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Research Article

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SALINITY-TOLERANT PLANT GROWTH-PROMOTING RHIZOBACTERIA'S (ST-PGPR) IMPACT ON SOIL QUALITY INDICES AND MAIZE GROWTH UNDER SALINE ENVIRONMENTS

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ABSTRACT

The most severe abiotic stress that maneuvers plant growth and harms modern agriculture is salinity. Food insecurity is considered to be a result of cereals being negatively influenced by this stress. Many strategies are used to lessen the effects of salinity, however, most of them are quite expensive. To lessen the influence of salinity on the maize crop, this pot study was carried out in a greenhouse utilizing four salts tolerant PGPR isolates. In the Arid Zone Research Center (AZRC) DI Khan, the hybrid maize Shahensha was grown in pots using ST-PGPR inoculum as a treatment. Rhizobacteria that encourage plant growth were isolated and produced significant benefits for maize planted in saline soil. The greenhouse investigation indicated that maize growth in pots was improved with the inoculation of all four PGPR (ECe = 9.3 dS m^{-1}), although the isolate AM_3 *Pseudomonas aeruginosa* demonstrated the highest growth and dry biomass. The comparison of inoculated strains with control exhibit that all four ST-PGPR strains simultaneously improved soil health in treated pot soil. It can easily be argued that inoculation may be a potential remedy for the salinity issue. It is therefore recommended that the ST-PGPR must be included in the production technology of crops growing in salinity-hit areas.

Keywords: *Salinity, ST-PGPR, Maize, PGPR, Greenhouse*

INTRODUCTION

The harmful consequences of salinity are experienced by approximately 20% of the irrigated agricultural area (Safdar *et al*., 2019). Clay soil can become sodic if there are problems with salt control. Clay undergoes expansion and dispersion when it encounters sodium (Na), which has a negative charge. Saline soils, which offer inadequate plant nutrition and high levels of osmotic stress, have a significant and deleterious impact on the growth of plants. All of a plant's primary metabolic functions, including growth, photosynthesis, protein synthesis, and lipid metabolism, are impacted when the plant is subjected to salt stress (Corwin, 2021). It's possible that proline can help regulate osmotic pressure, protect macromolecules from drying out, and play an important role in the body's antioxidative defense mechanism in the pentose phosphate pathway (Miller *et al*. 2010). Plants of the chickpea (*Cicer arietinum* L.) species demonstrated heightened Na/K fraction and poorer P assimilation in the shoot when they were subjected to salinity (Singh *et al*., 2018). Inoculating plants with PGPR, on the other hand, can help plants develop more healthily even when subjected to osmotic stress (Upadhyay *et al*., 2012). Utilizing PGPR bio-inoculants, i.e., *Agrobacterium*, *Pseudomonas*, *Azospirillum*, and numerous other bacterial species, is an ecologically responsive, and economically feasible method of recovering salinity-stricken land and improving biomass output (Berg

2009). As PGPR colonizes plant roots, its use can be beneficial in the creation of strategies to elevate the growth of wheat in salty conditions (Upadhyay *et al*. 2011). Inducing PGPR chemotaxis on root surfaces by root exudates i.e., carbs and amino acids enhances the possibility that bacteria will reach the plant roots (Somers *et al*. 2004). There have been reports of higher agronomic yields because of PGPR due to the generation of growth-stimulating plant hormones i.e., gibberellic acid (GA), indole-3-acetic acid (IAA), ethylene, zeatin, abscisic acid, and phosphorus solubilization (Idris *et al*., 2007). Salinity significantly reduces the yield of wheat, which on moderately salinized soils results in a loss of about 65 percent of the crop (Shafi *et al*. 2010). Although there is very little information available regarding the role of PGPR in wheat under salinity, it has been observed that using PGPR inoculum for cereal growth can decrease salt stress (Barriuso *et al*. 2008). This research was envisaged to investigate the effects of ST-PGPR application on the development and productivity of maize in a saline environment.

