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Multidisciplinary Academic Journal Publisher

Effect of microbial mineralization of phosphorus from different organic sources (PM, FYM) in salt affected soil on the growth of maize (*Zea mays* L.)

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Abstract: Soil salinization is serious threat dominant in arid and semi-arid region where irrigation is fundamental source of water in agriculture. In salt affected soils, phosphorus (P) availability is reducing because its precipitation with other cations i.e., Ca^{+2}, Zn^{+2} and Mg^{+2} ions there by creating salt-induced P deficiency in plant. Hence, there is a need to exploit environment friendly biological methods for salinity stress management. Halotolerant phosphorus solubilizing bacteria are ideal tool in the amelioration of salinity stress in plants. A pot experiment was performed to evaluate the effect of halotolerant phosphorus solubilizing bacteria (PSB) and organic manures (PM and FYM) in mineralization of phosphorus under salinity stress. For this, maize seeds were coated with PSB that was simply compared with non-inoculated PSB and organic manures (PM and FYM) under salinity stress ($7dSm^{-1}$). These treatments were designed in accordance with complete randomized design (CRD) with three replicates on maize crop. Results revealed that inoculation of PSB and application of organic manures (PM and FYM) enhance P uptake and maize growth compared to control and the plants under salt stress. Salinity stress adversely affects maize growth, but the application of PSB and organic manures were significantly counter-act this harmful effects. The highest amount of growth parameters, phosphorus (P) concentration and lowest sodium (Na) concentration were observed in plants treated with PSB combine with organic manures under salinity stress as compare to soil with salinity stress alone. Thus, combine application of PSB and organic manures is an eco-friendly option to enhance crop growth and P nutrition in saline soil under changing climate.

[Rimsha Rehmat, Haseeb Ayub, Muhammad Ubair Arif, Amar Ahmed Khan. **Effect of microbial mineralization of phosphorus from different organic sources (PM, FYM) in salt affected soil on the growth of maize (*Zea mays* L.).** *Life Sci J* 2021;18(11):27-41]. ISSN 1097-8135 (print); ISSN 2372-613X (online). http://www.lifesciencesite.com 4. doi:10.7537/marslsj181121.04.

Key words: Salinity, microbial mineralization, Maize

Introduction

Among environmental stresses, soil salinity is considered one of the most harmful abiotic stress that hinders crop growth and production (Zafar et al. 2020a). Salinity stress is the one where there is an excessive amount of soluble ions such as sodium (Na^+) and chloride (Cl^-) which adversely affects the growth of plant (Zafar et al. 2021). Soil salinity is determined in term of electrical conductivity (EC) which is the ability of material to conduct electric current. Amongst the several soluble salts present in salt affected soil, sodium chloride (NaCl) is dominant one. Salinity reduces the agriculture production of most crops, deteriorates the physiochemical properties of soil and influence ecological condition of the area. Impact of soluble salts in soil includes soil erosion, low fertility status, low production and less economic return. In salt affected soil, deposition of salts in rhizosphere causes osmotic stress, oxidative stress, hormonal and nutrient imbalance and specific ion toxicity, and thus limits water uptake from soil (Zafar et al. 2021).

Specific ions i.e., Na^+, Cl^- enter in transpiration stream and these salt ions injure cell of transpiring leaves, ultimately reduce plant growth and reproduction. High salt concentration affects photosynthetic activity by reducing leaf area, chlorophyll content of the leaves, inhibit photosystem II (PSII), CO_2 assimilation rate and electron transport chain (Kumar *et al*., 2020). Salinity negatively affects the chloroplast structure, function and rubisco activity. The reproductive growth of plant is adversely affected by inhibiting gamete formation and elongation of stamen which eventually increase programmed cell death in most of the plant tissues. Salinity stress also cause oxidative stress by enhancing the production of ROS includes singlet oxygen (O_2), hydrogen peroxide (H_2O_2), superoxide (O_2^-) etc. inhibit photosynthesis (Zafar et al. 2015). ROS cause protein oxidation, lipid peroxidation, damage nucleic acids (DNA, RNA), inactivation of enzyme

(Zafar et al. 2017; Zafar et al. 2019) and may also induce programmed cell death (Waqas et al. 2021; Zafar et al. 2020b).

