Desalination and Water Treatment
www.deswater.com
doi: 10.5004/dwt.2020.25515

Improving water use efficiency of crops for sustainable agriculture in dry lands

Ahmed Al-Busaidi[a,*], Mushtaque Ahmed[a], Hashel Al-Maskari[a], Shihab Al-Maamari[b]

[a]*Department of Soils, Water and Agricultural Engineering, College of Agricultural & Marine Sciences, Sultan Qaboos University, Oman, email: ahmed99@squ.edu.om (A. Al-Busaidi)*
[b]*Applied Biotechnology Department, Sur College of Applied Sciences, Oman*

ABSTRACT

Improving water use efficiency in agriculture especially in dry countries is the dire need of the day. Oman has limited groundwater and in many places it is saline water. Therefore, various approaches could be used to improve plant productivity in saline dry lands. One approach to overcome the limitation of plant growth due to shortage of water and soil drying could be to promote root growth for efficient uptake of water from greater soil volume. Ethylene is a plant hormone that is involved in the regulation of many plant physiological responses especially under stress conditions. Water stress has been extensively associated with elevated release of endogenous ethylene by the plant which results in root growth inhibition dramatically. Therefore, there are certain plant growths promoting rhizobacteria (PGPR) which contain a unique enzyme that decreases ethylene in the inoculated plant roots. The main aim of this project was to isolate and evaluate plant growth promoting rhizobacteria for increasing plant growth and water use efficiency of crops. Moreover, different compost could enhance the growth of bacteria and save water for better growth. For this purpose, different bacteria were isolated from saline soil of Barak, Oman. The best bacteria that gave better growth in saline media were selected. The best two bacteria were reproduced and used for field trials. They were compared with two bio-stimulants (Stimpo and Regoplant) and grown in three different composts (Kala, Growers and Al-Mukhasib). The study was done in greenhouse using radish and okra plants grown in pots and irrigated with freshwater and saline (4 dS/m) treated waste water.

Plant showed the best growth under freshwater irrigation compared with saline water. This happened due to salinity stress that affected water and nutrients movements from the soil to the plant. All used composts positively affected plant growth. However, Kala compost gave the best growth and productivity even under saline irrigation. The most important thing was how bacteria and bio-stimulants could improve plant growth and give significant effect especially under saline conditions. It was observed that Regoplant was good and gave better results for plant growth (plant height, fresh weight and fruit weight) with freshwater irrigation compared with saline condition. Whereas, Stimpo and bacteria showed positive effect under saline condition and they supported plant growth much better than Regoplant. However, Stimpo is still chemical compound and could have some side effects with long-term applications. Therefore, bacteria could be the best option for improving plant growth under saline conditions because it is from nature and could adapt with soil-water-plant conditions. Using these bacteria under Oman saline condition will improve the growth and productivity of different plants that could not survive under saline conditions.

Keywords: Enriched compost; Plant growth promoting rhizobacteria; Bio-fertilizers; Organic fertilizer

1. Introduction

Plant growth promoting rhizobacteria (PGPR) are comprised of diverse taxa of bacteria that commonly inhabit the rhizosphere or the interior of plant root tissues (Glick et al., 1995). PGPR enhance plant growth through several mechanisms, including solubilization of phosphorus and iron, phytohormone production, suppression of pathogens,

* Corresponding author.

Presented at the 13th Gulf Water Conference – Water in the GCC: Challenges and Innovative Solutions. 12–14 March 2019, Kuwait

and by lowering stress-ethylene concentrations in the rhizosphere (Glick et al., 2007; Dutta and Podile, 2010). Among these traits, suppression of ethylene production is one of the most important for alleviation of plant stress caused by drought, salinity, chemical toxicities. There are certain PGPR which contain a unique enzyme, ACC-deaminase that hydrolyses ACC and decreases ethylene in the inoculated plant roots. It is well documented that inoculation of seed/plant with these PGPR increases growth of inoculated plants. Better root growth can result in greater water use efficiency through exploiting greater soil volume. This ACC-deaminase biotechnology has been found very effective in increasing crop yields under different stress conditions such as drought, soil salinity, heavy metals, etc. on sustainable basis in many countries such as Canada, USA, India, Pakistan, China and Vietnam. However, it is very essential to evaluate this biotechnology under harsh climate, saline soils and arid environment such as Oman.