MATERIALS AND METHODS

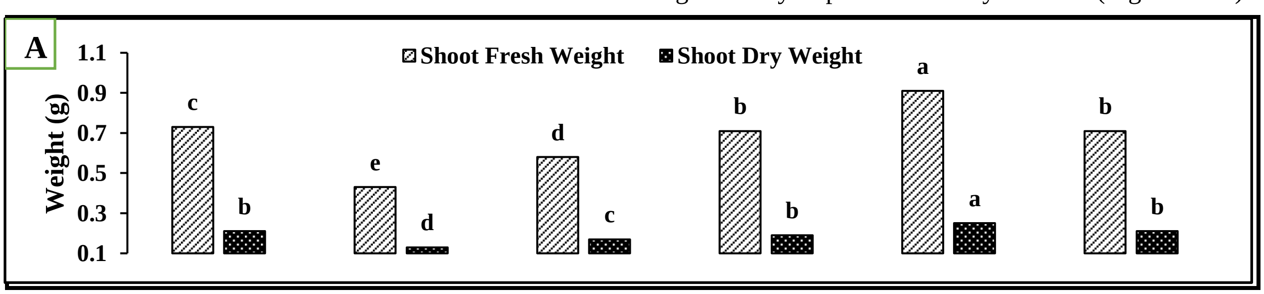
Collection and Isolation of PGPR: The current research utilized 4 salts resistant PGPR, which were isolated from the maize rhizosphere at Arid Zone Research Center (AZRC) DI Khan. These PGPR were found to have a w/v concentration of 6% sodium chloride. These strains have growth-promoting properties i.e., IAA, P solubilization, GA, proline, siderophores, reducing sugars (RS), and total solvable sugar synthesis at 6% sodium chloride for plants (Upadhyay *et al*. 2012).

Experimentation: A pot experiment with the maize hybrid Shahenshah that was inoculated with PGPRs (AM_1 *Pseudomonas aeruginosa*, AM_2 *Pseudomonas putida*, AM_3 *Enterobacter asburiae*, and AM_4 *Enterobacter mori*) was carried out at AZRC DI Khan. The salinity of the soil was measured at EC_e = 9.3 dS m^{-1}. 30 days after the seedlings emerged, the plants were dug up and observations were conducted on the overall as well as the shoot and the roots (dry biomass). According to the procedures developed by Kalra and Maynard (1991), the bulk density, organic carbon, electrical conductivity (ECe), and water-holding capacity of the pre-treated (saline soil before bacterial inoculum) and post-treated (rhizosphere soil following bacterial inoculum 30 days after sowing) soil from wheat grown in containers were analyzed. Bacterial populations in the soil around the rhizosphere were assessed for the number of colony-forming units (CFU) that they produced on a NA medium (Upadhyay *et al*. 2012), and Upadhyay *et al* (2011) methods were used to calculate the salt content of the soil.

Statistical analysis: Statistix version 8.1 was utilized throughout all of the analyses of variance. When conducting multiple range studies, the LSD test was utilized to identify significant differences between the several sets of data. When $p<0.05$, the findings were deemed to be significant.

RESULTS

Maize response to PGPRs: Controls consisted of non-inoculated treatments that were either subjected to or not subjected to NaCl stress. Extreme biomass was attained with inoculation of isolates AM_3 *Enterobacter asburiae*, AM_2 *Pseudomonas putida*, and AM_4 *Enterobacter mori*. The highest root biomass was attained following inoculation with AM_3 *Enterobacter asburiae*. Inoculation with isolates AM_3 *Enterobacter asburiae*, AM_2 *Pseudomonas putida*, and AM_4 *Enterobacter mori* significantly improved total dry biomass (Figure 1 a-c).



