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Potential of halotolerant PSB in enhancing availability of P from poultry manure (PM) and farmyard manure (FYM) to alleviate salt stress in maize crop

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Abstract: Halotolerant phosphorus solubilizing bacteria have a potential to enhance the growth and survival of maize under saline soil by following various mechanisms. The growth increment in maize plant in response to the inoculation of halotolerant PSB was observed in a pot study that was conducted in the rain protected glass house of ISES, University of Agriculture, Faisalabad. Different organic matter source in combination with PSB were used in this study and salt stress @7dSm^{-1} were applied. The experiment was completely randomized design (CRD) having three replications. The fertilizer dose and water were applied as recommended. Shoot dry weight of maize plants were increased by 27% and 32% with combine application of PSB and organic manures over uninoculated and amended control. However, salinity stress @7dSm^{-1} decrease shoots dry weight by 19% as compared to the control. A non-significant increase in the shoot dry weight was observed with the combine application of PSB with organic manure in saline soil as compare to the control. Root dry weight of maize plants were increased by 26.2% and 27.9% with combine application of PSB and organic manures over uninoculated and amended control. However, salinity stress @7dSm^{-1} decrease roots dry weight by 11.3% as compared to the control. A significant increase in the root dry weight was observed with the combine application of PSB with organic manure in saline soil as compare to the control. Data shows that K^+ concentration in soil increased by 1.5%, 4.7%, 6.9%, 11.1% and 11.8% respectively, in treatment having sole application of organic manures (PM and FYM), PSB and inoculation of PSB with organic manure in normal soil, as compare to control. Salinity stress reduced the 1.6% K^+ availability compare to control. However, the inoculation of PSB with organic manure help in mitigation of salinity stress and increase K^+ concentration 1.9% and 1.6% compare to salinity stress alone. Data shows that sole application of organic manures (PM and FYM), PSB and inoculation of PSB with organic manure in normal soil, increase the K^+ concentration in shoot of maize by 15.45%, 16.21%, 26%, 27% and 33% respectively, as compare to control. Salinity stress reduced the 20% K^+ concentration in maize compare to control. However, the inoculation of PSB with organic manure help in mitigation of salinity stress and increase K^+ concentration 19.5% in maize compare to salinity stress alone.
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Key words: Halotolerant, poultry manure (PM), salinity, maize

Introduction

In agriculture land salinity stress declines the fertility status of soil (Kumar *et al*., 2019). Less salt tolerance in many agricultural crops, is a major limitation to saline agriculture (Zafar *et al*., 2020). Soluble salts in the soil solution may impede plant growth for two reasons. 1) The occurrence of soluble salts in soil water reduces the ability of the plant to uptake water and this result in reduction of plant growth (Zafar *et al*., 2021). This is called as water deficit and osmotic effect of salinity. 2) Excessive concentration of soluble salts injured the plant cell by entering in the transpiration stream, may result more reduction in plant growth. This is termed as specific ion toxicity. Salinity has various detrimental effects on plant growth through lowering water potential of soil water, specific ion toxicity and nutrients imbalance (Zafar *et al*., 2021; Munns and Tester, 2008). These effects are results of high salt concentration. Salinity may affect the seed germination by the harmful effects of specific ion like sodium and chloride ions. The harmful effects including disturbance of protein synthesis, respiration and photosynthesis, disruption in macromolecules, enzyme's structure, damage to plasma membrane and cell organelles (Ucarli, 2020; Tahir et al., 2018).

Salinity also effects the hormone and nutrient balance at the time of germination. High salt stress retard seed germination because of less imbibition's of water by seed. High salinity level increases the synthesis of reactive oxygen species such as superoxide, hydrogen peroxide and hydroxyl radicals. These reactive oxygen species damage the lipid, proteins, DNA, RNA and cellular structure, leads to reduce seed germination (Zafar et al., 2021). Salt level may negatively affect seed germination by reducing the content of germination stimulants i.e., gibberellins, increasing abscisic acid concentration, and change membrane permeability and water relation in the seed (Lee and Luan, 2012).

