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Effect of phosphorus and zinc on yield and nutrient uptake by okra (*Abelmoschus esculentus* L.) under different salinity conditions

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Abstract
This present study was performed at the Department of agriculture chemistry and soil science, A. S. (P.G.) College, Lakhaoti (Bulandshahr), Uttar Pradesh, during *kharif* seasons of 2005 and 2006. The experimental design aimed to study the response of okra to different phosphorus and zinc fertilizer levels under two levels of soil salinity (EC). The obtained results from the two years showed that increasing level of phosphorus and zink up to 90 and 40 kg ha^{-1}, repectively increased green and dry pod yield of okra while soil salinity decreased yield dramatically due to osmotic stress. Results showed that the phosphorus uptake by the crop significantly increased by different phosphorus level. A consistent increase ire phosphorus uptake by okra pods was noticed with increasing levels of phosphorus and a maximum value (60.3 and 73.4 mh/pot) was recorded under 90 kg P_2O_5 ha^{-1} under normal condition (4 dSm^{-1}). This indicated increasing soil salinity (8dSm^{-1}) reduced the uptake of phospuorus and zinc because showing an antagonistic effect on the absorption of phosphorus and zinc by the crop.

Keywords: Effect, phosphorus, nutrient uptake, different salinity conditions

1. Introduction

Okra (*Abelmoschus esculentus* L.) or ladies finger is an economically important vegetable crop grown in the tropical and subtropical parts of the world. India is the first largest producer of okra followed by followed by Nigeria., it occupies an area of 4.98 lakh hectares with average production and productivity of 57.48 lakh tonnes and 11.75 t/ha, respectively, and is 3.9% of total vegetable production while in Uttar Pradesh, it occupies an area of 12.44 thousand ha with an average production and productivity of 159.3 thousand tonnes and 12.81 t/ha, respectively [12]. Okra provides an important source of vitamins, calcium, potassium and other mineral matters which are often lacking in the diet in developing countries [13].

Salinity is a major problem and lead to a reduction of biodiversity and land degradation. In many plant species, soil salinity is known to reduce growth and development through osmotic stress, ion toxicity, mineral deficiencies and induced physiological and biochemical disorders in metabolic processes [11]. Salinity stress is often associated with nutritional imbalance. The interaction between salt stress and other environmental factors influence the plant's response to the stress [2]. Excessive soil salinity reduces the productivity of many agricultural crops, including most vegetables, which are particularly sensitive throughout the ontogeny of the plant. The salinity threshold (EC) of the majority of vegetable crops is low (ranging from 1 to 2.5 dSm-1 in saturated soil extract. The objective of this research is to discuss the effects of salinity on vegetable growth and how management practices (fertilization) can prevent soil and water salinization and mitigate the adverse effects of salinity.

Phosphorus is a constituent of nucleic acid, phospholipids and several enzymes which are of great importance in the transformation of energy within the plant system, metabolism and also in respiration in plants [27]. Indian soils have poor to medium status in available phosphorus. Only about 30% of the applied phosphorus is available for crops and remaining part is converted to insoluble phosphorus. Phosphorus play a key role in the formation of energy rich bound phosphate (ADP and ATP). It has beneficial effect on root development, growth and also hartens maturity as well as improves quality of crop produce [3]. Zinc is an essential microelement required by higher plants, and is mainly absorbed in the form of Zn++. Zinc also plays an important role in the production of biomass [5]. In addition, Zn plays other indirect and significant roles as stabilizer of proteins, membranes, and DNA-binding proteins such as

Zn-fingers [1]. Zinc is required for the bio-synthesis of the plant growth regulator such as indole-3-acetic acid, Further more, zinc may be required for chlorophyll production, pollen function and fertilization. Zinc deficiency also affects carbohydrate metabolism, damages pollen structure, and decreases the yield [20, 8]. [4] found that application of zinc had a significant effect on okra yield. Zinc deficiency is one of the most widespread micronutrient deficiencies in the alkaline soil condition. So, it is very important to apply zinc fertilizer for increasing crop yields and improving crop quality.