Another strategy to enhance water use efficiency could be by improving water holding capacity of the soil. Compost could be a good candidate for this because it could not only increase water holding capacity of the soil but also improve other physicochemical and biological properties of different soils. Composting offers the most sensible and economic way to handle organic waste materials which create environmental problems, and at the same time it produces a high quality and inexpensive soil amendment. Through composting, the undesirable features of these materials (heavy metals and organic compounds, pathogens, odor, wider C:N ratio, etc.) can be changed to desirable characteristics. In general, finished composts are highly regarded for their ability to improve soil health and plant growth. The efficacy of the compost could be further enhanced if the essential nutrients required by the plants and other biological substances are added to the applied compost.

In Oman, agricultural production is highly dependent upon the availability of suitable irrigation water. Water is a very precious commodity and all efforts are required to increase the productivity per unit of water applied. Water scarcity in agriculture sector is becoming an extremely serious problem in hampering the crop yields (Abdelrahman et al., 2011). The problem of water scarcity is very serious in Oman and average rainfall is less than 125 inches per year (FAO, 2013) which is often below the required amount for many crops.

As global climate change is predicted to make rainfall more erratic, there is a pressing need to improve crop production and water use efficiency. For this purpose different physical, chemical and biological approaches could be used to produce more biomass per unit of water. Therefore, many engineering and other management practices are being investigated to improve the water use efficiency of the agricultural systems in Oman (Luedeling et al., 2005). Application of enriched compost and PGPR for improving yield of crops and physical, chemical and biological properties of soils has been investigated in other countries (Shahzad et al., 2008) but application of this technology under the arid environment needs to be evaluated. The integrated application of both the PGPR and enriched compost could be more beneficial with improvement in plant growth, yield and water use efficiency of crop under the harsh climatic conditions of Oman. Therefore, the aim of the study was to evaluate the combined effect of applying PGPR containing ACC deaminase and enriched compost in improving plant growth and water use efficiency of crops.

2. Methodology

Indigenous PGPR was isolated from the rhizosphere of crops grown under saline conditions in Barak area, Oman, and was screened for plant growth promotion under axenic conditions. Three composts (Kala, Growers and Al-Mukhasib) were selected from different commercial sources, characterized for their physicochemical and biological properties. All three composts were enriched with nutrients and biologically active substances. Then the efficacy of both PGPR and enriched compost were evaluated under pot experiment irrigated by fresh and saline waters. To get clear comparisons, two bio-stimulants (Stimpo and Regoplant) were used and their effects were compared with local bacteria.

2.1. Greenhouse experiment

Okra and radish seeds were inoculated with four types of bio-stimulants (bacteria 1, bacteria 2, stimpo and regoplant). All seeds were planted for germination in plastic trays filled with peat-moss. The seeds were left to grow for 3 weeks and germination rates were recorded.

Seedlings were transplanted to greenhouse in pots filled either with Kala or Growers or Al-Mukhasib composts (50% sand:50% compost). Pots of different composts and crops were irrigated either with freshwater or saline treated wastewater (4 dS/m). Around 200 pots were prepared with 4 pots per treatment as shown in Fig. 1.

During the experiment, different measurements were taken as following: soil salinity, soil moisture content, chlorophyll content (SPAD meter) and Okra plant height, fruit number and weight. Finally both crops were harvested. Soil samples for all treatments were taken within 10 cm depth. Soil and plant samples were analyzed in soil and water lab for some physico-chemical analysis.

3. Results and discussions

3.1. Soil moisture content

Soil moisture content usually depends on soil/compost types and plant growth and consumption. Fig. 2 shows the average soil moisture content of Mukasab, Growers and Kala composts. Soil moisture content was approximately equally distributed in all Growers compost treatments compared with other two composts, whereas, it varies with different treatments of Kala and Mukasab. For bacteria treatments, it can be seen that control and Regoplant had more moisture content in all three composts; whereas, bacteria 1, bacteria 2 and stimpo had lower values. Differences in moisture contents between different treatments could mean that plant was absorbing water and the evapo-transpiration losses depend on plant health and compost physical properties.

