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Root Biomass and Phosphorus Availability as influenced by Soil Salinity, Phosphorus Sources and Biofertilizers in Cowpea (*Vigna unguiculata* L.)

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ABSTRACT

A pot experiment was conducted at S.K.N. College of Agriculture, Jobner using cowpea crop to determine root biomass and phosphorus availability as influenced by soil salinity, phosphorus sources and biofertilizers in cowpea (*Vigna unguiculata* L.) during *kharif* 2015. The experiment included soil salinity (three levels of EC *i.e.,* 1.22, 4.0 and 6.0 dS/m), phosphorus sources (SSP, DAP and PROM), and biofertilizers (control, PSB and PSB + VAM) laid out in completely randomized design replicated thrice. The results showed that soil salinity S_1 (EC 1.22 dS/m) recorded highest root biomass (0.643 g/pot), phosphorus content in both roots (0.246 %) and soil (0.032%) over S_4 and S_6. Results further revealed that phosphorus rich organic manure (P_3) obtained significantly higher root biomass (0.636 g/pot), phosphorus content in both roots (0.240 %) and soil (0.033 %) over P_1 and P_2. Seed inoculation with PSB + VAM (B_2) gave significantly higher root biomass (0.684 g/pot), phosphorus content in both root (0.243%) and soil (0.032%) over B_0 and B_1. Among different combinations, application of phosphorus rich organic manure and biofertilizers (PSB+VAM) under normal water (EC 1.22 dS/m) proved better root biomass and phosphorus availability in the soil.

Key Words: Biofertilizers, Cowpea, Phosphorus, Root Biomass, Salinity.

INTRODUCTION

Cowpea is *kharif* pulse crops grown for vegetable, grain, forage and green manuring. Cowpea has great importance because of high yielding, short duration and quick growing varieties available. Green tender pods of cowpea are used as vegetable purpose. Cowpea pods contain protein (4.3%), moisture (84.6%), fat (0.2%) and carbohydrate (8.0%). In major portion of arid and semi-arid regions poor quality groundwater is used as a source of irrigation. The continuous use of poor quality irrigation water creates salinity or sodicity problems in soil. The problem is noted in the areas where scarcity of good quality water and use saline / sodic ground water as a major source of irrigation. Salt affected soils have an area of about 13.8 M ha in the country (Yadav *et al,* 2007) and 1.24 M ha in Rajasthan and found in almost all the district of Rajasthan (Sharma *et al,* 2004). Physical and chemical properties of irrigated soils adversely affect and cause accumulation of soluble salts in the root zone further unscientific and indiscriminate usages of saline water for irrigation reduce crop productivity (Chauhan *et al,* 1988). Phosphorus is most essential nutrient for pulse crop and very significant nutrient next only to nitrogen for the plant growth and development. It is a constituent of amino acids, phosphatides, proteins, nucleic acids,

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Table 1. Different salts and their ionic composition added in base for creating different salinities.

EC (dS/m)	mmol/kg					Final ECe (dS/m)
	Na^+	Ca^{+2}	Mg^{+2}	Cl^-	SO_4^{-2}	
1.00	9.6	1.2	1.2	2.2	6.0	1.22
4.00	16.6	5.6	5.6	7.8	24.0	4.14
6.00	25.6	11.2	11.2	1.28	39.0	6.10

phytin and several co-enzymes *viz*., pyrophosphate, thiamine and pyrodoxyl phosphate (Yadav *et al,* 2009). Vesicular arbuscular mycorrhiza can play a vital role in improving availability of phosphorus to plant in P deficient soils and reduce P-fertilizer application by about 25-30%. It is well recognized that VAM fungi improve growth and development of plant through increased availability of relatively immobile nutrients to the plants such as phosphorus and zinc (Tarafdar and Rao, 1997). The phosphate solubilizing bacteria (PSB) are heterotrophic and aerobic in character and it can solubilize nearly 20-30% of insoluble phosphate from the fixation sites (Tilak and Annapurna, 1993). An effort was consequently made to experiment the phosphorus availability under different levels that are soil salinity, phosphorus sources and biofertilizers to discover the effect of phosphorus availability and root biomass of cowpea.