However, the cultivar Pusa Sawani has some tolerance to salts and thus also to a larger pH range because Increasing soil salinity are closely related to fertilization practices. Therefore, the objective of this investigation is to analyze the effects of salinity on yield of okra and how phosphorus and zink fertilizer management practices can prevent soil salinization and mitigate adverse effects of salinity.

2. Materials and Methods

Two pot experiments were conducted at the Department of agriculture chemistry and soil science, A. S. (P.G.) College, Lakhaoti (Bulandshahr), Uttar Pradesh, during *kharif* seasons of 2005 and 2006 to study the response of okra to different phosphorus and zinc fertilizer levels under two levels of soil salinity (EC). The Research center is situated on the Bulandshahr-Garhmukteshwar road at a distance of 18 km from Bulandshahr (U.P.) towards Syana town. The latitude and longitude of the experimental site are 28.4° N and 77.1°E respectively with an elevation of about 207 m above mean sea level. The climate was semi-arid and subtropical characterized by extreme hot summer and cool winter. The soil was sandy loam, low in organic carbon, nitrogen and zink, medium in phosphorus and alkaline in reaction having a pH of 8.0. Treatments were consisting of different phosphorus levels (0, 30, 60 and 90 kg ha^{-1} from triple super phosphate), different zinc levels (0, 10, 20 and 40 kg ha^{-1} from zinc sulfate) and two levels of soil salinity (4 (Normal) and 8 $dS.m^{-1}$). The soil salinity level (4 (Normal) and 8 $dS.m^{-1}$) were prepared by adding calculated appropriate amount of $CaCl_2$, $MgCl_2$, NaCl and $MgSO_4$ to normal soil. The amount of phosphorus and zinc sulfate was calculated based on soil weight of pot. All the pots were fertilized with above mentioned fertilizers so that fertilizers were incorporated into the soil before seeding. The pots were arranged according to three-factor facrorial randomized block design (FRBD) in three replications. The pots were randomly arranged and rearranged several times during the growth period. The seed surface was sterilized by immersion in 2% sodium hypochloride solution for 10 min and 96% ethanol for 30 s, then seeds were washed with distilled water for several times. Ten seeds were sown directly in pots. Immediately after sowing, soils were watered and watering was carried out regularly every two days during the experiment. Yield of pod from each pot was recorded in gram separately in each replication. The pH, EC [22], available N was determined using the method as suggested by [26], while Olsen's available P and available K were determined by the methods as described by [14]. DTPA extractable Zn was determined by the methods as described by [17]. A representative soil sample from 0-15 cm depth was collected from the experimental pots for macro and micronutrient analysis after harvest of crop. The dried sample of pods and haulums were powdered in a Willy mill (having SS blades) for analysis of N, P and K where as for analysis of Zn the powder was made by grinding in a wooden mortar and pestle. The nitrogen from the pod dry matter was determined by Kjeldahls method whereas for determination of P, K and Zn, the acid extracts were made by using perchloric and sulphuric acids mixture (4:1). From the acid extracts the P was determined by unreduced vanadomolybdo phosphoric yellow colour method, K by flame photometric method (Jackson, 1973) while AA spectrophotometer was used for determination of Zn. After determining the contents the uptake value by each plant components were calculated by the formula.

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Dry matter yield (kg/ha) x Nutrient content (\%)}}{100}$$