Many plant studies reported that salinity decrease nitrogen uptake due to interaction between $NH_4^+$and Na^+ and/ or between NO_3^- and Cl^- that decrease the growth and productivity of the crop (Parihar *et al.*, 2015). Phosphorus availability is also decrease in saline soil due to i) low solubility of $Ca_3(PO_4)_2$complex (ii) ionic strength effect that decrease the activity of PO_4^{-3} (iii) phosphorus availability in soil solution is highly dependent on sorption process. In recent study, it has been demonstrated that calcium and magnesium concentrations in plant organs are transitory declined under different salinity level (Hussin *et al.*, 2013). For various crops, Na^+ is toxic ion interfere with K^+ uptake and transport leads to interference in stomatal movements and cause water loss and necrosis in leaves (Farooq *et al*., 2015). Competition between Na^+ and K^+ ions under saline condition severely decrease the K^+ content in maize plant and decrease 64% K^+ content in plant tissue under saline condition. In addition, salinity stress not only lower K^+ uptake, but severely disturbs the translocation and distribution of K^+ from shoot to root in maize (Shahzad *et al*., 2012).

In salt affected soil, phosphorus deficiency is one of the major nutrient constraints. Salinity reduced the uptake and assimilation of phosphorus in plant tissues. Therefore, plant show stunted growth, production of thin stem, dark green leaves, and death of older leaves. Salinity stress induces high ionic strength in soil, which ultimately decrease the availability of P. Besides, phosphorus availability in calcareous soils and saline soil is limited because it makes insoluble octa calcium phosphate ($Ca_4H\ (PO_4)_3.3H_2O$), dibasic calcium phosphate dehydrate ($CaHPO_4.2H_2O$), and hydroxyapatite ($Ca_{10}\ (PO_4)_6(OH)_2$) (Mahmood *et al*., 2013). The formation of these complexes reduced P solubility.

Salt stress impacts maize growth and development, although the plant's reaction differs depending on the degree of stress and the crop's growth stage. Salt stress affects maize growth due to osmotic stress in the early stages of stress. As a salt sensitive crop, shoot growth of maize is substantially hindered. Maize plant tolerates the salt at 1.8 dS/m^{-1} level without affecting the growth and production. When salt levels rise above this level, the plant life cycle is disrupted. The maize plant, like other field crops, is particularly vulnerable to salt stress during the early stages of growth, such as germination and seedling stages.

In soil a complex microbial diversity is present around root zone, which considered as the natural relations between microbes and plants. Many soil microorganisms have ability to survive in changing environmental conditions can be illustrate in terms of resilience and resistance. Salinity stress affects microbial diversity and its functions. Recently, a root adhering plant growth promoting bacteria (PGPB) has evolved that inhabiting hyper saline conditions and considered as an environment friendly option to get maximum crop production from salt affected soils (Talaat, 2015). The role of these bacteria in plant growth promotion is well documented. Microorganisms, including bacteria, fungi and archaea, are capable of adapting a wide range of external osmolarity (Ruppel *et al*., 2013). Halotolerant bacteria include *Pseudomonas* spp. *Bacillus aryabhattai*, *Stenotrophomonas*, *Pseudoalteromonas ruthenica* etc have been isolated from zone of various halophytic plants (Kumar *et al*., 2019). Various studies revealed that PGPB promote the growth of salinity stressed crops by various mechanisms (Etesami and Beatties, 2018). Halotolerant bacteria can survive in various salt concentrations and counteract the impact of salt ion by different mechanisms including synthesis of extracellular protease, accumulation of osmolytes for cellular osmoregulation, maintain homeostasis to decrease the toxic effects of salt ions, activation of Na^+/H^+ antiporters, and activation of defense system against oxidative stress (Kumar *et al*., 2020). In addition, these microorganisms synthesize ACC deaminase, phytohormones, exopolysaccharides, volatile compounds, mobilization of mineral, osmotic adjustment, photosynthesis enhancement, siderophore production, biological nitrogen fixation and antioxidant defense system. Thus, these microscopic creatures, support plant to tackle many environmental stresses by adopting different direct and indirect mechanisms (Talaat, 2015).

Plant growth promoting rhizobacteria (PGPR) have been shown to elicit salt stress and provide nutrients for plants in soils with low fertility and high salinization. Furthermore, the complex and dynamic interactions between PGPR and plant roots under salt stress also affect the soil but do not harm to the environment. In this regard, the application of PGPR to improve plant growth in saline-alkali soil has been extensively investigated. A variety of PGPR have now being proven to enhance plant productivity under salt stress (Sahay and Patra, 2013). PSB can be beneficial bioinoculants to alleviate salinity stress and further improve the quantitative and qualitative factors related to plant and soil productivity. There have been a large number of relevant reports on phosphate solubilizing microorganisms enhancing the phosphorus status of plant (Ludueña *et al.*, 2018).