Maize (*Zea mays* L.) is monoecious and highly cross-pollinated crop of Asia. In Pakistan, maize is rapidly becoming a major crop and is the 3rd most important cereal crop after wheat and rice. Globally, maize top ranked among food crops and also a dominant source of raw material for industries (Jiang *et al*., 2017). Maize is grown under broad range of soil and climatic conditions. Maize is moderately salt sensitive crop, suffers serious depletion in productivity due to high salinity stress. Salinity reduces the growth of maize due to specific ion toxicity and reduction in water potential of soil solution. It has been estimated that in cereal crops i.e., barley, rice, wheat and maize almost 70% production losses are due to contamination of soil by salinity and sodality (Hussain *et al*., 2019). Maize sensitivity to salt is linked to greater Na^+ accumulation in the leaves. Excessive Na^+ concentrations outside plant cell influence the influx of K^+ inside cell, which is an important essential nutrient for plant growth (Farooq et al. 2020; Tahir et al. 2018). Beside these, within plant cell high Na^+ concentration induce numerous physiological disorders including decrease shoot growth by repressing leaf initiation and enlargement, decrease flowering and fruiting. In the stressed plant nitrate reductase activity can be disrupted by uptake and accumulation of Cl^- ion which further affect the photosynthetic capacity of plants. Phosphorus in soil normally present as soluble phosphate ions (PO_4^{-3}, $H_2PO_4^{-1}$ and HPO_4^{-2}) are either adsorbed by clay surfaces or form insoluble mineral complexes such as $Mg_3(PO_4)_2$ and$Ca_3(PO_4)_2$ with cations in salt affected soils or $FePO_4$ and $AlPO_4$ in acidic soils, thus P become unavailable to the plant. Among total soil phosphorus only 0.1% is in soluble form which is bioavailable for plants. Soil salinity hamper the availability of because phosphate ions make insoluble complex with Ca^{+2} ions (Shrivastava and Kumar, 2015). Thus, the interaction between uptake of phosphorus in plant and salinity is complex phenomena. It is reported that in agriculture land if accumulated p is become bioavailable that would be sufficient for optimum growth for almost 100 years (Adnan *et al*., 2020). Across the globe, virtually 44.12 MT of phosphatic fertilizers are applied every year, out of which 80% is being lost because of its adsorption, immobilization and complexation reactions in soil. Recently, more research has been available on soil, plant and microbes' interaction. There are variety of microorganisms in the soil, which play significant role in nutrient cycling and plant growth promotion. PGPR are beneficial free-living bacteria that exert beneficial effects on plant growth. PGPR raise plant growth under unfavorable condition through various mechanisms such as increase in nutrient availability by phosphorous mineralization, siderophore production and biological nitrogen fixation, decrease deposition of Na^+ ions in plant root zone by synthesizing exopolysaccharides (Etesami and Beattie, 2017), lower ethylene level by producing ACC daminase enzyme, enhance production of defense enzymes (Islam *et al*., 2016), enhance accumulation of organic solutes such as proline, glycine, change hormonal status of plant and maintain nutritional and ionic balance in plant (Bishe and Dandge, 2019).

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 (Zhao and Zhang, 2015). 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 upto 7dSm^{-1} in nine pots. For lining of pots, polyethylene sheets ere used each pot was filled with almost 10kg of saline soil.

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

(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 hypochlorite 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.

Chlorophyll contents (SPAD value)

The chlorophyll contents in leaf were determined by using chlorophyll meter (Minolta SPAD. 502 Meter). Chlorophyll contents were measured prior to harvesting and record reading from leaf tip to leaf blade.

Harvesting

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

Physical parameters

Maize plants were harvested after 8 weeks of sowing and record data for the following parameters, like Shoot length (cm), Shoot fresh weight (g), Root length (cm), Root fresh weight (g)

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 sodium determination

Sodium 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, Na^+ concentration in soil were determined by using calibration curve (U.S. Salinity Laboratory Staff, 1954; Method, 10).

Na^+ determination in plant

Sodium 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.

RESULTS AND DISCUSSION

Shoot fresh weight (g)

The data given in figure 1 and table 2, illustrate that application of salinity stress caused a reduction in shoot fresh weight of maize. However, combine application of PSB along with organic manures (PM and FYM) increase the shoot fresh 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 fresh weight by 12%, 16%, 15%, 19% and 22% over the control. Salinity stress decreased shoot weight by 20% over the control. However, application of PSB with organic manure increased the shoot fresh weight by almost 20% to 26% under salinity stress as compare to salinity stress alone.

Application of organic manure (FYM) with PSB promotes the shoot fresh weight of maize and reduces the adverse effect of salt stress (Table 2). According to Diacono and Montemurro (2015) incorporation of organic manure is an effective low input eco-friendly approach to minimize the toxic effect of salinity stress. Our results are concomitant with the earlier reported study that the combine application of organic manures with PSB enhances shoot growth of maize under saline condition (Liu *et al*., 2019). PSB promote maize growth may be due to production of IAA, accumulation of osmolytes and mineralization of organic manures which enhance mineral nutrients and also improves physical and chemical properties of salt affected soils which ultimately enhance growth and development of maize.