MATERIALS AND METHODS

A pot trial was conducted at Department of Plant Physiology, College of Agriculture, Jobner during 2015 in cage house in completely randomized design (CRD) with three replications in which three salinity levels (S_1: 1.22, S_4: 4.0 and S_6: 6.0 dS/m), phosphorus sources (P_1: SSP, P_2: DAP and P_3: PROM) and biofertilizers levels (B_0: control, B_1: PSB and B_2:PSB + VAM) are used and by this means, making nine combinations of treatments with three replications. The physico-chemical properties of experimental soil were bulk density (1.51 Mg/m^3), particle density (2.59 Mg/m^3), Na (9.50 me/L), Ca (1.2 me/L), Mg (1.2 me/L), CEC (7.8 cmol (P^+) kg/soil), exchangeable Na (0.65 cmol/kg) and ESP (9.55 %). To attain the ECe level of 4 and 6 dS/m Cl^- and SO_4^{-2} of Na, Ca and Mg were added as solution keeping the ratio of 3:1 of Cl^- : SO_4^{-2} and thoroughly mix in the soil before seeding (Table 1). The experimental soil consist pH (8.40), organic carbon (1.83 g/kg), nitrogen (127.10 kg/ha), phosphorus (21.24 kg P_2O_5/ha) and potassium (147.50 kg K_2O/ha) before the sowing of cowpea. Cylindrical ceramic pots (28 cm height and 20 cm diameter) were filled with 10 kg of soil before the sowing. During filling the pots, the broken pieces of stone were placed in the bottom hole to allow free drainage of water. The variety 'RC-19' of cowpea was sown on 7th July, 2015 with sowing of 5 seeds per pot. Following the physiological maturity, harvested the cowpea on 15th September, 2015. After the harvest of crop the roots were removed and weighed on electronic balance for the calculation of total root mass per pot. Total soil phosphorus was determined by $HClO_4$ digestion (Jackson, 1973) Olsen's method and available phosphorus by colorimetrically extracting the soil with 0.5N $NaHCO_3$ at pH 8.5 (Olsen *et al,* 1954). For microbial biomass phosphorus (P mic) soil samples were fumigated with liquid ethanol free chloroform ($CHCl_3$) in desiccators (Srivastava and Singh, 1988).

RESULTS AND DISCUSSION

Effect of soil salinity

A perusal of results revealed that root biomass of cowpea was decreased significantly ($P<0.05$) with higher levels of salinity (Table 2). Root biomass were decreased significantly up to 11.50 and 17.88 per cent under S_4 and S_6 treatments over S_1 (normal soil), respectively. Higher soil salinity levels reduced nutrient availability due to fixation

Table 2. Effect of salinity, phosphorus sources and biofertilizers on root biomass, P content in roots, total P, available P_2O_5 and microbial biomass P in soil

Treatments	Root biomass (g/pot)	P content in roots (%)	Total P content (%)	Available P_2O_5 (kg/ha)	Microbial biomass P (µg/g soil) Month I	Month II	At harvest
Salinity							
S_1	0.643	0.246	0.032	22.07	28.71	25.87	21.89
S_4	0.569	0.235	0.028	21.43	26.32	23.54	19.61
S_6	0.528	0.217	0.025	20.74	22.23	20.70	16.64
SEm. ±	0.008	0.004	0.0004	0.28	0.51	0.38	0.35
C.D.(P=0.05)	0.021	0.012	0.0011	0.80	1.43	1.08	1.00
Phosphorus							
P_1	0.535	0.221	0.024	20.75	22.36	20.94	16.78
P_2	0.569	0.236	0.029	21.47	26.20	23.40	19.51
P_3	0.636	0.240	0.033	22.02	28.70	25.77	21.86
S. Em. ±	0.008	0.004	0.0004	0.28	0.51	0.38	0.35
C.D.(P=0.05)	0.021	0.012	0.0011	0.80	1.43	1.08	1.00
Biofertilizers							
B_0	0.520	0.217	0.026	20.75	22.31	20.88	16.85
B_1	0.572	0.237	0.029	21.46	26.29	23.35	19.30
B_2	0.648	0.243	0.032	22.03	28.66	25.88	21.99
S. Em. ±	0.008	0.004	0.0004	0.28	0.51	0.38	0.35
C.D.(P=0.05)	0.021	0.012	0.0011	0.80	1.43	1.08	1.00

