of straw (mmol kg^{-1}): The K content of wheat straw was decreased significantly with phosphorus rates over control in both the soils (Table 3). Maximum K concentration was observed in control in both the soils. The decrease in K content might be due to the reason that ammonium ion (NH_4^+) would increase the fixation of K in the soil. Joshi *et al*. (1989) reported that under saline-sodic soil conditions, the uptake of Na^+ was more which resultantly reduced the uptake of potassium in wheat straw.

Results (Table 3) revealed that phosphorus rates significantly reduced the uptake of Na^+ in both the soils. Maximum Na^+ was noted in the control (160.2 and 168.5 mmol kg^{-1}), respectively for soils S1 and S2. Relatively higher concentration of Na^+ under saline-sodic conditions may be attributed to the increase amount of Na^+ in soil solution. Higher application of phosphorus along with nitrogen and potassium depressed the uptake of Na^+ in wheat straw. Low concentration of Na^+ in wheat straw as a result of phosphorus, nitrogen and potassium in saline and saline-sodic soils could be attributed to the dilution effect as well as the other ions, which competed sodium ions on exchange sites. Azam (1993) observed the similar results and reported that application of NP and K fertilizers significantly lowered the uptake of Na^+ in wheat straw from saline-sodic soils.

Maximum chloride (Cl^-) contents like Na^+ were observed in control on both the soils. Phosphorus levels significantly lowered the Cl^- content of straw in soils S1 and S2 (Table 3). The low concentration of Cl^- in wheat straw as a result of P rates along with N and K fertilizers might be practically due to the dilution effect because of better growth and particularly due to competition between chloride and nitrate ions (liberated during nitrification process) resultant less uptake of chloride. Siddique and Hassan (1991) recorded the similar results and reported that phosphorus along with N and K fertilizers significantly reduced the uptake of chloride ions.

Growth and yield were significantly enhanced by application of phosphorus on saline-sodic soils. The increase in growth and yield was more with similar levels of phosphorus from silty clay loam than that from the silt loam soils. It can be concluded that for getting maximum grain yield of wheat, phosphorus may be added @ 100 kg P_2O_5 ha^{-1} on saline-sodic soils. The uptake of N and P was increased, whereas K^+, Na^+ and Cl^- decreased with phosphorus application.

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