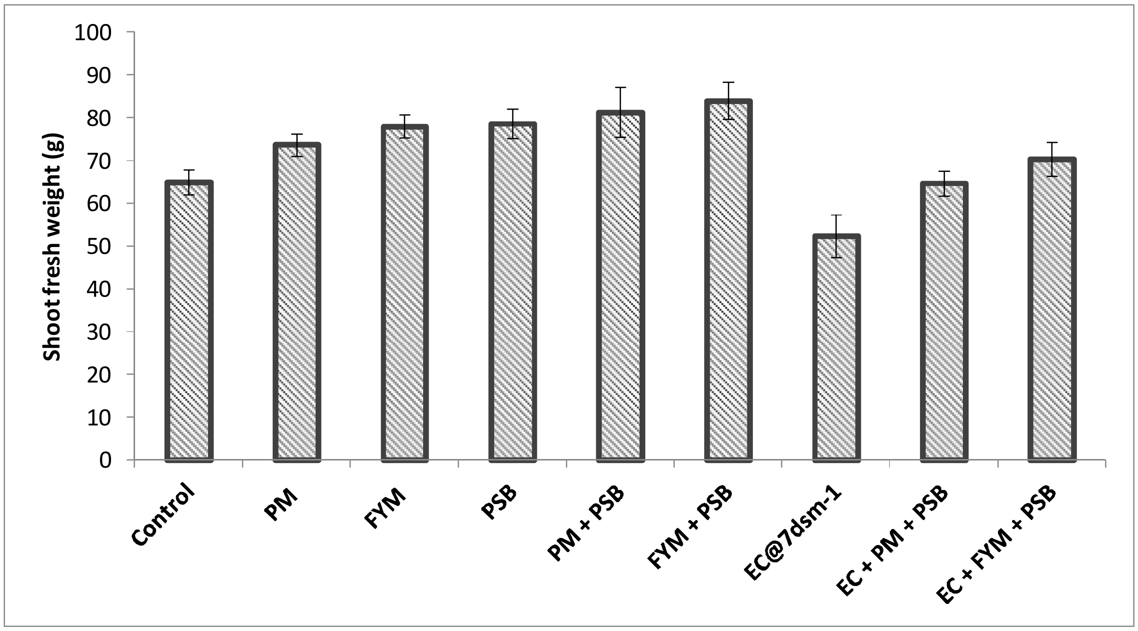

Fig.1. Effect of organic manures with PSB on shoot fresh weight (g) of maize in salt affected soil.

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

Source	DF	SS	MS	F	P
Treatment	8	2420	302.5	9.72	0.000
Error	18	560	31.111		
Total	26	2980.00			
Grand Mean 72.00	**C.V**	7.75			

Shoot length (cm)

The data given in Table 3 illustrate that inoculation of PSB with organic manures (PM and FYM) enhance shoot length under salinity stress. Maximum shoot length was observed in treatment where combine application of PSB with organic manures (PM and FYM) in normal soil as compare to sole application of organic manures (PM and FYM), PSB and un-inoculated control. However, minimum growth of shoot was observed under salinity stress.

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 length by 8%, 4%, 13%, 16% and 17% over the control. Salinity stress decreased shoot length by 7.2% over the control. However, application of PSB with organic manure increased the shoot length by almost 4.4% to 7.2% under salinity stress as compare to salinity stress alone.

Our finding shows that inoculation of halotolerant PSB with organic amendment (FYM) promote the shoot length of maize crop under salt stress soil (Fig. 2). Ge and Zhang (2019) reported that bioinoculant increase salt tolerance in cucumber by nitrogen fixation, IAA production, potassium and phosphorus solubilization. Inoculation of this strain increase root and shoot length, fresh and dry weight, chlorophyll content, antioxidant enzymes and soluble sugar content of crop. PSB with organic manures decrease ion toxicity by controlling various physiological processes in maize by Ilangumaran and Smith (2017) and increase shoot length by regulationg plant hormones and nutrient balance under saline condition.

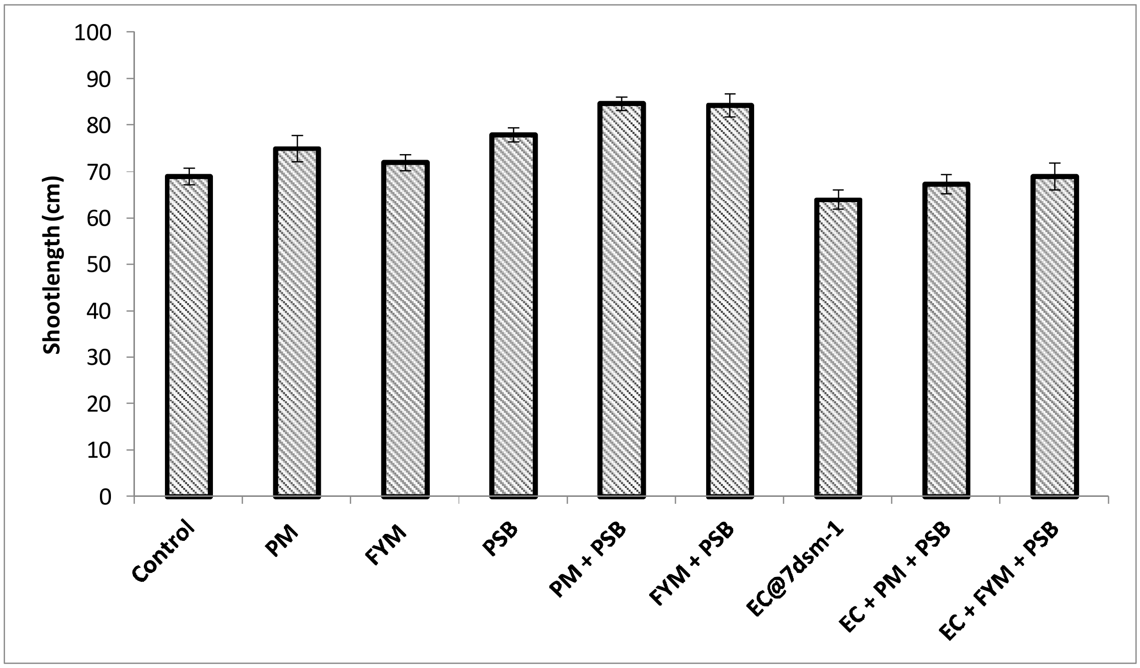

Fig.2. Effect of organic manures with PSB on shoot length (cm) of maize in salt affected soil.