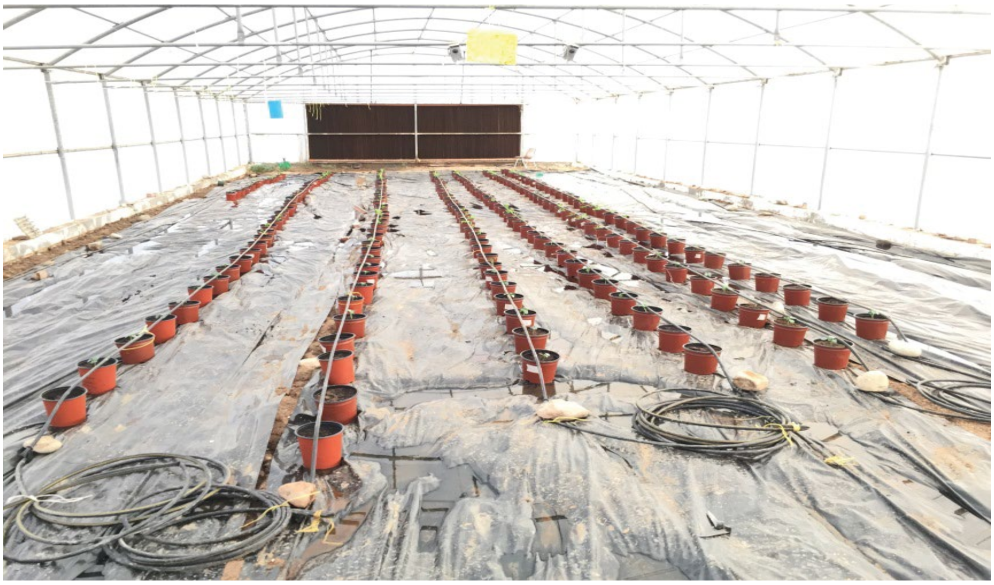

Fig. 1. Pots of different composts irrigated with fresh and saline waters.