Halotolerant phosphorus solubilizing bacteria (PSB) are one of the major PGPR, enhance bioavailability of P through mineralization-immobilization, dissolution-precipitation and sorption-desorption under saline condition (Jiang *et al.*, 2020). PSB produced various kinds of organic acids and other acids such as isobutyric, oxalic, gluconic acid during metabolism thus acidifying the soil (Penn and Camberato, 2019) and subsequent P liberate from $Ca_3 (PO_4)_2$ complex in calcareous soils. They release extracellular enzyme under salinity stress, which increase P availability (George *et al.*, 2018). PSB is beneficial bioinoculants in amelioration of salinity stress. However, less details are available on the application of halotolerant phosphorus solubilizing bacteria to promote crop productivity under salt affected soils (Rehmat et al 2021). Keeping in view the beneficial effect of halotolerant phosphate solubilizing bacteria, the study will be planned with the objective to find out the role of PSB in mineralization of phosphorus from organic sources (FYM, Poultry manure) in salt affected soil.

Objectives

- To compare the effect of organic manure (FYM and PM) in amelioration of salinity stress.
- To determine the potential of halotolerant PSB in enhancing availability of P from poultry manure (PM) and farmyard manure (FYM).

MATERIALS AND METHODS

For evaluating the effect of microbial mineralization of phosphorus from different organic sources (PM and FYM) in salt affected soil, A pot experiment was conducted in rain protected wire house at Institute of Soil and Environmental Sciences (ISES), University of Agriculture, Faisalabad. The explanation regarding the use of different experimental materials and techniques which acquire during the entire investigation are given below.

Soil preparation

Soil was collected from research area of Institute of Soil and Environmental Sciences, University of Agriculture Faisalabad, for filling the pots. Before pot filling, soil was homogenized, air dried at room temperature, grinding with wooden roller and sieving with mesh size of less than 2mm sieve. Chemical and physical properties of soil like soil pH, ECe, and cations, anions and P were analyzed before starting the experiment by following standard laboratory procedure given in ICARDA manual (Estefan *et al.*, 2013) (Table 1).

Table 1. Physico-chemical characteristics of soil used for pot experiment

Characteristics	Unit	Value
PHs	_________	7.7
Textural class	_________	Sandy clay loam
Clay	%	25.68
Sand	%	60.35
Silt	%	13.98
Ece	dS/m^{-1}	2
Saturation percentage	%	32.53
Total soluble salt (TSS)	_________	20
Available phosphorus	mg/kg	9.88
Cl^-	me/L	2.4
SAR	$(mmol\ L^{-1})^{1/2}$	24.93

Treatment plan:

- T1 = Control
- T_2 = Poultry manure (PM) 1%
- T_3 = Farmyard manure (FYM) 1%
- T_4 = Phosphorus solubilizing bacteria (PSB)
- T_5= PM 1% + PSB
- T_6= FYM 1% + PSB
- T_7= Salinity stress @7dsm^{-1}

- T_8 = Salinity stress @7dsm^{-1} + PM 1% + PSB
- T_9 = Salinity stress @7dsm^{-1} + FYM 1% + PSB

Imposition of salinity:

After analyzing the soil, it was contaminated with salt using (salt name) as an artificial source of salinity. The calculated amount of mixed salt was added in soil to develop EC up to 7dSm^{-1} in nine pots. For lining of pots, polyethylene sheets ere used each pot was filled with almost 10kg of saline soil.

$$Amount\ of\ NaCl\ (g\text{L}^{-1}) = TSS \times Eq.weight\ of\ NaCl\ /1000$$

(Hand book 60: U.S. Salinity Lab. Staff, 1954).

Application of organic amendments:

The organic manures (PM and FYM) were collected from livestock and poultry farm, university of Agriculture, Faisalabad. Before pots filling organic manure were homogenized, air dried, grinded and sieved with mesh size of less than 2 mm sieve. Calculated amount of air-dried organic manures (PM and FYM) was added in pots before sowing seeds.

Inoculum preparation and seed inoculation:

For inoculation, selected bacterial strain was inoculated in 100 ml LB broth media along with un-inoculated control. The selected bacterial strain was incubated at 28± 2ºC for three days in orbital shaking incubator at 120 rpm. Seeds of maize were surface sterilized by dipping in 75% ethanol for 30 second and 5% sodium hypo chloride for 2-3 minutes and followed by 3 washing with autoclaved distilled water in laminar flow hood. Maize seeds were coated with peat-based slurry having inoculum of desired strain (3 days old) containing CFU (108-109 mL^{-1}) for seed inoculation and 10% sugar solution per 100mL of inoculums per Kg peat was added. After those inoculated seeds were dry in shade for at least 6-8 hours. Six inoculated seeds with respective strain were sown in pot according to treatment.