Table 3. Analysis of variance for shoot length (cm)

Source	DF	SS	MS	F	P
Treatment	8	646.000	80.7500	5.33	0.0001
Error	18	272.667	15.1481		
Total	26	918.667			
Grand Mean 72.444		**C.V** 5.37			

Root fresh weight (g)

The data given in fig. 3 illustrate that application of salinity stress caused a reduction in root fresh weight of maize. However, combine application of PSB along with organic manures (PM and FYM) increase the root fresh 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 fresh weight by 9%, 7%, 11%, 23% and 21% over the control. Salinity stress decreased root weight by 20% over the control. However, application of PSB with organic manure increased the root fresh weight by almost 6.8% to 7% under salinity stress as compare to salinity stress alone.

In our study, combine application of organic manure with PSB (T8 and T9) shows best results in case of salt stress (Table. 4). Many researchers proposed that growth and yield trait of maize under salinity stress could be significantly enhances by inoculation of PSB compare with uninoculated maize plant (Feng *et al*., 2019). Our findings are according to previously reported research of Etesami and Maheshwari (2018) shows that plant growth promoting bacteria were able to alleviate the adverse effects of salinity stress on plant growth. Halotolerant PSB may enhance root growth and dry biomass of maize due to production of plant growth regulator, accumulation of compatible solutes, solubilization and mineralization of P from organic sources under saline condition.

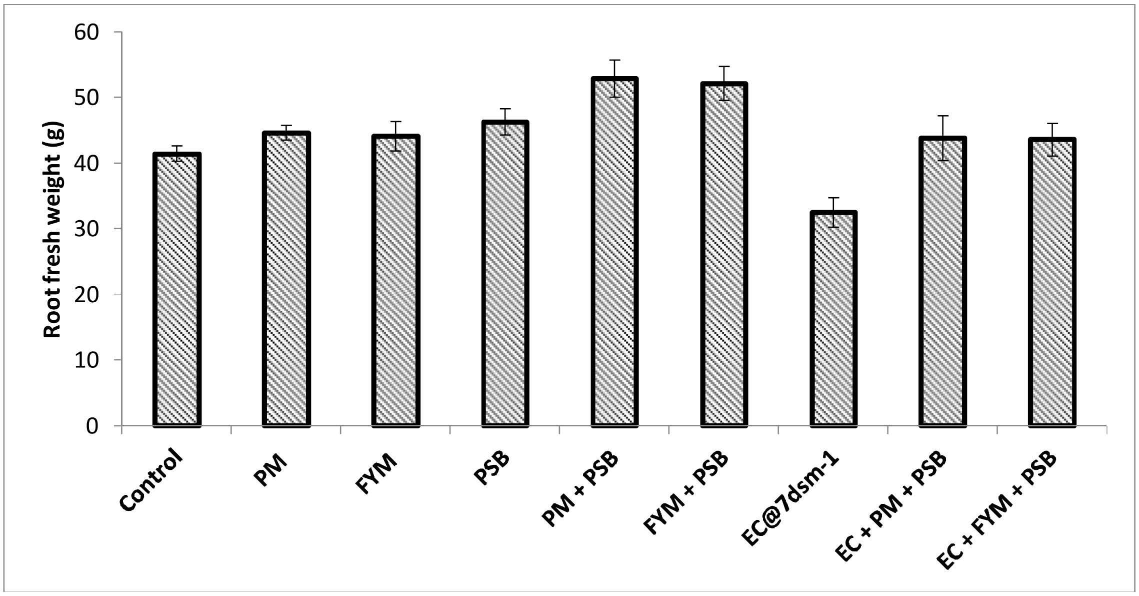

Fig. 3. Effect of organic manures with PSB on root fresh weight (g) of maize in salt affected soil.

Table 4. Analysis of variance for root fresh weight (g)

Source	DF	SS	MS	F	P
Treatment	8	112.469	14.0586	1.78	0.000
Error	18	141.811	7.8784		
Total	26	254.279			
Grand Mean 15.785	**C.V** 17.78				

Root length (cm)

The data given in Fig. 4 illustrate that inoculation of PSB with organic manures (PM and FYM) enhance root length under salinity stress. Maximum root length was observed in treatment where combine application of PSB with organic manures (PM and FYM) in normal soil as compare to sole application of organic manures (PM and FYM), PSB and un-inoculated control. However, minimum growth of root was observed under salinity stress.