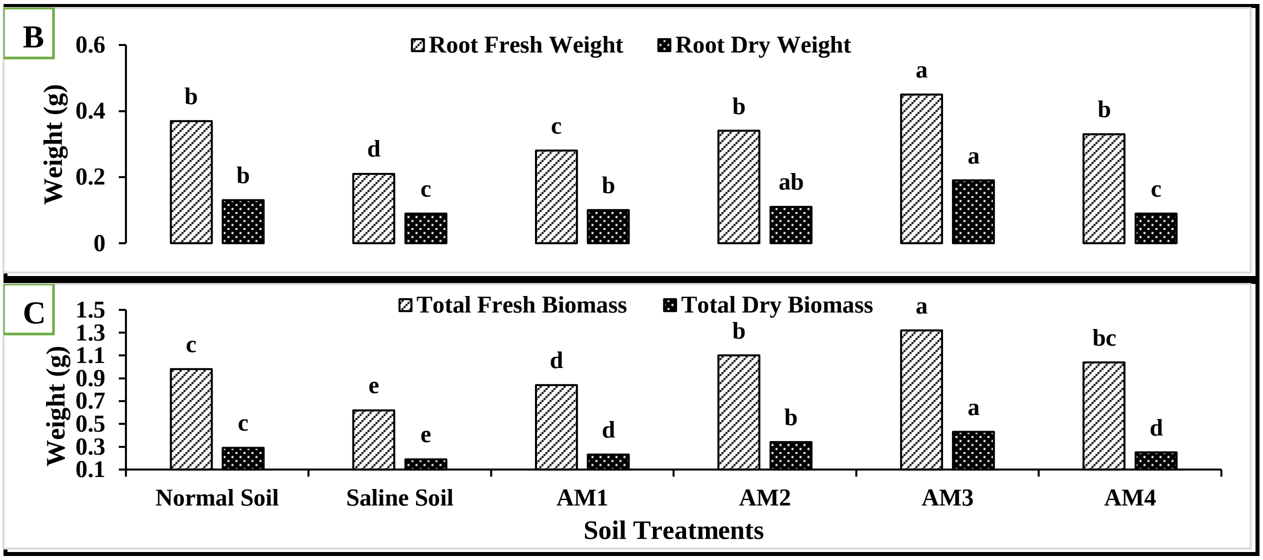


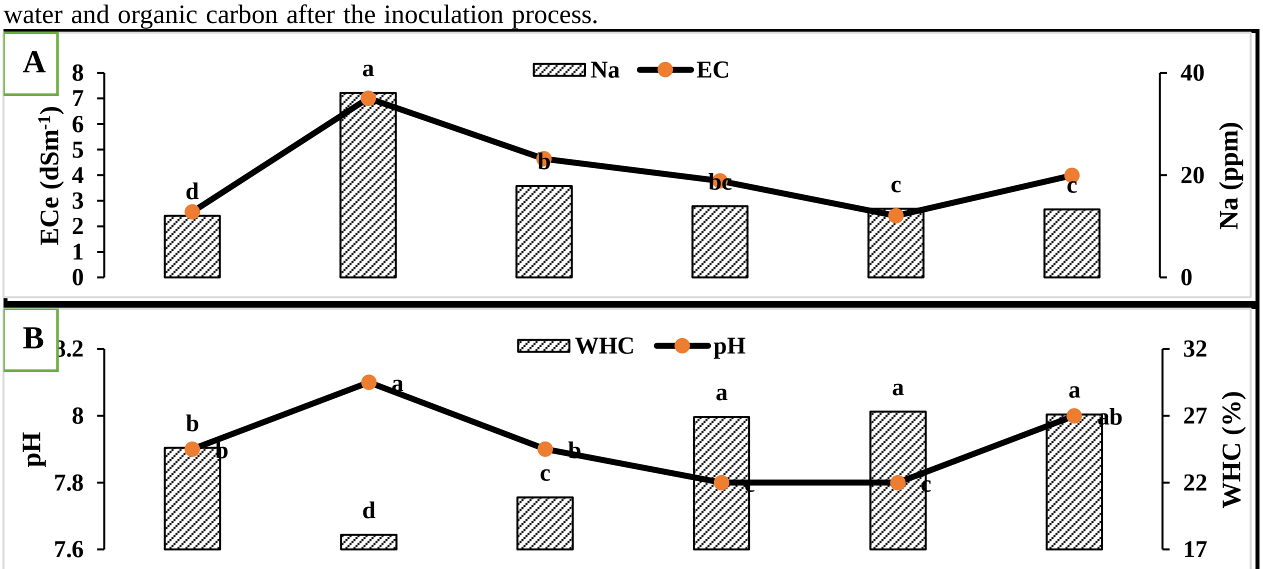
Figure 1 (a-c): The influence of PGPR on the growth characteristics of maize grown in salty environments

Effect of PGPRs on soil microbial population: The rhizosphere possessed the most bacterial populations, and all of the PGPR strains showed rhizo-adaptation in wheat (i.e., the optimal Cfu population; see Table 1). The greatest was observed in AM_3 *Pseudomonas aeruginosa* and AM_4 *Enterobacter asburiae*.

Table 1: PGPR's impact on the bacterial population under salinity

Treatments	**BP (cfu g^{-1} soil)**
Uninoculated (Normal Soil)	7 x 10^4
Uninoculated (Saline Soil)	2 x 10^2
AM_1 *Pseudomonas aeruginosa*	6 x 10^5
AM_2 *Pseudomonas putida*	5 x 10^6
AM_3 *Enterobacter asburiae*	7 x 10^7
AM_4 *Enterobacter mori*	6 x 10^7

Effect of PGPRs on soil indices: When compared to the control, the soil that had been inoculated with PGPR showed a larger increase in both its capacity to hold water and organic carbon after the inoculation process. On the other hand, the bulk density of the soil did not change, even though the ECe, pH, and sodium content of the soil were all reduced (Figure 2 (a-c).