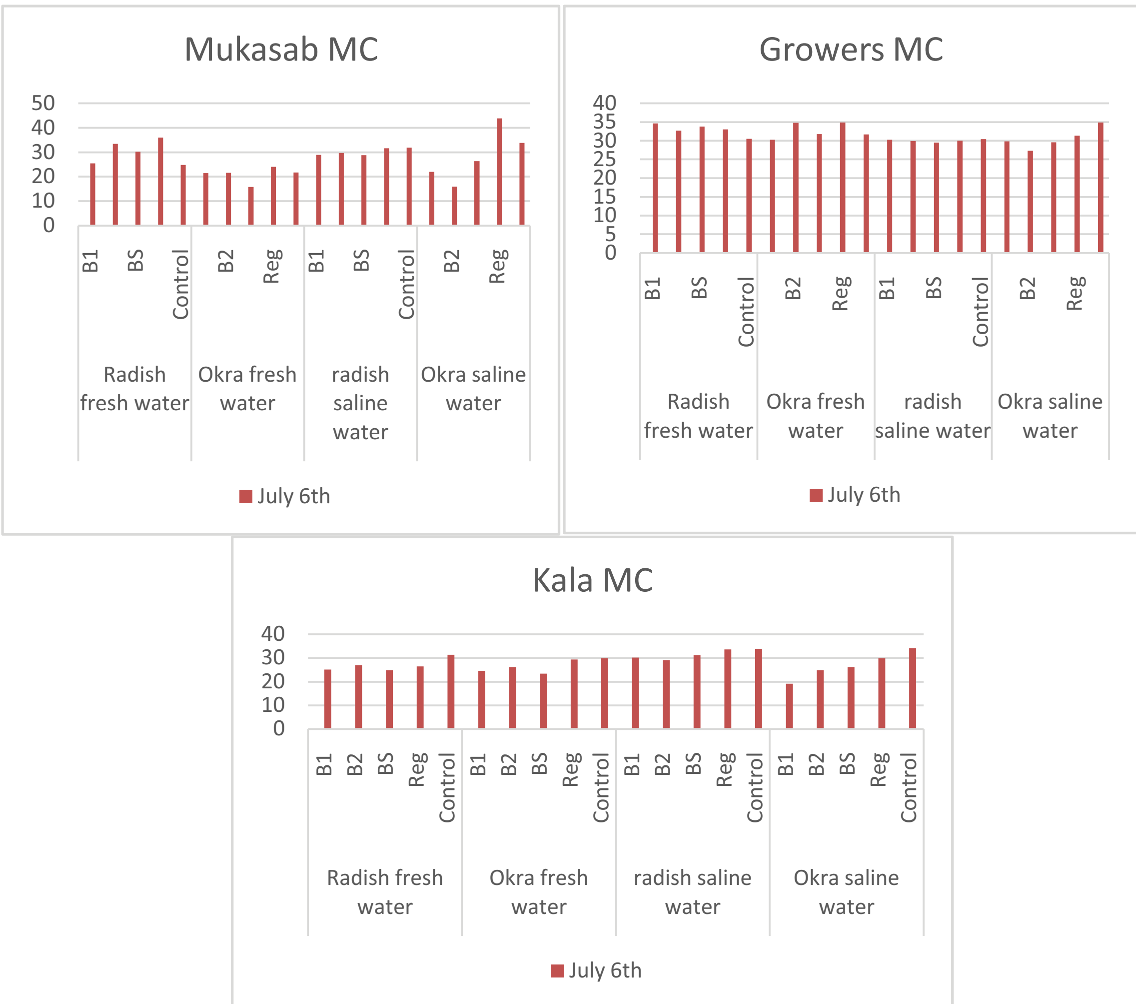

Fig. 2. Soil moisture content under different treatments.

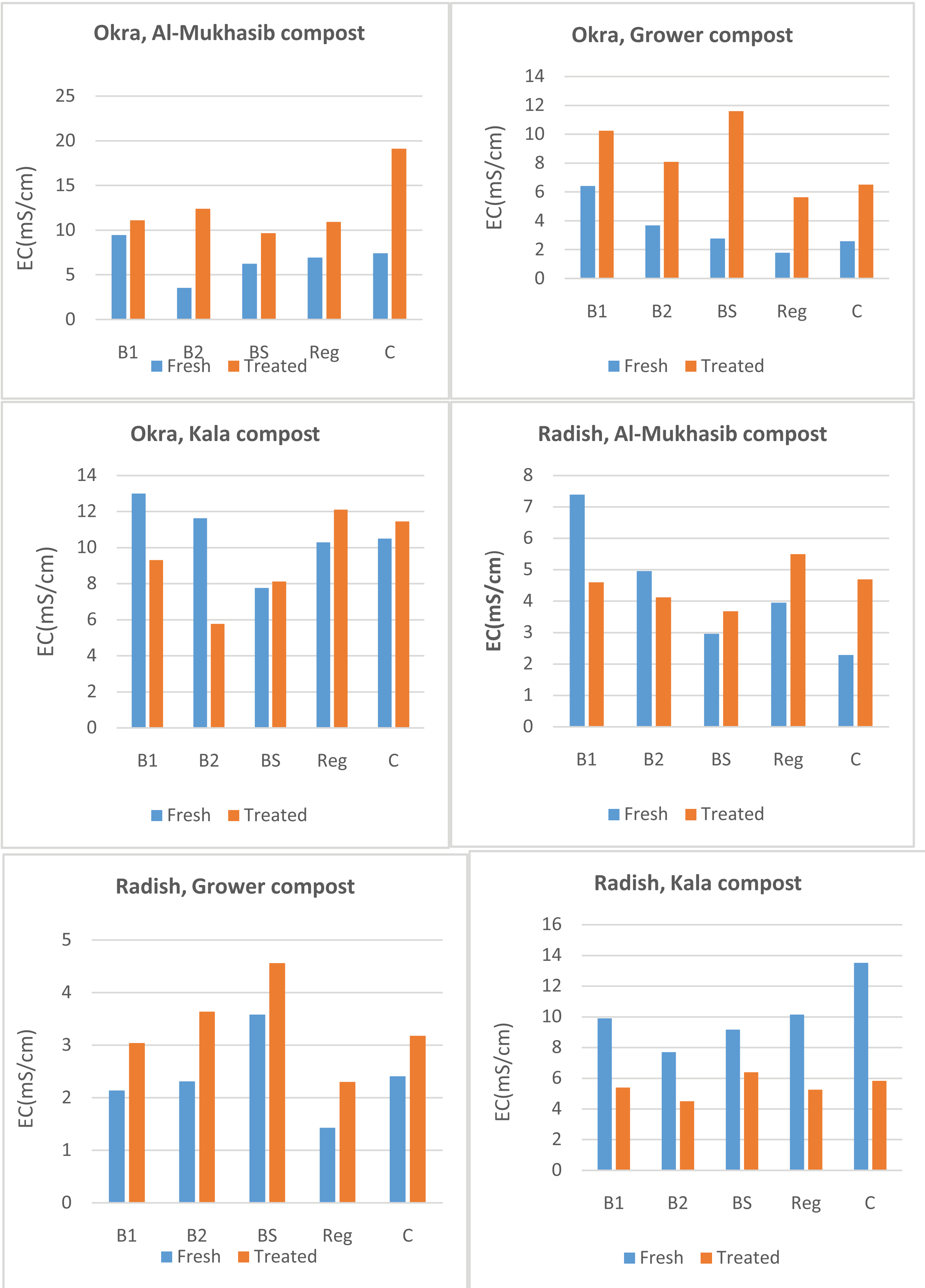

Fig. 3. Soil salinity as affected by different treatments.