Fertilizer application

Recommended NPK fertilizers N (as urea), P (as di-ammonium phosphate) and K (as sulfate of potash) was applied at the rate of 160, 80 and 60 kg ha^{-1}. A basal dose of nitrogen was applied in 3 splits while potassium and phosphorus were applied at the time of sowing. Throughout experiment, crop was irrigated according to its water requirement.

Harvesting

After 8 weeks of sowing harvest the maize plants root and shoot with sharp iron cutter and measured shoot length, shoot dry weight, and dry weight of root. After that samples were stored each paper bags having one sample in it and kept for sun drying.

Shoot dry weight (g)

Dry weight of shoots of all genotypes were sited in an electrical drying oven at 65±5^{o}C till persistent weight obtained. Then an electrical weight balance was used to determine dry weight of shoots.

Root dry weight (g)

After sun drying of plant root samples, root samples were dried at 65±5 ^{o}C till constant weight obtained to get dried weight of roots by using an electrical weight balance.

Post-harvest analysis:

Available phosphorous determination

5g of sieved soil sample was taken in 250 ml flask and add 0.5 M sodium bicarbonate ($NaHCO_3$) solution whose pH was adjusted at 8.5 was used for the extraction of soil sample. Take 5mL of clear filtrate solution in 100mL volumetric flask and5ml of color developing reagent (CDR) was added in it, then volume was made up to the mark by adding distilled water. Spectrophotometer was used for determination of phosphorous. (Milion Roy Company) where wavelength used was 880 nm wavelengths with the help of standard curve (Jackson, 1962).

Soil potassium determination

Potassium in soil extract was determined by following flame photometry technique. Run a series of suitable standard on flame photo meter and draw a calibration curve. Standard solutions were used to standardize the instrument. After standardization, K^+ concentration in soil were determined by using calibration curve (U.S. Salinity Laboratory Staff, 1954; Method, 10).

Plant sample preparation:

After harvesting, dry weights of shoot were measured and these samples were further analyzed for P, and K^+ concentrations. These oven dried shoot samples were grinded to powdered form using grinding mill. For ionic determination, take 0.5 g of grinded shoots samples in a flask (conical) and add 10 mL concentrated sulphuric acid (H_2SO_4) into it and then kept overnight. Next day, hot plate was used for heating the flasks and then digested by adding 2ml of hydrogen peroxide (H_2O_2), till the material became clear. These flasks were allowed to cool and then transferred all material to volumetric flask. Make 50 ml volume by adding DI water. Samples were then filtered by using filter paper.

Phosphorus determination in plant

Pipette 5 ml of clear filtrate solution of plant sample in to 100 ml flask and add 5ml of color developing reagent (ammonium vanadomolybdate) in it, then make the volume up to mark by adding DI water. Spectrophotometer was used for determination of phosphorous. Where 410 nm wavelength was used, and prepare calibration curve by using standard curve (Jackson, 1962). Determine P concentration in shoot sample from the calibration curve.

K^+ determination in plant

Potassium filtrate were determined by following flame photometry technique. Run a series of suitable standard on Sherwood 410 flame photo meter and draw a calibration curve. After standardization, Na^+ and K^+ concentration in shoot sample were determined by using calibration curve.

Statistical analysis

The above collected data were analyzed by using completely randomized design under factorial arrangement. Due to salt stress changes occur in maize varieties was evaluated by (ANOVA) analysis of variance technique. To check the interactive effects of significantly different means of treatments LSD test was used with the help of Statistics software 8.1. Substantial variances between treatments were checked at the $P<0.05$ levels.

Shoot dry weight (g)

The data given in (fig 1) illustrate that application of salinity stress caused a reduction in shoot dry weight of maize. However, combine application of PSB along with organic manures (PM and FYM) increase the shoot dry weight of maize under salinity stress. According to results, maximum growth was obtained in the treatment where PSB was applied along with organic manures (PM and FYM) with no salinity stress as compare to control and application of organic manures alone.

The treatments having sole application of organic manures (PM and FYM), PSB and combine application of PSB with organic manures in normal soil increased the shoot dry weight by 10%, 13%, 16%, 27% and 32% over the control. However, salinity stress decreased shoot dry weight by 19% over the control. But, application of PSB with organic manure increased the shoot dry weight by almost 33% to 38% under salinity stress as compare to salinity stress alone.