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 length by 15%, 15.3%, 20%, 24% and 22% over the control. Salinity stress decreased root length by 16% over the control. However, application of PSB with organic manure increased the root length by almost 14% to 7.5% under salinity stress as compare to salinity stress alone.

In our study, we found that salinity stress decreases the root length of maize plant but the inoculation of halotolerant PSB with organic amendments increase the root length under saline condition (Table 5). Our findings are consistent with previous study Ullah and Bano (2015) which state that halotolerant PSB *Arthrobacter pasens* and *Bacillus* sp. enhance the root and shoot length, root and shoot fresh and dry mass of *Zea mays* L. under saline condition. This may be due to production of IAA, accumulation of organic osmolytes, K^+ and P solubilization.

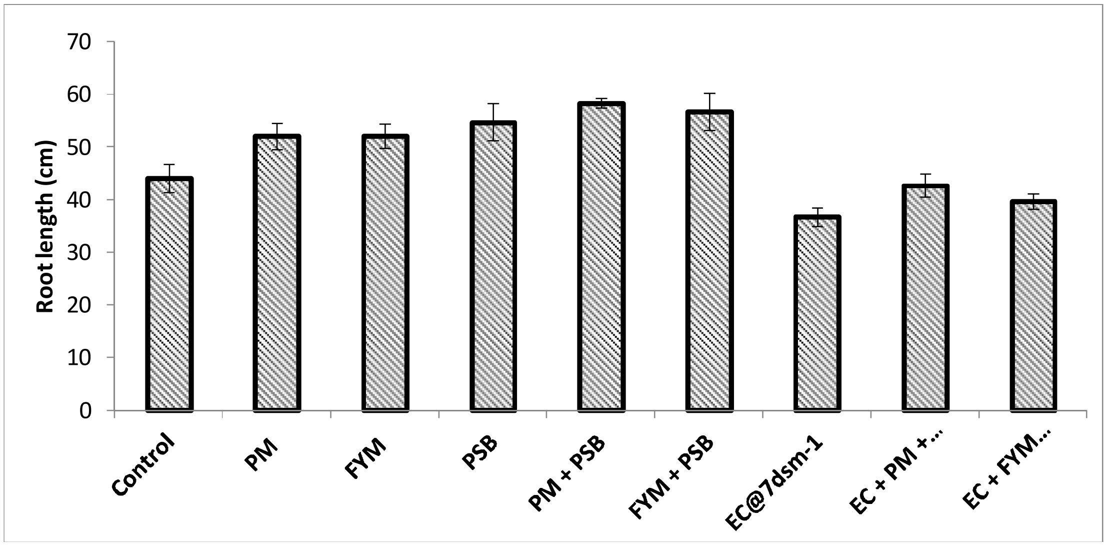

Fig.4 Effect of organic manures with PSB on root length (cm) of maize in salt affected soil.

Table.5 Analysis of variance for root length (cm)

Source	DF	SS	MS	F	P
Treatment	8	860.76	107.595	6.54	0.000
Error	18	296.32	16.462		
Total	26	1157.08			
Grand Mean 44.593	**C.V** 9.10				

Chlorophyll content (SPAD value)

Data in Figure 5 and Table 6, revealed that the maximum chlorophyll content was measured in the treatment having combine application of organic manures (PM and FYM) with PSB under normal condition. But the chlorophyll contents of maize leaves were significantly decreased under salinity stress as compare to control and other treatments. However, combine application of organic manures (PM and FYM) with PSB play dominant role in mitigation of inhibitory effect of salinity stress on the chlorophyll content of maize and resultantly increase in the chlorophyll content of maize even under salinity stress as shown by fig 5.

It was observed 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 chlorophyll content 24.3%, 21.6%, 15.6%, 23.4% and 26.1% respectively, as compare to control. However, the chlorophyll content was decrease 16.6% under salinity stress as compare to control. But the combine application of organic manures (PM and FYM) with PSB increase chlorophyll content 26% and 22.8%under salinity stress @7dSm^{-1} as compare to treatment were salinity stress alone.

In our experiment, we found that salinity stress reduces the chlorophyll content in maize leaf but the halotolerant PSB has good potential for eliminate salt stress along with organic amendments. The phenomena can be explained by the fact that PSB produce IAA, antioxidant enzyme and nutrient solubilization which may enhance the chlorophyll content in maize. Previous study Kang *et al*. (2019) demonstrated that inoculation of *Bacillus* strain increases the chlorophyll content in vegetative parts of the plants under stress condition by regulating antioxidant enzymes activity, increase uptake and assimilation of mineral nutrients and reduce osmotic stress.