3.2. Soil salinity (ECe)

Soil salinity could increase or decrease with time depending on original salts, salts added, consumed or leached down the profile. In case of saline irrigation, it is expected that soil salinity increases more than freshwater irrigation which can be seen clearly with both crops in Fig. 3. Irrigation amount, soil and compost water holding capacity could increase or decrease leaching process and affect salts accumulated in the soil. At the end of the study (Fig. 3), it can be seen that Kala compost had higher salinity values compared with other composts which could mean that Kala compost was continuously releasing nutrients to the soil solution and feeding the plants. The most interesting thing is that bacteria 1 and 2 were more active under Kala compost and helped in decreasing soil salinity under saline treatments. This finding needs extra investigation.

3.3. Chlorophyll content

Chlorophyll is an indicator for green color which is usually related to the nitrogen absorbed by plant. From Fig. 4, it can be seen that Kala compost gave the highest values for chlorophyll content which mean that Kala could have more nitrogen compared with other composts. Moreover, saline treatments had negative effect on chlorophyll content which mean plant cannot absorb nitrogen when soil salinity is high.

3.4. Okra height

As shown in Fig. 5, it can be seen that Kala compost was the heights compared with other composts. Plant grown under freshwater irrigation got better results than saline conditions. However, Bacteria 2 was more active in supporting Okra growth compared with other treatments. Bacteria 1, Bacteria 2, stimpo have good height in both fresh and saline water irrigation. However, Regoplant was good in fresh water irrigation but not in saline water irrigation and control have the lowest height in fresh and saline water irrigations.

3.5. Okra fruit weight

Plant productivity is the most important thing for the farmer and consumer. Okra fruits were highly affected by