3. Results and Discussion

Green pod yield

A study of table -1 revealed that the green pod yield of okra decreased significantly at 8 dSm level of soil salinity. The increase in yield was significant for each level of phosphorus application as compared to control. The increase in the green pod yield with 30. 60 and 90 kg P ha were 10.5, 18.9 and 26.8 % over control, respectively The adverse effect of salinity on okra production is due to osmotic effect, which lowers the osmotic potential of the medium, a possibility under salt stress condition [9] and [15]. A further study of Table- 1indicated that the green pod yield of okra increased significantly with phosphorus application during both the years of experimentation. Response of phosphorus application have also been observed by [21] and [7]. Application of zinc sulphate also increased the green pod yield of okra. The crop grown with $ZnSO_4$ level @ 10, 20 and 40 kg ha^{-1} produced 6.2, 11.2 and 15.7 %, respectively more green pod yield over control. The maximum green pod yield was recorded at 40 kg followed by 20 kg $ZnSO_4$ ha^{-1}. The ressponse due to zinc sulphate application may be attributed to the deficient status of available zinc in soil. The interaction between salinity and phosphorus had significant effect on green pod yield of okra. The maximum value of green pod yield (52.5 and 49.3 g/pot) was recorded at 90 ka P_2O_5 ha^{-1} and control treatments. The magnitude of increase was greater under control treatment and maximum green pod yieid was recorded with 90 kg P_2O_5 ha^{-1} and control treatment. Soil salinity tended to reduce the green pod production at all the levels of applied phosphorus. The adverse effect of soil salinity was much more pronounced under phosphorus application. Green pod yield of okra was also affected significantly by salinity and ZnSO4 interaction. (Table -2). Soil salinity at higher level (8 $dSrn^{-1}$) produced lower pods yield (44.8 and 41.6 g/pot) in the presence and absence of phosphorus. Application of phosphorus increased the pod yield of okra under both the levels of soil salinity. The results are in agreement with those reported by [25].

Table 1: Effect of salinity, phosphorus and zink levels on green and dry pod yield of okra during two year (2005 and 2006)

			Pod yield (g/pot)			
		Green			**Dry**	
Treatments	2005	2006	pooled	2005	2006	Pooled
Salinity level (dSm^{-1})						
4 (Normal)	48.23	46.2	47.215	9.5	8.5	9

8	38.6	35.5	37.05	7.5	6.5	7
SEm±	0.27	0.26	0.265	0.029	0.03	0.0295
CD at 5%	0.55	0.53	0.54	0.057	0.07	0.0635
Phosphorus levels (kg/ha)						
0	38.1	36.3	37.2	7.5	7.1	7.3
30	42.1	40.3	41.2	8.2	7.8	8
60	45.1	43.5	44.3	8.9	8.5	8.7
90	48.3	46.5	47.4	9.4	9	9.2
SEm±	0.39	0.37	0.38	0.41	0.42	0.415
CD at 5%	0.79	0.76	0.775	0.83	0.85	0.84
Zink levels (kg/ha)						
0	40.1	38.5	39.3	7.9	7.4	7.65
10	42.6	41	41.8	8.3	7.8	8.05
20	44.6	43	43.8	8.7	8.2	8.45
40	46.4	44.8	45.6	9.1	8.6	8.85
SEm±	0.39	0.37	0.38	0.41	0.4	0.405
CD at 5%	0.8	0.75	0.775	0.82	0.9	0.86

Table 2: Interaction effect of salinity x zink and phosphorus x salinity on green pod yield of okra during two year (2005 and 2006)

Treatments	**Phosphorus levels (kg/ha)**							
	0		30		60		90	
	2005	2006	2005	2006	2005	2006	2005	2006
Salinity level (dSm^{-1})								
4 (Normal)	42.8	40.7	47.8	45.8	50.0	46.9	52.5	49.3
8	33.5	31.4	36.5	34.5	40.5	37.4	44.8	41.6
SEm±	0.55	0.54	0.49	0.74	0.78	0.81	0.83	0.88
CD at 5%	1.12	1.1	0.1	1.52	1.63	1.65	1.68	1.83
	Zink levels (kg/ha)							
	0		10		20		40	
	2005	2006	2005	2006	2005	2006	2005	2006
Salinity level (dSm^{-1})								
4 (Normal)	45.3	43.2	47.8	45.6	49.5	47.2	50.5	48.4
8	35	32.9	37.5	35.3	39.8	37.5	42.3	40.2
SEm±	0.54	0.53	0.52	0.55	0.62	0.65	0.72	0.76
CD at 5%	1.11	1.09	1.1	1.14	1.28	1.32	1.53	1.62

Table 3: Interaction effect of salinity x zink and phosphorus x salinity on dry pod yield of okra during two year (2005 and 2006)