and transformation of nutrients in soils and affect with the absorption and uptake of nutrients due to water stress by disproportionate ionic composition have reduced nutrient metabolisms mainly which cause poor plant root growth and development (Shrinivasrao *et al,* 2004). An examination of results revealed that total phosphorus, available P_2O_5 content in soil were decreased significantly ($P<0.05$) under at higher salinity levels (Table 2). In S_4 and S_6 total P were decreased up to 12.50 and 21.87 per cent in soil to over S_1 (Normal soil), respectively. The result further revealed that per cent decrease in available P_2O_5 up to 2.98 and 6.41 under treatment S_4 and S_6 over S_1, respectively in the soil (Table 2). Higher levels of soil salinity significantly ($P<0.05$) decreased the microbial biomass P with development of growth stages (Table 2). The microbial biomass P decreased up to 8.32 and 22.57 per cent under S_4 and S_6 over normal soil at the time of one month growth stage, respectively. The subsequent decrease was 9.00 and 19.98 per cent at second month growth stage and it was 10.41 and 23.98 per cent at the time of harvest. Decreased in availability of phosphorus might be due to higher saline conditions in soil and this magnitude of decrease in phosphorus was more prominent in Ca dominated soil than the Na dominated soil. This might due to the accumulation of toxic ion in soil (Rao *et al,* 1993).

The results clear that phosphorus content in root biomass of cowpea was decreased significantly ($P<0.05$) with higher levels of soil salinity (Table 2). The highest decreased in P content in root biomass was observed under S_6 treatment and it was

Table 3. Effect of salinity, phosphorus sources and biofertilizers on calcium, sodium and magnesium content in grain and straw of cowpea

Treatments	Ca content (%)		Na content (%)		Mg content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw
Salinity						
S_1	0.216	0.617	0.250	0.264	0.124	0.079
S_4	0.227	0.639	0.254	0.273	0.128	0.084
S_6	0.255	0.739	0.265	0.284	0.085	0.085
SEm. ±	0.003	0.008	NS	NS	0.002	0.002
C.D.(P=0.05)	0.008	0.023	0.012	0.019	NS	NS
Phosphorus sources						
P_1	0.216	0.619	0.289	0.294	0.125	0.080
P_2	0.232	0.642	0.255	0.283	0.127	0.083
P_3	0.249	0.735	0.234	0.248	0.128	0.084
S. Em. ±	0.003	0.008	0.004	0.007	0.002	0.002
C.D.(P=0.05)	0.008	0.023	0.012	0.019	NS	NS
Biofertilizers						
B_0	0.217	0.612	0.284	0.298	0.121	0.079
B_1	0.232	0.648	0.256	0.272	0.129	0.083
B_2	0.248	0.735	0.239	0.256	0.130	0.084
S. Em. ±	0.003	0.008	0.004	0.007	0.002	0.002
C.D.(P=0.05)	0.008	0.023	0.012	0.019	NS	NS

lower by 4.47 and 11.78 per cent in root biomass respectively in comparison to S_4 and S_1. A data pertaining to P content in grain and straw of cowpea show that P content reduced significantly with higher soil salinity levels (Fig.1). The P content was decreased under treatment S_4 and S_6 up to 20.87 and 28.66 per cent in grain and 8.49 and 16.33 per cent in straw respectively as compared to S_1. This reduction in phosphorus might be due to synergism effect between PO_4^{3-} and SO_4^{2-} and antagonism effect between PO_4^{3-} and Cl^- ions. Antagonism effect between Cl^- and P also find out in wheat (Manchanda *et al,* 1991). Further experimental results show that Ca content in grain and straw of cowpea increased significantly ($P<0.05$) under higher soil salinity level (Table 3). An improvement in Ca content in grain was recorded up to 12.33 and 18.05 per cent and in straw 15.64 and 19.77 per cent due to S_6 over the rest of the treatments, respectively. The effect of soil salinity treatment on both Na and Mg was observed non significant in the grain and straw of cowpea (Table 3). This may be due to Ca absorption in Cl^- salinity and SO_4^{2-} salinity because of activity of Ca reduce and activity of Cl in later higher and also reduced Ca absorption in SO_4^{2-}dominated salinity may have improved Mg absorption in to the soil (Manchanda *et al*.1991). These results were in accordance with the findings of Virdiya *et al* (2008) who reported improvement in Ca, Mg and Na, content in plant with higher soil salinity levels.