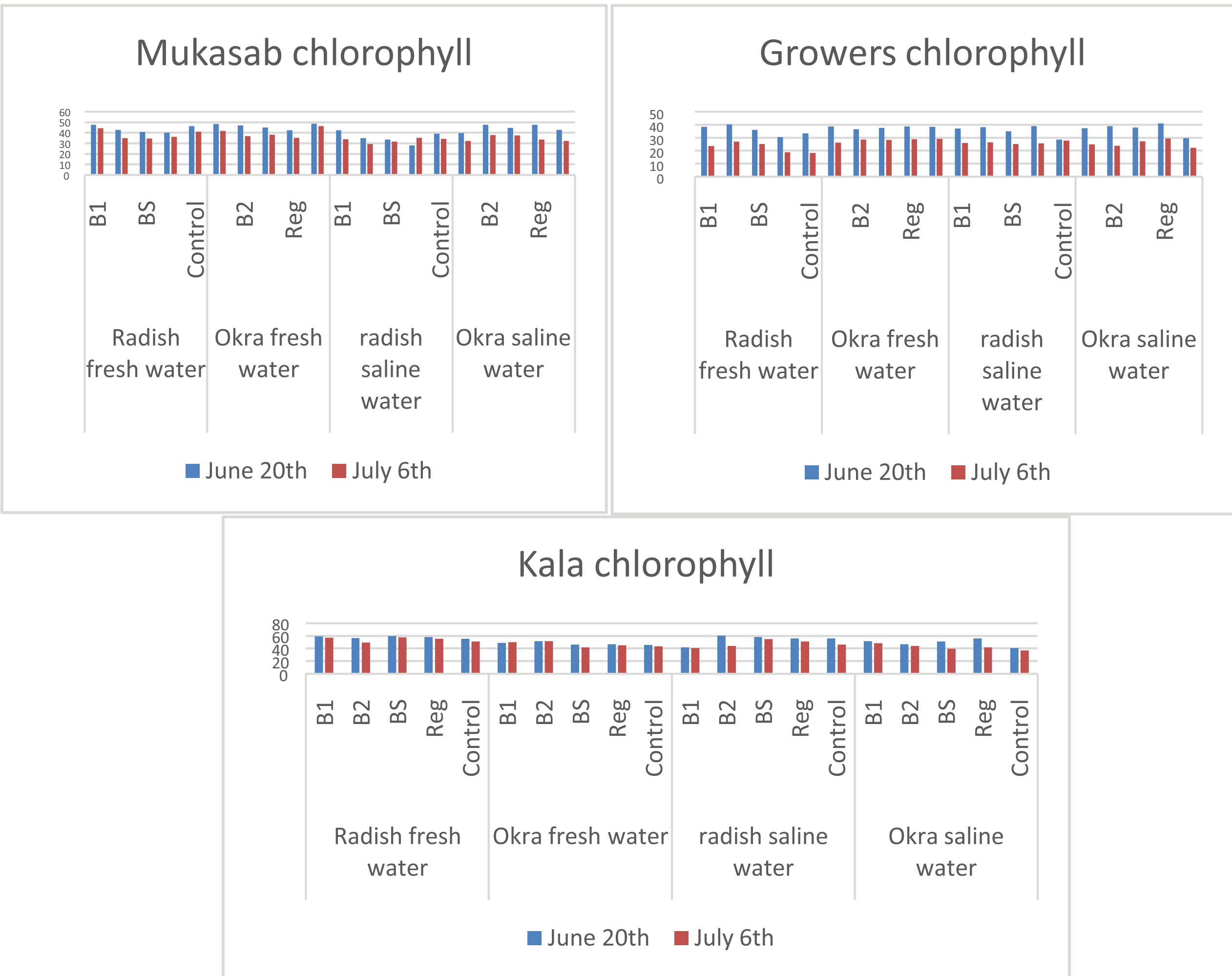

Fig. 4. Chlorophyll content as affected by different treatments.

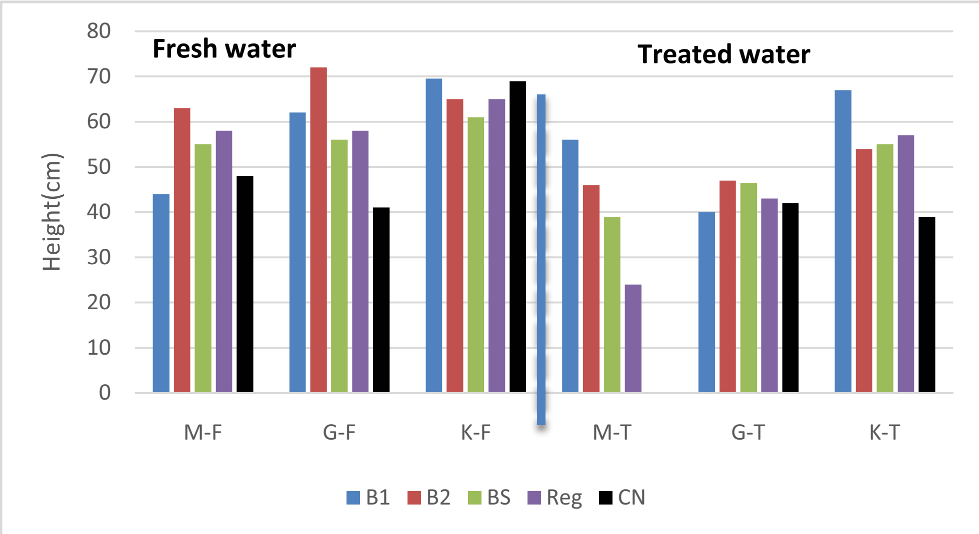

Fig. 5. Okra height as affected by different treatments.

fresh-saline irrigation followed by compost type and finally with bacteria treatments (Fig. 6). Salts present in irrigation water suppressed okra productivity and gave zero or low fruits compared with freshwater irrigation.

Compost was the media supporting plant growth. Therefore, it looks like that Kala compost was the best compost that gave the highest productivity of okra fruits compared with other composts. The most interesting thing is that bacteria 1 and 2 gave the best productivity within all composts. It seems that native bacteria were supporting plant growth by improving nutrient absorbance and reducing salinity stress.

Regoplant and control showed no fruits production under saline treatments compared with freshwater irrigation; whereas, stimpo, bacteria 1 and bacteria 2 gave good amount of fruits under both qualities of water. The highest fruit weights were with Kala compost as clearly shown in Fig. 6 and bacteria 1 was the best. In general, treatments with B1, B2 and BS were adding values to the plants by improving productivity and reducing soil and water stresses.