Treatments	**Phosphorus levels (kg/ha)**							
	0		30		60		90	
	2005	2006	2005	2006	2005	2006	2005	2006
Salinity level (dSm^{-1})								
4 (Normal)	8.4	7.9	9.4	8.8	9.8	9.2	10.3	9.5
8	6.6	6.1	7.0	6.4	8.0	7.4	8.6	7.8
SEm±	0.06	0.04	0.07	0.08	0.09	0.09	0.12	0.13
CD at 5%	0.13	0.9	0.15	0.17	0.20	0.20	0.26	0.28
	Zink levels (kg/ha)							
	0		10		20		40	
	2005	2006	2005	2006	2005	2006	2005	2006
Salinity level (dSm^{-1})								
4 (Normal)	8.8	7.9	9.4	8.9	9.7	9.1	9.9	9.4
8	7.0	6.5	7.3	6.8	7.6	7.3	8.4	7.9
SEm±	0.06	0.05	0.08	0.08	0.11	0.13	0.14	0.16
CD at 5%	0.13	0.12	0.17	0.17	0.24	0.28	0.30	0.34

Table 4: Interaction effect of phosphorus x zink on phosphorus uptake (g/pot) by okra during two year (2005 and 2006)

Treatments	**Zink levels (kg/ha)**							
Phosphorus levels (kg/ha)	0		10		20		40	
	2005	2006	2005	2006	2005	2006	2005	2006
0	36.8	35	38.9	37.1	41.3	39.5	45	43.2
30	40.7	38.9	44.5	42.7	46.1	44.3	53.2	51.4
60	48.4	46.6	52.4	50.6	55.9	54.1	56.8	55.0
90	54.6	52.8	57.8	56.0	55.6	53.9	60.2	58.4
SEm±	2.01	2.11	2.12	2.15	2.34	2.37	2.46	2.47
CD at 5%	4.06	4.32	4.50	4.57	4.75	4.82	5.10	5.13

Dry pod yield

A perusal of the data presented in table-1 indicated that dry pod okra decreased significantly with 8 dSm^{-1} level. Like green pod yield, phosphorus levels affected the dry matter yield of okra significantly and maximum yield (9.4 and 9.0 g/pot) was recorded at 90 kg P_2O_5 ha^{-1} application. The increase in dry pod yield of okra due to 30, 60 and 90 kg P_2O_5 ha^{-1} over control was 9.3, 18.7 and 25.3%, respectively. The reduction in dry pod yield may be ascribed to an increased sodium concentration in soil solution. Similar results were also reported by [16]. Zinc sulphate application to the soil also proved to be beneficial as it enhanced the dry pod yield of okra over control. The average increase in dry pod yield as result of 10, 20 and 40 kg $ZnSO_4$ ha^{-1}. was 5.0. 10.1 and 15.2 %, respectively during both the years of experimentation. The experimental soil was poor in available zinc, therefore response to the levels of zinc sulphate application was most likely and consistent with zinc status of soil. The interaction between soil salinity x phosphorus had a significant effect on the dry pod yield of okra (Table-2). Soil salinity reduced the yield of okra under all the levels of applied phosphorus during both the years of experimentation. But phosphorus addition enhanced the dry pod yield of okra under both the levels of soil salinity. The maximum dry pod yield (10.3 and 9.5 g/pot) was recorded at 90 kg P_2O_5 ha^{-1} level in non-saline (normal) conditions. Zinc sulphate x salinity interaction had a significant effect on the dry pod yield of okra (Table-3). The dry pod yield was reduced at 8 dSm^{-1} soil salinity levels indicating an adverse effect on dry pod production. Application of zinc sulphate enhance the yield significantly under the levela of soil salinity. Thus zink sulphate mitigated the adverse effect of soil salinity on okra production. The maximum yield (9.9 and 9.4 g/pot) was recorded with the application of 40 kg $ZnSO_4$ ha^{-1} under normal soil (4 dSm^{-1}). Similar findings were reported by [23].

