The effect of halophilic, alkaliphilic and haloalkaliphilic rhizosphere bacteria on different vegetative growth characteristics, soil and GN15 almond rootstock nutrients

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INTRODUCTION

Currently, the use of soil biotechnology to exploit the potential of beneficial soil microorganisms to produce a maximum yield in stress conditions has received much attention due to soil quality improvement and environmental health and safety. High efficiency, environmental friendliness, and being economic are some of the advantages of indigenous soil bacteria usage (Koskey et al, 2021).

Halophiles are microorganisms with optimal growth at NaCl concentrations over 0.2 M. (Oren et al., 1991). Alkaliphiles require an alkaline pH of 9 or more for their growth and have an optimal growth pH of around 10, whereas haloalkaliphiles require both an alkaline pH (>pH 9) and high salinity (up to 33% [wt/vol] NaCl) (Horikoshi, 1999). Selection of native microorganisms from the group of halophiles and alkaliphiles that also have plant growth-promoting characteristics can alleviate the effect of salinity and alkalinity stress factors directly or indirectly (Rai et al., 2020).

Almond (Prunus amygdalus L.) yields are reduced by 25%, 50%, and 100% in electrical conductivity of 2.8, 4.8, and 7 dS m-1 respectively. (Collin et al., 2019). In this study, we aimed to investigate the effect of three types of extremophilic indigenous bacteria (halophilic, alkaliphilic and haloalkaliphilic bacteria) to induce salinity and alkalinity resistance in almond rootstocks under these stress conditions of the soil.

METHODOLOGY

Isolating, purifying, and preserving 54 different strains from three groups of bacteria (halophilic, alkaliphilic, and haloalkaliphilic) were carried out from the rhizosphere of almond groves soil samples in Khorasan Razavi (Iran). Afterward, three PGPR properties including tri-indole acetic acid, dissolution of mineral phosphates, and Exo-polysaccharide were measured in all strains in the laboratory. Then, the roots of 108 GN15 almond rootstocks were inoculated with two superior bacterial strains and sterilized control from three groups of bacteria in four saline-alkaline artificial soils (2, 4, 8, 16 dS m^{-1} with 10, 15, 15, 20 SAR respectively). More than 50 different morphological characteristics, biochemical traits, soil and plant macro, micro nutrient concentration along with some specific ions (Na^+ and Cl^-) were measured in the treatments.

Fig 1. Almond groves-Koohsorkh -Khorasan Razavi-Iran

RESULTS

Alkaliphilic, haloalkaliphilic and halophilic were superior in terms of production capacity and amount of plant growth-promoting attributes, respectively. H10, H22, A11, A7, HA7, and HA9 were the best isolates in the laboratory.

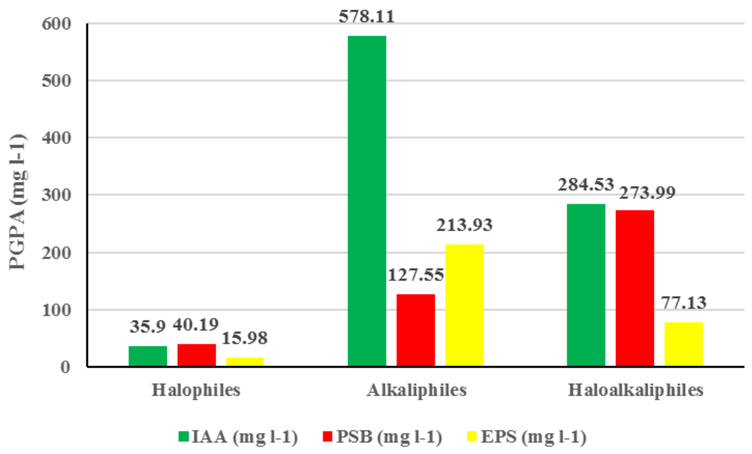

Fig 4. The production of IAA,PSB and EPS by tree groups of bacteria strains

Halophilic bacteria caused the largest increase in shoot fresh weight (19.83 g); however, the fresh weight of the roots (22.61 g) was maximal in the haloalkaliphilic group. The highest root-to-shoot ratio was observed in the HA9 strain of haloalkaliphilic bacteria with 1.31.

