8th International Conference on Water Resources and Arid Environments (ICWRAE 8): 51-57
22-24 January 2019*, Riyadh, Saudi Arabia*

Evaluating the Efficacy of Plant Growth Promoting Rhizobacteria and Enriched Compost to Enhance Yield and Water Use Efficiency of Crops for Sustainable Agriculture in Dry Lands

Ahmed Al-Busaidi, Baby Shaharoona and Mushtaque Ahmed

Department of Soils, Water and Agricultural Engineering, College of Agricultural & Marine Sciences, Sultan Qaboos University, P.O. Box: 34, Al-Khoud123, Muscat, Oman

Abstract: The aim of this project was to 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 wastewater. Plant showed the best growth under freshwater irrigation compared to saline water. Whereas, Kala compost gave the best growth and productivity even under saline irrigation. Regoplant gave better results for plant growth and productivity with freshwater irrigation compared to saline condition. Whereas, Stimpo and bacteria showed positive effect under saline condition and they supported plant growth much better than regoplant. 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.

Key words: Enriched compost・Plant growth promoting rhizobacteria・Water use efficiency・Bio-fertilizers・Organic fertilizer

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 [1]. PGPR enhance plant growth through several mechanisms, including solubilization of phosphorus and iron, phytohormone production, suppression of pathogens and by lowering stress-ethylene concentrations in the rhizosphere [2]. 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 plant growths promoting rhizobacteria (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 increase 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 like drought, soil salinity, heavy metals etc. on sustainable basis in many countries, for example, Canada, USA, India, Pakistan, China, Vietnam but it is very essential to evaluate this biotechnology under harsh climate, saline soils and arid environment like the Sultanate of Oman.

Another strategy to enhance water use efficiency could be to improve water holding capacity of soils. Compost could be a good candidate for this because it could not only increase water holding capacity of soil but could also improve other physicochemical and biological properties of soils. Composting offers the most sensible and economic way to handle organic waste materials which create environmental problems and at the same time

Corresponding Author: Ahmed Al-Busaidi, Department of Soils, Water and Agricultural Engineering, College of Agricultural & Marine Sciences, Sultan Qaboos University, P.O. Box: 34, Al-Khoud123, Muscat, Oman.
E-mail: ahmed99@squ.edu.om.

it produces a high quality and inexpensive soil amendment [3]. 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 into it.

In the Sultanate of 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 extremely serious problem in hampering the crop yields [4]. The problem of water scarcity is very serious in Oman and average rainfall is less than 125 inches per year [5] which is often below the required amount for 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 [6]. Application of enriched compost and PGPR for improving yield of crops and physical, chemical and biological properties of soils have been investigated in other countries [7] 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 and could be proved synergistic in improving growth, yield and water use efficiency of crop under the harsh climatic conditions of the Sultanate of Oman.Therefore, this project was planned to evaluate combined application of PGPR containing ACC-deaminase and enriched compost for increasing plant growth and water use efficiency of crops.

MATERIALS AND METHODS

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.

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 filed with peat-moss. The seeds were left to grow for 3 weeks and germination rates were recorded.

Fig. 1: Pots irrigated with fresh water

Seedlings were transplanted to greenhouse in pots filed 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 samplesfor all treatments were taken within 10 cm depth. Soil and plant samples were analyzed in soil and water lab for some physico-chemical analysis.

RESULTS AND DISCUSSIONS

Soil Moisture Content: Soil moisture content usually depends on soil/compost types and plant growth and consumption. Figure 2, is showing the average soil moisture content of Mukasab, Growers and Kala composts. Soil moisture content was approximately equally distributed in all Growers compost treatments compared to other two composts. Whereas, it was vary with different treatments of Kala and Mukasab. For bacteria treatments, it can be seen that control and regoplanthad more moisture content in all three composts. Whereas, bacteria1, bacteria2 and stimpohad lower values. Differences in moisture contents between different treatments could mean that plant was absorbing water and the evpo-transpiration losses depend on plant health and compost physical properties.

Soil Salinity (Ece): Soil salinity could increase or decrease with time depends on original salts or salts added or consumed or leached down the profile. In case of saline irrigation, it is expected that soil salinity increase 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 to other composts which could mean that Kala compost was continuously releasing nutrients to the soil solution and feeding the plants. The most interesting thing, that bacteria 1 & 2 were more active under Kala compost and helped in decreasing soil salinity under saline treatments. This finding needs extra investigation.