Table 2 shows that inoculation of halotolerant PSB with organic amendments (PM and FYM) increase the shoot dry weight of maize under salt stress. PSB overcome the negative effect of salt stress. These findings are compatible with the results of earlier studies exhibit that application of salt tolerant PSB enhances the growth and production of crops in saline soil (Ullah and Bano, 2019). This may be due to ability of PSB in production of phytohormones, synthesis of EPS and nutrient solubilization.

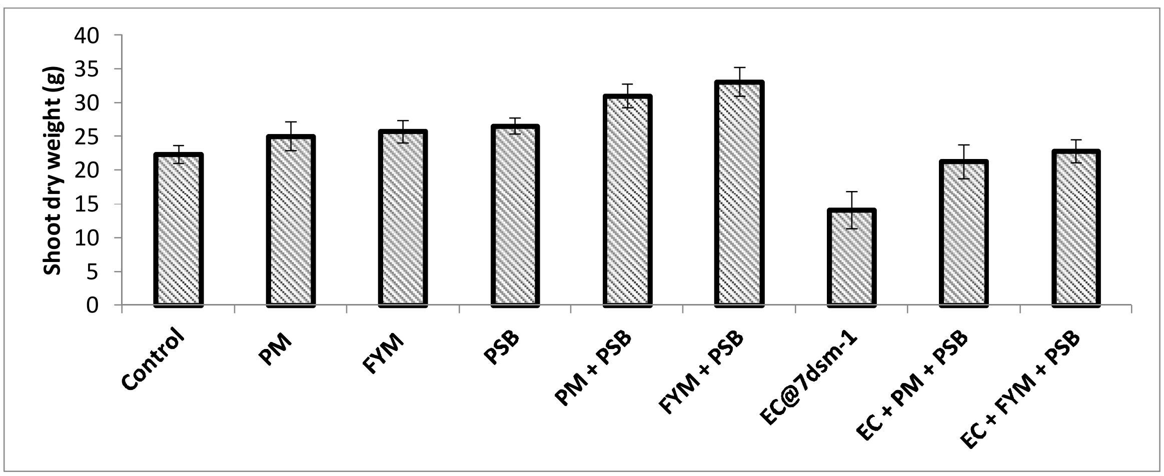

Fig.1. Effect of organic manures with PSB on shoot dry weight (g) of maize in salt affected soil.

Table.2. Analysis of variance for shoot dry weight (g)

Source	DF	SS	MS	F	P
Treatment	8	746.063	93.2579	8.06	0.000
Error	18	208.376	11.5764		
Total	26	954.439			

Grand Mean 24.666 **C.V** 13.79

Root dry weight (g)

The data given in (fig. 2) illustrate that application of salinity stress caused a reduction in root dry weight of maize. However, combine application of PSB along with organic manures (PM and FYM) increase the root dry weight of maize under salinity stress. According to results, maximum growth was obtained in the treatment where PSB was applied along with organic manures (PM and FYM) with no salinity stress as compare to control and application of organic manures alone.

The treatments having sole application of organic manures (PM and FYM), PSB and combine application of PSB with organic manures in normal soil increased the root dry weight by 16%, 17%, 20%, 26.2% and 29.7% over the control. Salinity stress decreased root dry weight by 11.3% over the control. However, application of PSB with organic manure increased the root dry weight by almost 28% to 27.3% under salinity stress as compare to salinity stress alone.

In our study, application of organic manures with PSB strain showed maximum dry mass of root under salinity stress. Inoculation of halotolerant PSB with organic amendments, increase the root fresh and dry weight of maize plant as compare to control and salinity stress alone. This can be explained by the fact that PSB accumulates of osmolytes in leaf tissues helps to regulate the plant water status. Previous studies Suprasanna *et al*. (2016) have demonstrated that PGPR produce various organic osmolytes and accumulate in the cytoplasm helps to maintain osmotic balance of plant. Rehmat *et al*. (2021) reported that microbes play important role in alleviation of adverse effect of salt stress.