Nutrient uptake (kg ha^{-1})

Phosphorus

A study table-4 indicated that there was a significant reduction in phosphorus uptake with salinity level (8 dSm^{-1}) over control, The extent of decrease under 8 dSm^{-1} level was 17.3 % over control. This reduction in phosphorus uptake may be ascribed to lower dry pod production. The phosphorus uptake by the crop significantly increased by different phosphorus level. A consistent increase ire phosphorus uptake by okra pods was noticed with increasing levels of phosphorus and a maximum value (60.3 and 73.4 mg/pot) was recorded under 90 kg P_2O_5 ha^{-1}. The uptake of phosphorus by okra pods was affected significantly with zink sulphate levels. A gradual increase in phosphorus uptake by the crop was recorded upto 40 kg $ZnSO_4$ ha^{-1} ha application. The results are closed with the findings of [6]. The interaction between salinity and phosphorus had a significant effect on uptake of phosphorus by okra pods. Soil salinity reduced the uptake of phosphorusby by crop at all the levels of phosphorus significantly. Phosphorus uptake was improved with its application at both the levels of soil salinity and maximum uptake value was recorded at 90 kg P_2O_5 ha^{-1} and control treatment. The uptake of phosphorus by okra pods was also influenced signilicantly with P x Zn interaction. It is evident from the data that the application of phosphorus increased the uptake of phosphorus significantly at all the levels of $ZnSO_4$. Similarly zinc sulphate also improved phosphorus utilization by okra pods. The maximum value of phosphorus uptake (74.8 and 73.0 mg/pot) was recorded at 90 kg P_2O_5 ha^{-1} and 40 kg $ZnSO_4$ ha^{-1} during both the years of experimentation. The results are in agreement with those reported by [18] and [24].

Zink

A perusal of the data in table -5 revealed a significant reduction in zinc uptake by okra pods due to increase in soil salinity over control. This reduction may be due to lower dry pod production at higher salinity level. The increasing levels of phosphorus upto 60 P_2O_5 kg ha^{-1} tended to increase the uptake of zinc by okra pods. Thereafter, reduction in Zn uptake was noticed at 90 kg P_2O_5 kg ha^{-1} addition. This reduction in Zn uptake may be ascribed to antagonistic relationship between Zn and P. The increasing supply of zinc sulphate resulted in a significant increase in the uptak of Zn by okra pods over control during. The magnitude of tncrease in zinc uptake by okra pods was significant upto the highest level of $ZnS0_4$ application both the years of experimentation. [10] also reported an increase in Zn uptake by the crop with its addition. The increase in zink sulphate may be due to increase in dry pods production and Zn content in okra pods with zink sulphate addition. The interaction between soil salinity and phosphorus had a significant eftect on the utilization of zinc by okra pods. Application of phosphorus tended to increase the uptake of zinc by okra pods upto 60 and brought about a decrease at higher levels of (90 kg P_2O_5 kg ha^{-1}) under no salinity (Normal). However contrary to this the zinc uptake was drastically reduced as salinity level increased upto 8 dSm^{-1}over control. The maximum uptake of zinc was recorded at 60 kg P_2O_5 kg $ha^{-1}$and control during both the years of experimentation. This indicated soil salinity reduced the uptake of zinc showing an antagonistic effect on the absorption of zinc by the crop and minimum value of Zn uptake was recorded under without phosphorus and 8 dSm^{-1}salinity levels. The other interactions were not found statistically significant on Zn uptake during present investigation

Table 5: Interaction effect of phosphorus x salinity on zink uptake (ppm/pot) by okra during two year (2005 and 2006)

Treatments	Phosphorus levels (kg/ha)							
Salinity level (dSm^{-1})	0		30		60		90	
	2005	2006	2005	2006	2005	2006	2005	2006
4 (Normal)	0.15	0.12	0.16	0.14	0.18	0.18	0.16	0.15
8	0.12	0.11	0.13	0.12	0.12	0.13	0.13	0.12
SEm±	0.008	0.006	NS	NS	NS	NS	NS	0.006
CD at 5%	0.017	0.013	NS	NS	NS	NS	NS	0.013

4. Conclusions

The application of phosphorus and zink also increased the green and dry pod yield of okra crop significantly. Salinity (8dSm^{-1}) had an adverse effect on crop yields. The contents and uptake of nutrients were also affected by different levels of nutrient, it is safely inferred that higher yield of okra with good quality can be obtained by manipulating nutrients doses even under moderate salinity condition.

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