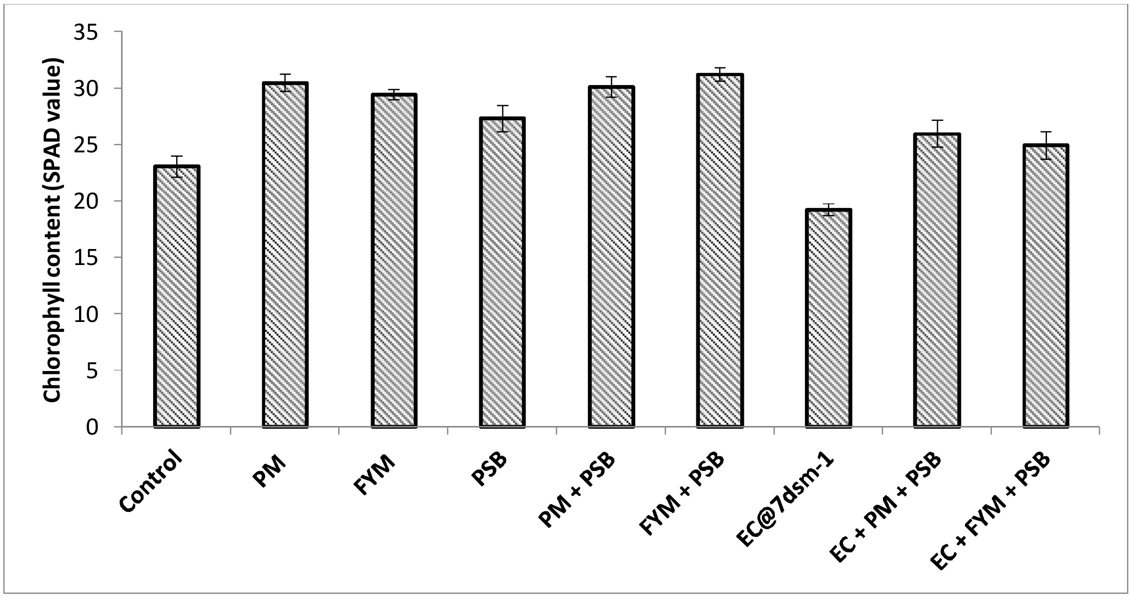

Fig.5. Effect of organic manures with PSB on SPAD (chlorophyll contents) in salt affected soil.

Table.6 Analysis of variance for chlorophyll content (SPAD value).

Source	DF	SS	MS	F	P
Treatment	8	381.003	47.6254	19.4	0.000
Error	18	44.213	2.4563		
Total	26	425.216			
Grand Mean	26.870	**C.V**	5.83		

Phosphorus concentration in soil (mg/kg)

The data in fig 6 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 7 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*., 2019).

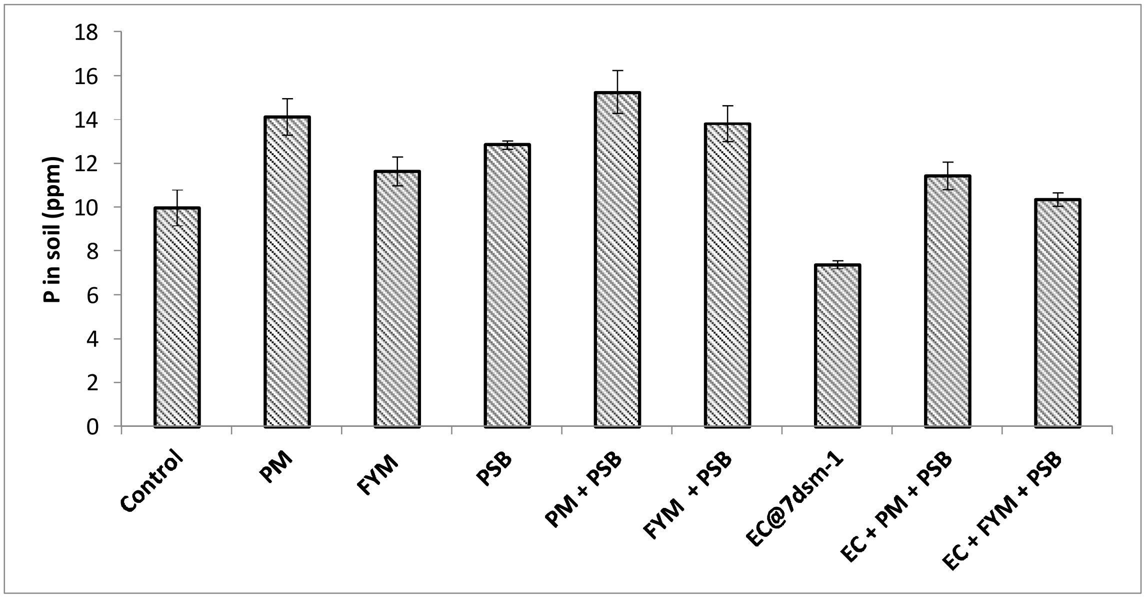

Fig 6. Effect of organic manures with PSB on the P concentration in salt affected soil.

Table 7. 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		

Phosphorus concentration in shoot (%)

The data in fig 7 illustrate that salinity stress decrease the bioavailability and uptake of phosphorus. 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 of PSB were 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 8 shows that highest P content in shoot of maize were observed when halotolerant PSB are applied in combination with organic manure (PM) under salt stress. Halotolerant PSB increase P concentration in maize plant through mineralization of insoluble P from organic sources. Our findings are according to Zhou *et al*. (2019) demonstrated that inoculation of halotolerant phosphorus solubilizing strain has ability to increase P content and reduce Na^+ content in salt stress plant. This might be due to production of various organic acids and synthesis of exopolysaccharide by PSB.