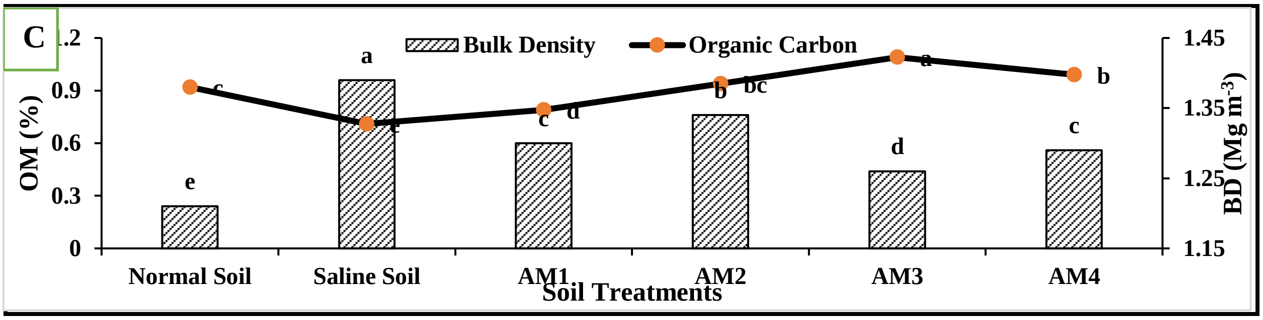


Figure 2 (a-c): The influence of PGPR on soil characteristics in salty environments

DISCUSSION

There have been reports of species variances in the amount of salt that different types of plants can tolerate. The salinity tolerance level of maize sits somewhere between moderate and high (Ali et al. 2007). The term "plant growth-promoting bacteria" refers to any free-living bacteria that, in either a direct or indirect manner, encourage the growth of plants (Rabie and Almadini 2005). In experiments carried out in pots inside of a saline environment, all four PGPR used had a significant impact on the growth of wheat and the health of the soil; to put it another way, all four PGPR encouraged growth. The trials were carried out in greenhouses (Upadhyay et al. 2012). Because of the introduction of PGPR, the saline environment may have experienced an improvement in nutrition, which could be the cause of the observed increase in biomass. Previous research has shown that the application of particular PGPR can somewhat moderate the negative effects of salt on the growth of tomato, pepper, canola, cotton, and wheat. This was proved by the fact that the negative effects of salt were shown to be mitigated (Yue et al. 2007). Rhizo-adaptation or a rhizosphere effect can be proved by the fact that the population of PGPR developed over time after being sown in the soil of a plant's rhizosphere when the plant was treated with PGPR (Table 1). Hiltner (1904) was the first person to describe the rhizosphere effect. The rhizosphere effect can be defined as the attraction of microorganisms to nutrients that are released from plant roots, which leads to an increase in the number and activity of microorganisms in the area surrounding plant roots. Nevertheless, in addition to creating an environment that is abundant in carbon, the roots of plants also initiate crosstalk with the bacteria in the soil. This allows plant roots to produce signals that are detected by soil microorganisms, which in turn causes soil bacteria to transmit signals that commence colonization of the new territory (Kohler et al. 2006). These bacterial populations will inhabit the rhizosphere and interact with one another through a variety of processes, such as root exudates and chemotaxis, symbiosis, quorum-sensing, and others. These methods include root exudates chemotaxis and symbiosis (Bais et al. 2006). The use of PGPR not only influences the growth of plants but also has a positive effect on the health of salty soil. Organic carbon and the capacity of the soil to store water both rose in PGPR-treated soil, but ECe, sodium concentration, and pH all decreased. When compared to the controls, which were grown on soil that had not been treated, this result was significantly higher. Bacteria able to solubilize phosphate may be contributing to a reduction in pH by producing organic acids with a low molecular weight. (Rodriguez et al. 2004). According to Tao et al. (2008), certain strains of bacteria are capable of simultaneously engaging in the solubilization and mineralization processes. Maintaining a pH that is somewhat close to neutral, helps contribute to an improvement in the soil's health. The synthesis of exopolysaccharides by PGPR strains also helps in binding cations, including sodium. As a result, it may lower the amount of sodium that is available for plant absorption, which in turn contributes to the easing of salt stress in plants (Upadhyay et al. 2011).

CONCLUSION

The findings of this inquiry led to the conclusion that a comprehensive understanding of the mechanisms and modes of action of PGPR inoculants is lacking. This conclusion was reached as a result of the investigation. PGPR may lead to an improvement in the overall health of the soil in salty areas. *Enterobacter asburiae* is a powerful rhizobacterium that can tolerate high levels of salt and has the potential to boost the development of maize in areas with high levels of salt.

The use of PGPR is not harmful to the environment, and it helps to reduce the adverse consequences of applying an excessive amount of fertilizer in agricultural settings. As a consequence of this, they contribute to the maintenance of a sustainable equilibrium between the expansion and production of crops and the qualities of the underlying soil.

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AUTHOR CONTRIBUTIONS

Sami Ullah and Ayesha Irum conducted this research trial. Bint E Haider, Asma Hanif, Ghazanfar Ullah, and Sadaf Noreen wrote this paper. Iqtidar Hussain and Umar Khitab Saddozai analyze the data. Mahnoor Mazhar set the references. All authors read and approved the final version.

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