3.6. Radish fresh weight

Radish is a short growing crop. Therefore it could be a fast indicator for short-term effects or stress. From Fig. 7, it can be seen that water salinity and type of compost were the main parameters that affected radish productivity. There was a big difference in Radish productivity between three composts in which Kala got the highest values followed Mukasab and finally Grower. Moreover, there was a clear effect of water salinity within each compost where salts suppressed radish growth.

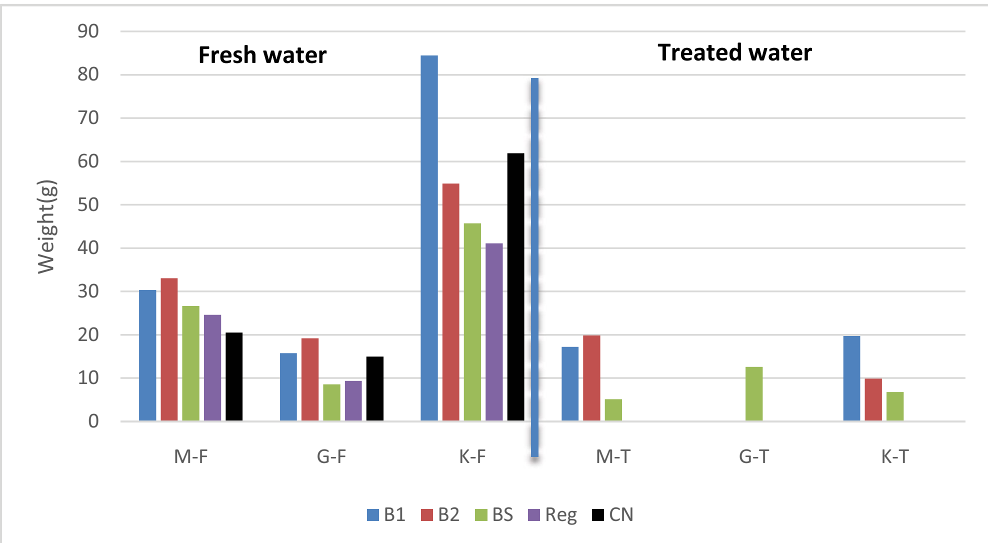

Fig. 6. Okra fruit weight as affected by different treatments.