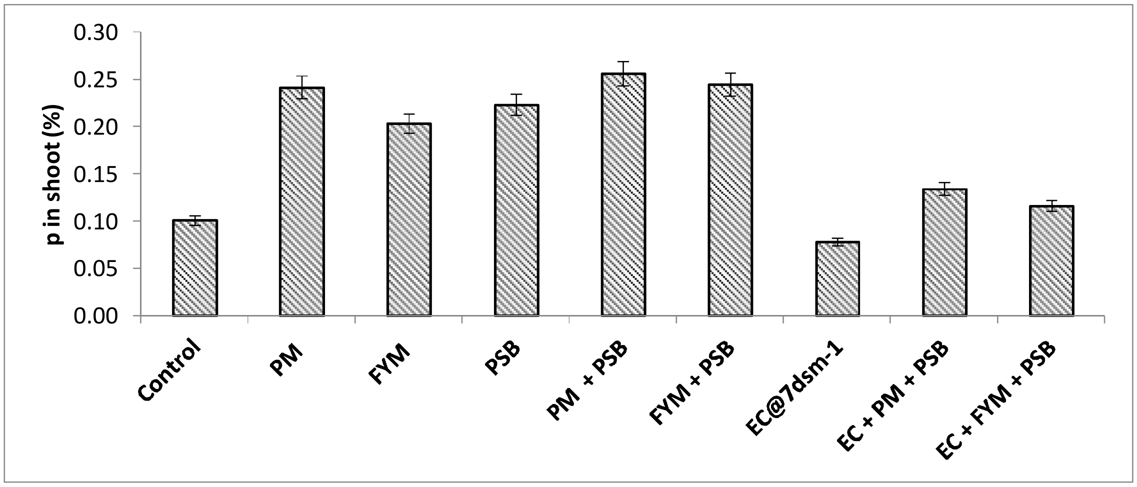

Fig.7. Effect of organic manures with PSB on the P concentration in maize plant in salt affected soil.

Table. 8. Analysis of variance for P concentration in shoot of maize

Source	DF	SS	MS	F	P
Treatment	8	1.168E+07	1460237	167061	0.000
Error	18	157.333	18.111		
Total	26	1.168E+07			

Grand Mean 1776.7 **C.V** 4.17

Na^+ concentration in soil (mg/kg)

The data in fig 8 illustrate that the salinity stress noticeable increase the Na^+ concentration in soil as compare to saline soil amended with organic manures (PM and FYM) and control. The lowest Na^+ concentration was observed in the soil where inoculation of PSB with organic manures (PM and FYM) in normal soil as compare to control. Results shows that application of organic manures (PM and FYM) and inoculation of PSB play a significant role in mitigation of 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, decrease the Na^+ concentration 7%, 7.2%, 13.4%, 25% and 20.8% respectively, as compare to control. The highest Na^+ concentration 9.2% was noted in saline soil as compare to control. However, the inoculation of PSB with organic manure help in mitigation of salinity stress and decrease Na^+ concentration 6.5% and 6.7% compare to salinity stress alone. Table 9 shows that combine application of organic manures with PSB decrease Na^+ concentration in saline soil. The reason for decreasing Na^+ concentration in soil may be due to production of exopolysaccharide by PSB which bind Na^+ ions and decrease bioavailable concentration in saline soil. Arora *et al*. (2020) demonstrated that exopolysaccharide producing bacteria improve nutrient uptake and water potential in the root zone of crops. Inoculation of plant growth promoting bacteria and biochar improves growth and physiology of maize under salinity stress (Akhtar *et al*., 2015).

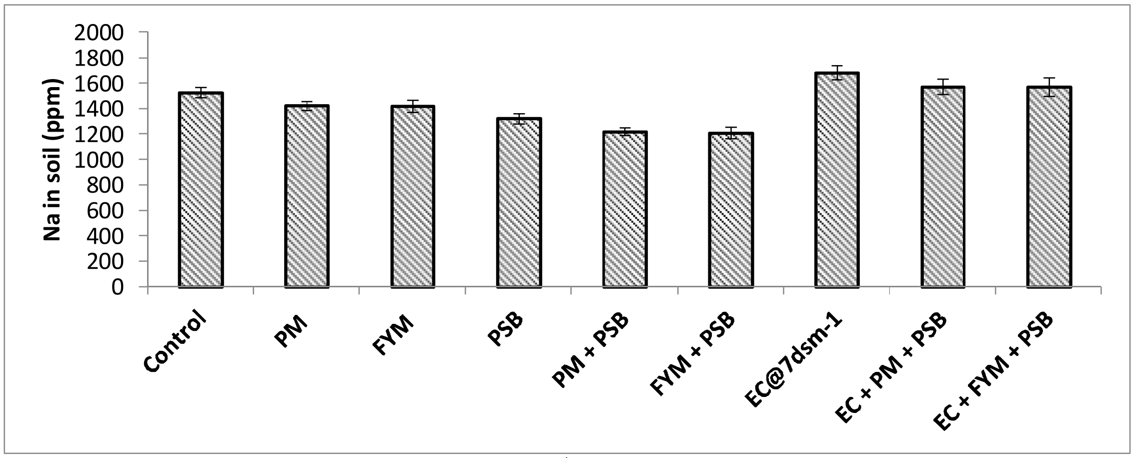

Fig.8. Effect of organic manures with PSB on the Na^+ concentration in salt affected soil.