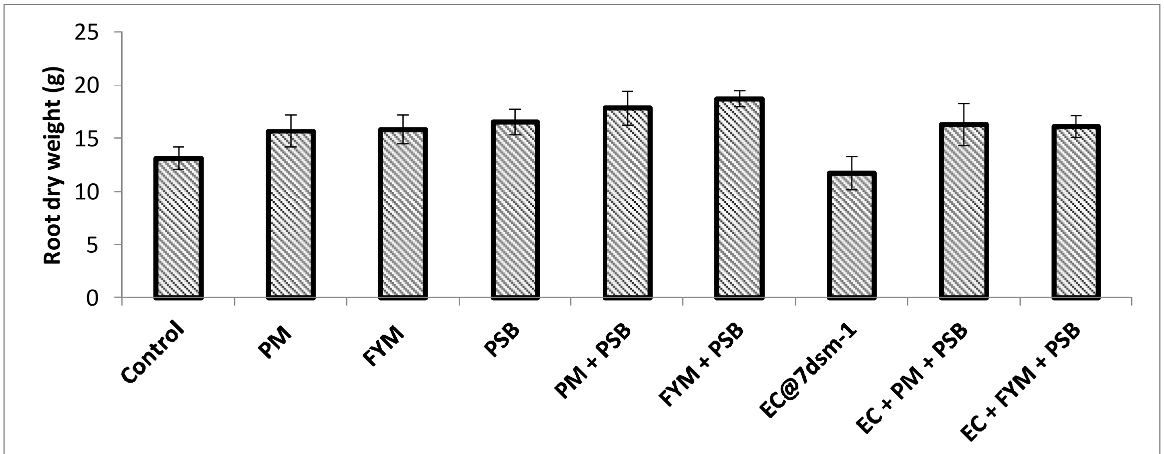

Fig.2. Effect of organic manures with PSB on root dry mass (g) of maize in salt affected soil.

Table.3. Analysis of variance for root dry weight (g)

Source	DF	SS	MS	F	P
Treatment	8	1494.74	186.843	10.3	0.000
Error	18	326.00	18.111		
Total	26	1820.74			
Grand Mean 48.519	**C.V** 8.77				

Phosphorus concentration in soil (mg/kg)

The data in (fig 3) illustrate that salinity stress decrease the availability of phosphorus. But the combine application of PSB with organic manures (PM and FYM) play a dominant role in mitigating the harmful effects of salinity stress and increase the bioavailability of P. Inoculation significantly increase the concentration of P under salinity stress in comparison with without PSB. The P concentration in soil vary with respect to different organic sources (PM and FYM).

It was noted that the treatments having sole application of organic manures (PM and FYM), PSB and combine application of PSB with organic manure in normal soil, increase the P concentration 29%, 14.2%, 22.3%, 35% and 25.3% respectively, as compare to control. The highest P concentration 35% was noted in pots amended with PSB and PM as compare to FYM with PSB and control. But, under salinity stress P concentration was decrease 26% over the control. However, the combine application of organic manure with PSB help in mitigation of salinity stress and increase P concentration 35.4% and 28.7% compare to salinity stress alone.

Table 4 shows that combine application of PSB with PM counteract the adverse effect of salt and increase P content in soil. Our results are according to Zhang *et al*. (2020) reported that application of organic manure with beneficial bioinoculant in saline soil could significantly alleviate the problem of salinity and also increase P availability. The reason for better P concentration in saline soil may be due to production of organic acids by PSB which solubilize and mineralized insoluble P complex. Previous studies revealed that inoculation of PSB *Bacillus megaterium* strain increase biomass production and phosphorus content in *Brassica napus* (Zheng *et al*., 2020).

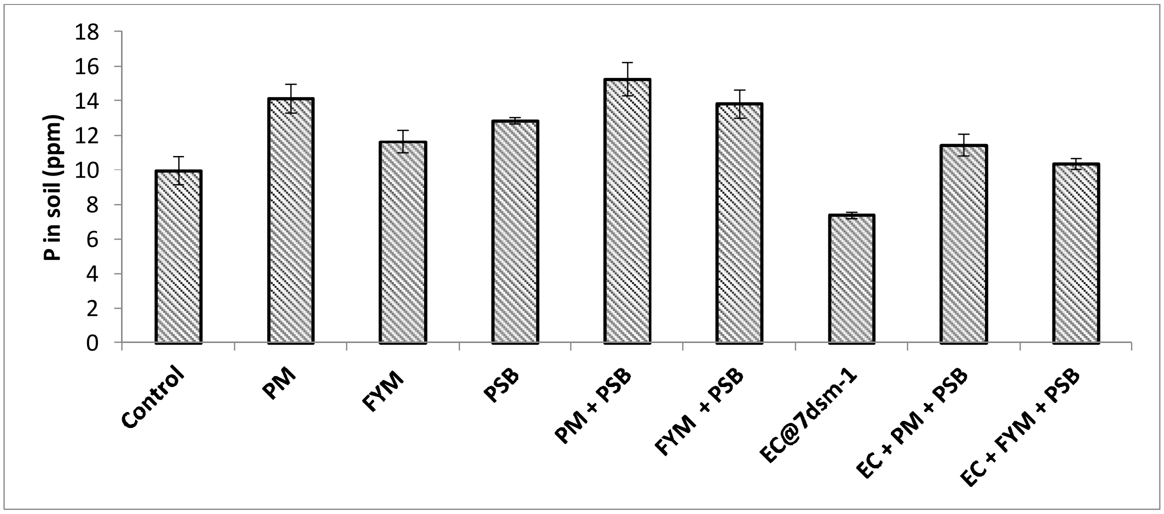

Fig.3. Effect of organic manures with PSB on the P concentration in salt affected soil.