Effect of phosphorus sources

The results revealed that root biomass of cowpea was significantly ($P<0.05$) increased under the application of phosphorus rich organic manure (PROM) over SSP and DAP (Table 2). The soil amendment with PROM significantly improves root biomass by 11.77 and 18.87 per cent over the other treatments, respectively. This could be attributing higher uptake of nutrients enhance carbohydrate synthesis and photosynthetic and then translocations to different parts inter calary meristems for improving meristematic development in apical buds and which at the end improved root growth of the plant (Sharma *et al,* 2001; Shekhawat and Sharma, 2001). The results showed that different phosphorus sources significantly ($P<0.05$) improved the total P content, available P_2O_5 and microbial biomass P in soil (Table 2). The increment in total P content was up to 13.79 and 37.50 per cent under application of PROM over DAP and SSP, respectively. The available P_2O_5 in soil was recorded up to 2.56 and 6.12 per cent higher under the application of PROM over DAP and SSP (Table 2). Further result showed that application of phosphorus as PROM also improve the microbial biomass phosphorus by 9.54 and 28.35 per cent over the rest of the treatments at one month growth stage, respectively. The consequent improvement was 10.12 and 23.06 per cent at second month growth stage and 12.04 and 30.27 per cent at the time of harvest stage over DAP and SSP. During the decomposition of organic matter released organic acids like acetic acid, formic acid, citric acid, oxalic acid and these organic acids turn unavailable phosphate into available phosphate form (Kumawat *el al,* 2013) and significantly improved the available P in soil compared to other treatments. It provided substances important for microbial activity and growth, which was responsible for improvement in soil microbial biomass P in the soil. Similar findings also reported by Majumdar *et al* (2007) and Mahanta and Rai (2008).

The experimental data showed that phosphorus content in root biomass of cowpea significantly ($P<0.05$) increased under the different sources of P (Table 2). The highest P content in root biomass was significantly increased up to 8.56 per cent under application of PROM over SSP and remained at par with DAP, respectively. Different phosphorus sources have positive result on the phosphorus content in grain and straw of cowpea, in which, under PROM recorded a significant increase in grain up to 46.20 and 69.02 per cent and in straw up to 10.71 and 22.04 per cent over the remaining treatments (Fig.1). The greater availability of nutrients enhanced the plant root system which resulted in greater P accumulation in the crop (Basak and Subodh, 2002). The data indicated that application of PROM significantly ($P<0.05$) improved Ca content in grain and straw of cowpea (Table 3). An increment in Ca content under PROM application in grain and straw was recorded up to 7.36 and 15.27 and 14.48 and 18.73 per cent over DAP and SSP, respectively. Further Na content in cowpea grain and straw tend to decreased significantly ($P<0.05$) under PROM application as phosphorus sources (Table 3). The decrement in Na content in grain and straw was obtained under PROM application and it was lower in grain by 11.77 and 19.04 per cent and in straw was lower by 3.75 and 15.63 per cent over rest of the treatments. Phosphorus sources were obtained non significant in Mg content in grain and straw of cowpea (Table 3). Cation like Ca, K and Mg content in grain and straw increased at the same time, whereas Na cation decreased significantly under PROM application. The Na+ ion counters with soil-P and get fix in insoluble form (Na-phosphate) in the soil so that Na availability reduced to plant with higher levels of phosphorus. A decrease in Na absorption occur by plants ultimately Ca, Mg content increase and Na^+ cation may also replace by $H_2PO_4^-$ anion from exchangeable site so that Na content reduced in grain and straw Yadav and Jakhar (2001) .

Effect of biofertilizers

The root biomass of cowpea significantly ($P<0.05$) increased under the dual inoculation of PSB+VAM (Table 2). Root biomass was increased significantly up to 13.28 and 24.11 % under PSB+VAM over PSB and control, respectively. This might be due to the VAM had favorable effect on the root establishment and development so that P availability enhanced in soil. In other words better root environment by PSB + VAM besides secretion