Table.9. Analysis of variance for Na^+ concentration in soil

Source	DF	SS	MS	F	P
Treatment	8	650860	81357.5	8416	0.000
Error	18	174	9.7		
Total	26	651034			
Grand Mean	1439.0	**C.V**	3.22		

Na^+ concentration in shoot (mg/kg)

The Figure 9 and Table 10, illustrate that the salinity stress noticeable increase the Na^+ concentration in plant as compare to saline soil amended with organic manures (PM and FYM) and control. The lowest Na^+ concentration was observed in plants where inoculation of PSB with organic manures (PM and FYM) in normal soil as compare to control and control under salt stress. Results shows that application of organic manures (PM and FYM) and inoculation of PSB significantly ($P<0.05$) decreased the Na^+ concentrations in maize compared with the control under salt 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, decrease the Na^+ uptake in plant 9.1%, 9.8%, 20.5%, 23.5% and 24.3% respectively, compare to control. The highest Na^+ uptake 6% was noted in maize plant under salinity stress as compare to control. However, the inoculation of PSB with organic manure help in mitigation of salinity stress in maize plant and decrease Na^+ uptake 5.7% and 4.6% compare to salinity stress alone.

The data in table 10 showed that salinity stress increase Na^+ concentration in maize plant but inoculation of halotolerant PSB with organic manures decrease Na^+ content in maize. This might be due to production of exopolysaccharide by PSB which bind Na^+ ions and reduce the bioavailable fraction of ions for plants. Our findings are according to Silambarasan *et al*. (2019) reported that PSB produce exopolysaccharide under saline condition.

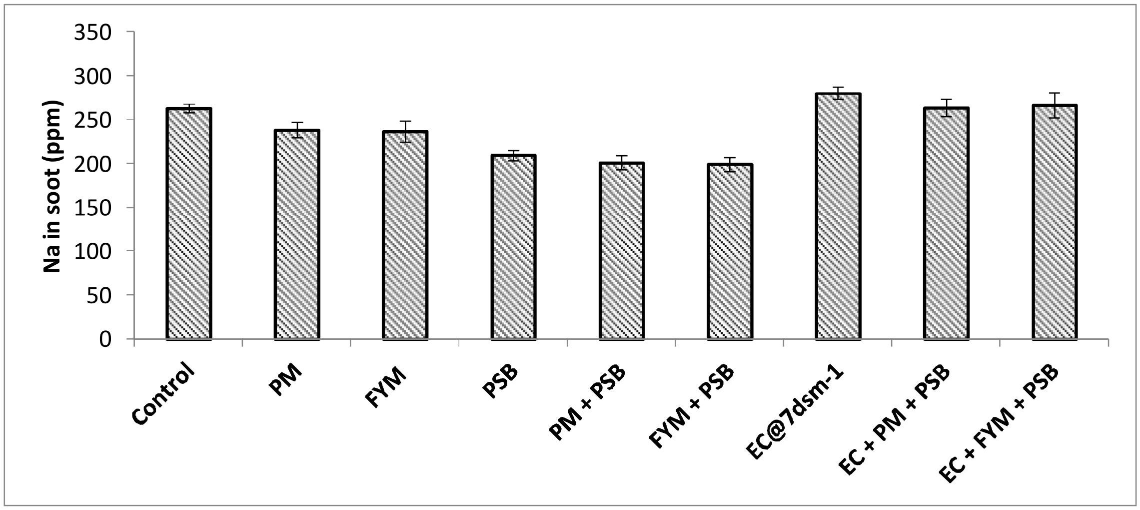

Fig.9. Effect of organic manures with PSB on the Na^+ concentration in maize plant in salt affected soil.

Table.10. Analysis of variance for Na^+ concentration in shoot of maize

Source	DF	SS	MS	F	P
Treatment	8	22645.2	2830.65	256	0.0001
Error	18	198.7	11.06		
Total	26	22843.9			
Grand Mean	240.07	**C.V**	1.38		

Conclusions

Sailinity reduces the agricultural production of most crops and furthermore deteriorates the physiochemical properties of soil and influence ecological condition of the area. Our results proved that halotolerant phosphorus solubilizing bacteria have a potential to enhace the growth and survival of maize under saline soil. The highest amount of growth parameters, phosphorus (P) concentration and lowest sodium (Na) concentration were observed in plants treated with PSB combine with organic manures under salinity stress as compare to soil with salinity stress alone. Thus, combine application of PSB and organic manures is an eco-friendly option to enhance crop growth and P nutrition in saline soil under changing climate.

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11/12/2021