Table.4. Analysis of variance for P concentration in soil

Source	DF	SS	MS	F	P
Treatment	8	143.115	17.8894	13.6	0.000
Error	18	23.762	1.3201		
Total	26	166.877			
Grand Mean 11.880	**C.V**	9.67			

K^+ concentration in soil (mg/kg)

Figure 4 shows that the inoculation of PSB with organic manures (PM and FYM) were significantly increase the K^+ concentration in saline soil compare to control under salinity stress. Salinity stress decreases the bioavailability of K^+. Results, shows that coupling PSB with organic manures (PM and FYM) play dominant role in mitigation of inhibitory effect of salt stress. However, the highest concentration of K^+ were observed in pots amended with organic manure (PM and FYM), PSB and combination of PSB with organic manures (PM and FYM) in normal soil compare to control and control under salinity stress.

It was revealed that the treatments having sole application of organic manures (PM and FYM), PSB and inoculation of PSB with organic manure in normal soil, increase the K^+ concentration 1.5%, 4.7%, 6.9%, 11.1% and 11.8% respectively, as compare to control. The highest K^+ concentrations 11.1% and 11.8% were noted in soil amended with PSB and organic manures as compare to control. Salinity stress reduced the 1.6% K^+ availability compare to control. However, the inoculation of PSB with organic manure help in mitigation of salinity stress and increase K^+ concentration 1.9% and 1.6% compare to salinity stress alone.

Table 5 showed that high Na^+ concentration in saline soil decrease the K^+ content in maize plant but the application of PSB with organic amendments enhance the concentration of K^+ in inoculated plant compare to uninoculated control. The reason for increase in K^+ content may be due to the ability of PGPB to solubilize K^+, production of IAA and exopolysaccharide. This finding also supports the previous study Vanissa *et al*. (2020) reported that PGPB solubilize insoluble K^+ and convert into soluble K^+.

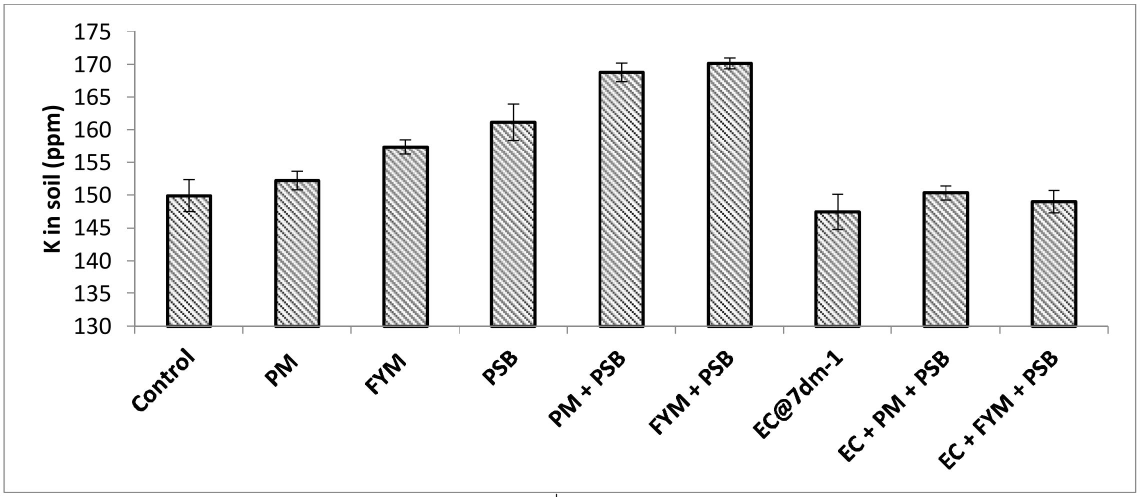

Fig.4. Effect of organic manures with PSB on the K^+ concentration in salt affected soil.