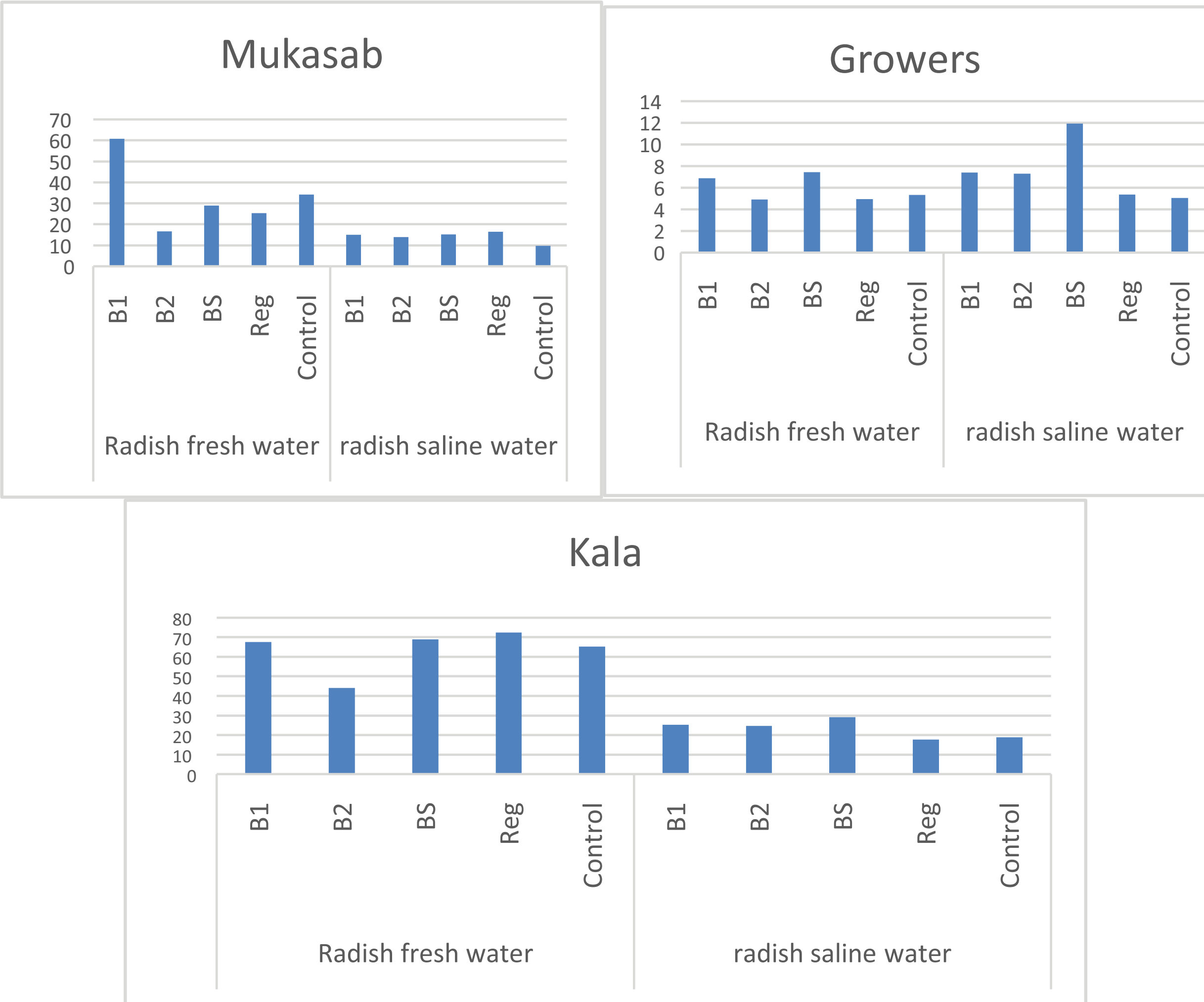

Fig. 7. Radish fresh weight as affected by different treatments.

For bacteria treatments, bacteria 1 was the best followed by bio-stimulants treatments. This finding is confirming what was found with Okra crop which mean bacteria 1 is the best for Oman saline conditions.

4. Conclusion

Plant growth can be affected by different parameters such as salts, organic matter and bacterial activities. From this study, it was found that soil salinity was the major parameter that affected plant growth and productivity. Application of different composts and bacteria had a role in supporting plant growth and its productivity.

For the composts application, it was found that Kala compost was the best compost in creating good environment for plant growth by providing more water and nutrients in root zones compared with Mukasab and Grower composts. In addition it was enhancing bacterial growth by providing almost all needed parameters for better bacterial growth.

Bacteria obtained from Oman environment (native bacteria) was the best bio-stimulants in which it gave the best data for plant growth even under saline conditions; whereas, other bio-stimulants vary and gave lower support for plant compared with native bacteria.

In general, regoplant was a good agent under normal conditions but not in saline soils. Stimpo and plant growth promoting rhizobacteria (bacteria 1 and 2) did well under saline condition. However, bio-stimulant was not a native product and could not work well under Oman harsh conditions. Therefore it cannot be recommended for future application. However further studies should be done to evaluate that. Plant growth promoting rhizobacteria (bacteria 1 and 2) were native bacteria adapted to saline and hot conditions. It is the best for salt-affected soils in Oman. However, more research should be done to elaborate its mechanisms and understand the best growth condition for them so better plant growth can be found under Oman salt-affected soils.

References

Abdelrahman, H., Alkhamisi, S., Ahmed, M., and Ali, H., 2011, Effects of Treated Wastewater Irrigation on Element Concentrations in Soil and Maize Plants. Commun Soil Sci Plant Anal, 42: 2046–2063.

Dutta S, and Podile AR., 2010, Plant growth promoting rhizobacteria (PGPR): the bugs to debug the root zone. Crit Rev Microbiol, 36: 232–244.

FAO, 2013, FAOSTAT statistical database (available at faostat.fao.org).

Glick BR., Cheng Z., Czarny J., and Duan J. 2007, Promotion of plant growth by ACC deaminase containing soil bacteria. Eur J Plant Pathol, 119: 329–339.

Glick BR., Karaturovı´c DM., and Newell PC., 1995, A novel procedure for rapid isolation of plant growth promoting pseudomonads. Can J Microbiol, 41: 533–536.

Luedeling, E., Nagieb, M., Wichern, F., Brandt, M., Deurer, M., and Buerkert, A., 2005, Drainage, salt leaching and physicochemical properties of irrigated man-made terrace soils in a mountain oasis of northern Oman. Geoderma, 125: 3–4.

Shahzad K., Bashir S., and Ramay MI., 2008, Impact of HR practices on the perceived performance of university teachers in Pakistan, Int Rev Bus Res, 4: 302–315.