Soil pH was variable and significant from 6.9 to 7.5 in all treatments. Soil EC was significantly reduced in 8 and 16 dS m^{-1} treatments to the 5.2 and 9.2 dS m^{-1} respectively with the bacterial application.

With soil salinity increase, plant N and K decreased; and the concentration of plant Mg, Fe, Na, and Cl along with soil P, Na, and Cl increased. The increasing trend of EC, P, and Cl elements in the soil and Zn of plants under the influence of bacteria was similar to quantitative amounts of growth enhancers; and it was more in alkaliphilic, haloalkaliphilic, and halophilic, respectively. While the amount of plant Mg, P, and K and soil Fe were affected by the pH changing by bacteria and were observed in halophilic, alkaliphilic, and haloalkaliphilic, respectively.

The plant P was eight times higher than the optimal P of almond leaves and 39.5 times greater than the initial P of soil. Soil K of treatments was 21 times bigger than the initial soil K. Plant Fe was 12 times more than the soil Fe, and the concentration of plant zinc was about 0.3 mg l^{-1} more than on the soil. Also, plant sodium was one-eighth of soil sodium and plant Cl was one-half of soil chlorine under the influence of bacteria.

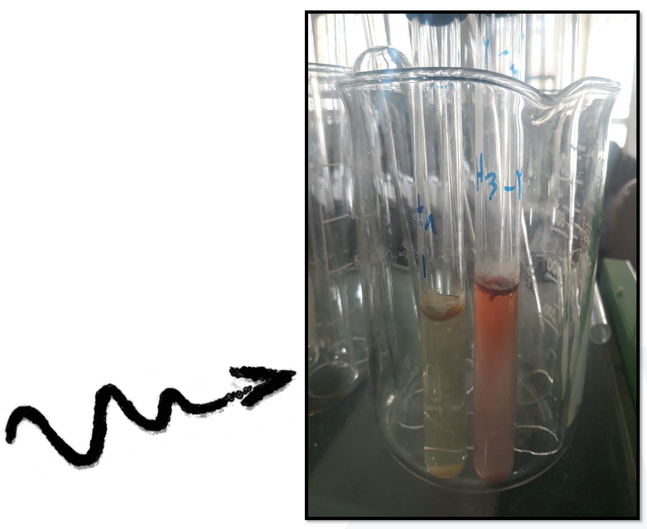

Fig 2. PGPA measurements of strains in lab

CONCLUSIONS

The halophilic bacteria increased biochemical properties such as chlorophyll, proline, and total sugar, decreased plant uptake of specific ions such as sodium and chlorine, and increased uptake of primary macronutrients such as plant N, P, and K. While alkaliphilic bacteria improved morphological characteristics such as plant height, leaf area, increased the absorption of microelements (Fe and Zn). Haloalkaliphilic bacteria were effective in magnesium uptake, root development, and improvement of plant water relations.

These data showed higher efficiency and performance of native soil bacteria at higher salinities (16 dS m^{-1}). The greater effect of haloalkaliphilic bacteria on root growth than shoot growth can be attributed to the production of more indole auxin compounds compared to other properties in them that increased root growth (Kudoyarova et al, 2019).

The halophilic bacteria showed less PGPR properties in the lab but they were more effective than the other two groups, due to their different complicated mechanisms to the availability and absorption of essential elements or inhibition of absorption of toxic ions which represents the complex interactions of soil, plants, and bacteria in saline and alkaline soils (Gamalero et al., 2020).

The 8 dS m^{-1} salinity acted as a turning point for almond rootstocks under the influence of extremophilic bacteria. So that with salinity increase to more than that, the use of bacteria strains improved different parameters. This study indicated that the results of soil nutrient concentration with quantitatively measured values of PGPA in the laboratory were more consistent than the plant concentration of elements. H10 and H22 strains from the halophilic group were the most effective strains in increased resistance in the almond rootstocks.

Fig 3. inoculation of strains to almonds rootstocks

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