Table .5. Analysis of variance for K^+ concentration in soil

Source	DF	SS	MS	F	P
Treatment	8	1789.58	223.697	70.8	0.000
Error	18	56.86	3.159		
Total	26	1846.43			
Grand Mean 156.29	**C.V**	4.14			

K^+ concentration in plant (%)

Figure 5 shows that the inoculation of PSB with organic manures (PM and FYM) were significantly increase the K^+ concentration in saline soil compare to control under salinity stress. Salinity stress decreases the bioavailability of K^+. Results, shows that coupling PSB with organic manures (PM and FYM) play dominant role in mitigation of inhibitory effect of salt stress. However, the highest concentration of K^+ were observed in maize plant, which were grown in soil amended with organic manure (PM and FYM), PSB and combination of PSB with organic manures (PM and FYM) in normal soil compare to control and control under salinity stress.

It was revealed that the treatments having sole application of organic manures (PM and FYM), PSB and inoculation of PSB with organic manure in normal soil, increase the K^+ concentration 15.45%, 16.21%, 26%, 27% and 33% respectively, as compare to control. The highest K^+ concentrations 27% and 33% were noted in maize plant, which were grown in soil amended with PSB and organic manures as compare to control. Salinity stress reduced the 20% K^+ concentration in maize compare to control. However, the inoculation of PSB with organic manure help in mitigation of salinity stress and increase K^+ concentration 19.5% in maize compare to salinity stress alone.

The current study showed that salt stress significantly decreases the K^+/Na^+ ratio in maize, but the application of organic manures with PSB mitigate the adverse effect of salt stress (Table.6). Various studies illustrate that in saline soil high Na^+ content competes with K^+ for uptake in plant roots (Garg and Bhandari, 2016). Application of halotolerant PSB with organic manure overcomes the adverse effects of salt by regulation nutrient balance through mineralization of P and K^+ from organic sources. The results of present study in line to Vanissa *et al*. (2020) reported that inoculation of *Arthrobacter* sp. and *Bacillus* sp. increase K^+/Na^+ ratio and promote the growth of *Zea mays L*. by producing various plant hormones such as auxin, cytokinin's, gibberellins and abscisic acid in saline soil condition.

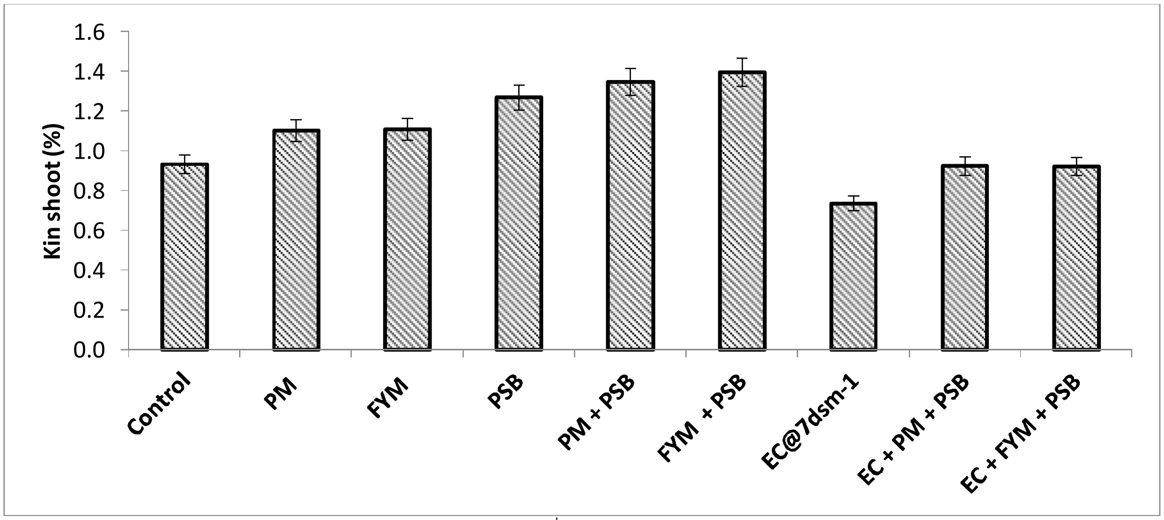

Fig.5. Effect of organic manures with PSB on the K^+ concentration in maize in salt affected soil.

Table 6. Analysis of variance for K^+ concentration in shoot of maize

Source	DF	SS	MS	F	P
Treatment	8	1.194E+08	1.492E+07	1715026	0.000
Error	18	156.667	8.70370		
Total	26	1.194E+08			

Grand Mean 10827 **C.V** 3.03

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