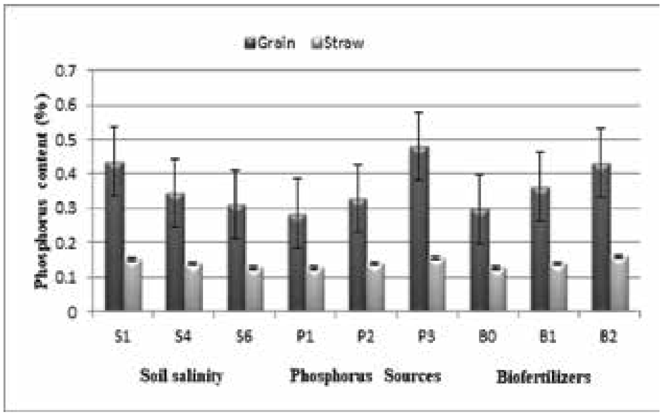

Fig. 1 Effect of salinity, phosphorus sources and biofertilizers on phosphorus content in grain and straw of cowpea

of growth promoting substances like auxins, Cytokinin etc. and improved the availability of phosphorus (Totawat *et al*. 2000). Moreover total P content, available P_2O_5 and microbial biomass P were found significantly ($P<0.05$) superior under dual inoculation of PSB +VAM in soil over rest of the treatments (Table 2). Total P increased up to 10.34 and 23.07 % under PSB+VAM, respectively over PSB alone and no inoculation. Seed inoculated with PSB and soil inoculated with VAM (PSB+VAM) significantly ($P<0.05$) recorded the maximum available P_2O_5 up to 2.64 and 6.16 per cent in soil over the other treatments, over PSB and no inoculation, respectively. The microbial biomass P increased significantly ($P<0.05$) biofertilizers over no inoculation at all growth stages and further decreased at later crop growth stages. Microbial biomass P increased up to 9.01 and 28.46 per cent under PSB alone and PSB + VAM over control at one month growth stage, respectively. The equivalent increase at second month growth stage was 10.83 and 23.94 per cent and at the time of harvest stage was 13.93 and 30.50 per cent. The available phosphorus content in soil increase due to stimulate the microbial activity in soil and after decaying of their bodies in soil by the phosphorus solubilizing bacteria. Highest soil microbial biomass P in soil was found under dual inoculation of PSB+VAM and lowest in soil under control (no inoculation). A similar finding in SMB-P with application of PSB+VAM was also recorde by Saini *et al* (2005) and Singh *et al* (2012).

Data explained that dual inoculation of PSB+VAM significantly increased P content in root biomass of cowpea (Table 2). The highest biomass was observed under PSB+VAM, which remained at par with PSB and 11.98 per cent higher over control, respectively. Further results indicated that biofertilizers significant increased phosphorus content in grain and straw of cowpea (Fig.1). The highest phosphorus content in grain and straw were observed under application of PSB+VAM and noted an increment in grain up to 19.33 and 44.96 per cent and in straw up to 13.66 and 26.40 per cent, respectively over rest of the treatments. It might be due to improvement in root growth by the increased in availability of P under PSB + VAM besides secretion of growth promoting substances (Totawat *et al,* 2000). Combined effect different organisms and solubilization effect of two or more organisms improved phosphorus content by the PSB or better phosphorus uptake under VAM applied pots was also reported by Rao (1998), Tarafdar and Rao (1997) and Saini *et al* (2005). It is obvious from the data that inoculation with biofertilizers Ca content increased significantly ($P<0.05$) in grain and straw of cowpea (Table 3). An improvement in Ca content in grain was recorded by 6.89 and 14.28 per cent and in straw was 13.42 and 20 .09 per cent due to inoculation of PSB+VAM over the other treatments, respectively. Further that the significantly ($P<0.05$) lower Na content was observed under cowpea grain inoculated with PSB and soil inoculated with VAM produced in grain and straw over rest of the treatments. Application of PSB+VAM was recorded lowest value of Na content in grain and straw of cowpea and it was lower up to 9.85 and 18.82 per cent in grain and 8.73 and 14.11 per cent in straw over rest of the treatments. The Mg content in grain and straw was found to be non significant biofertilizers (Table 3). Application of biofertilizers increase Ca^{2+} and Mg^{2+} content and decreased Na^{+}

content be due to improve in phosphorus availability by the increase in phosphorus availability from fixed phosphate and then Na which counters with soil-P and get fixed in their unavailable form (Na-phosphate) become very less available to plant and higher Ca and Mg availability. These findings also find out by Parsad *et al* (2012).

CONCLUSION

Application of PROM and PSB+VAM increased the phosphorus content in grain and straw indicated that phosphorus fertilization with PSB+VAM mitigates the adverse effect of soil salinity by inducing tolerance to salinity in the crop. This showed that salinity tolerance in cowpea could possibly be enhanced to some extent by application of PROM as source of phosphorus along with inoculation of PSB + VAM.

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