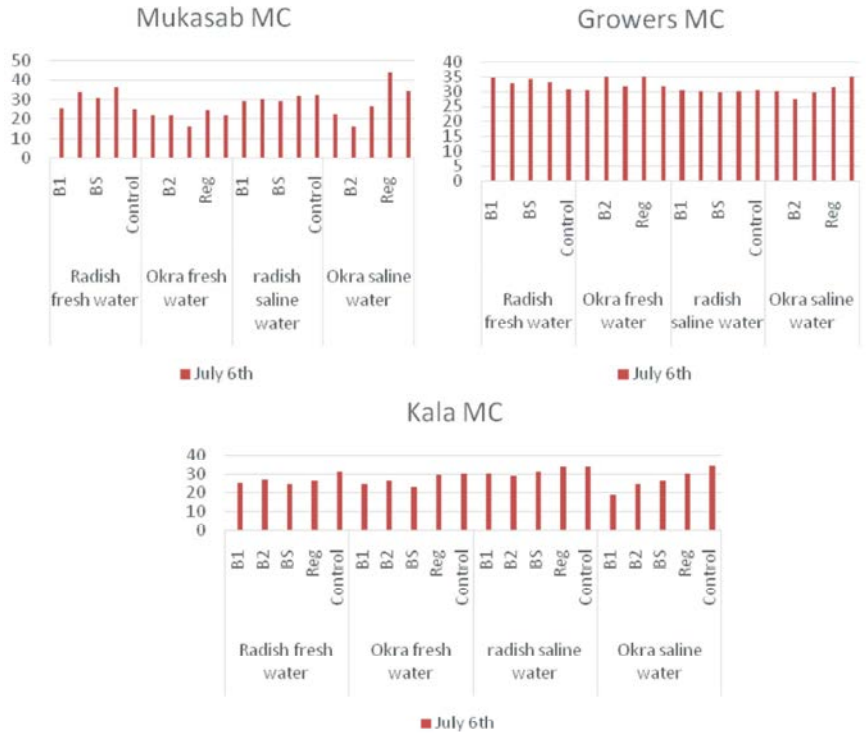

Fig. 2: Soil moisture content under different treatments

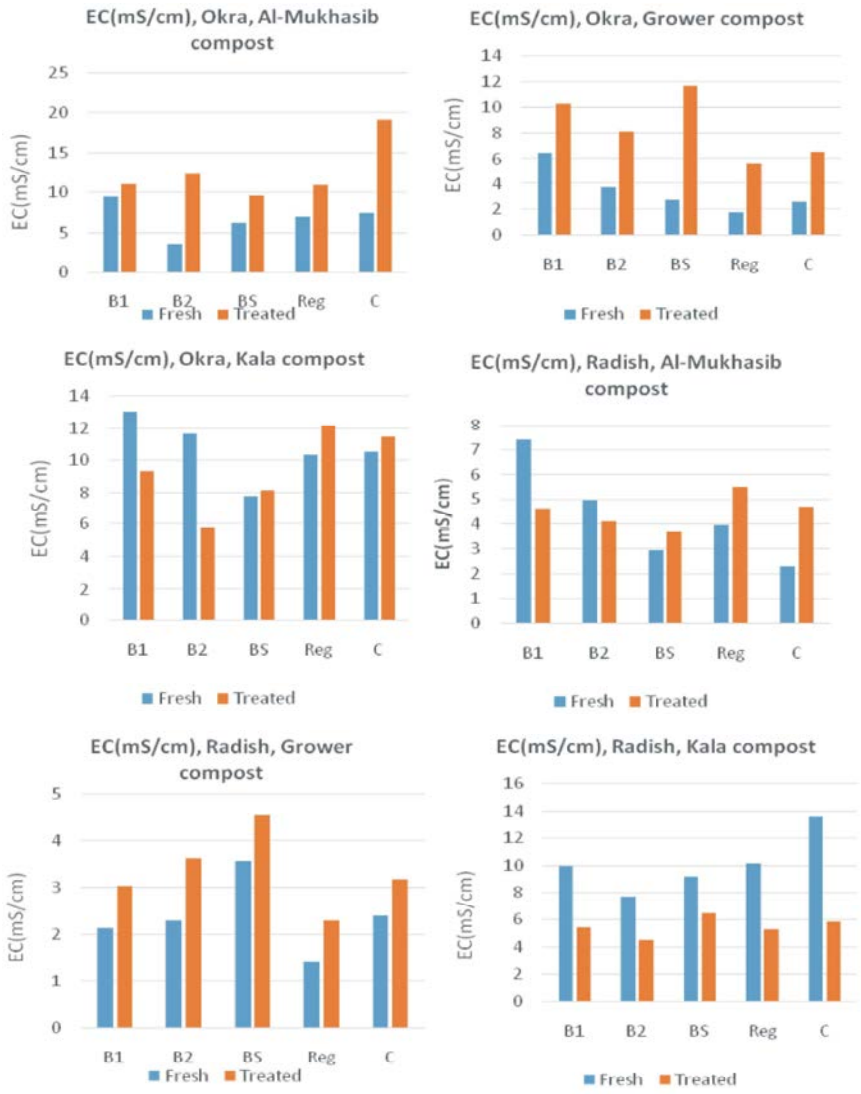

Fig. 3: Soil salinity as affected by different treatments

Chlorophyll Content: Chlorophyll is an indicator for green color which usually related to 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 to other composts. Moreover, saline treatments had negative effect on chlorophyll content which mean plant cannot absorb nitrogen when soil salinity is high.

Okra Height: As shown in Figure 5, it can be seen that Kala compost was the heights compared to other composts. Plant grown under freshwater irrigation got better results than saline conditions. However, Bacteria 2 was more active in supporting Okra growth compared to other treatments. Bacteria1, Bacteria2, 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 andcontrol have the lowest height in fresh and saline water irrigations.

Okra Fruit Weight: Plant productivity is the most important thing for the farmer and consumer. Okra fruitswere highly affected by fresh-saline irrigation followed by compost type and finally with bacteria treatments (Fig. 6). Salts presents in irrigation water suppressed okra productivity and gave zero or low fruits compared to freshwater irrigation.

Compost was the media supporting plant growth. Therefore, it looks like that Kala compost was the best compost gave the highest productivity of okra fruits

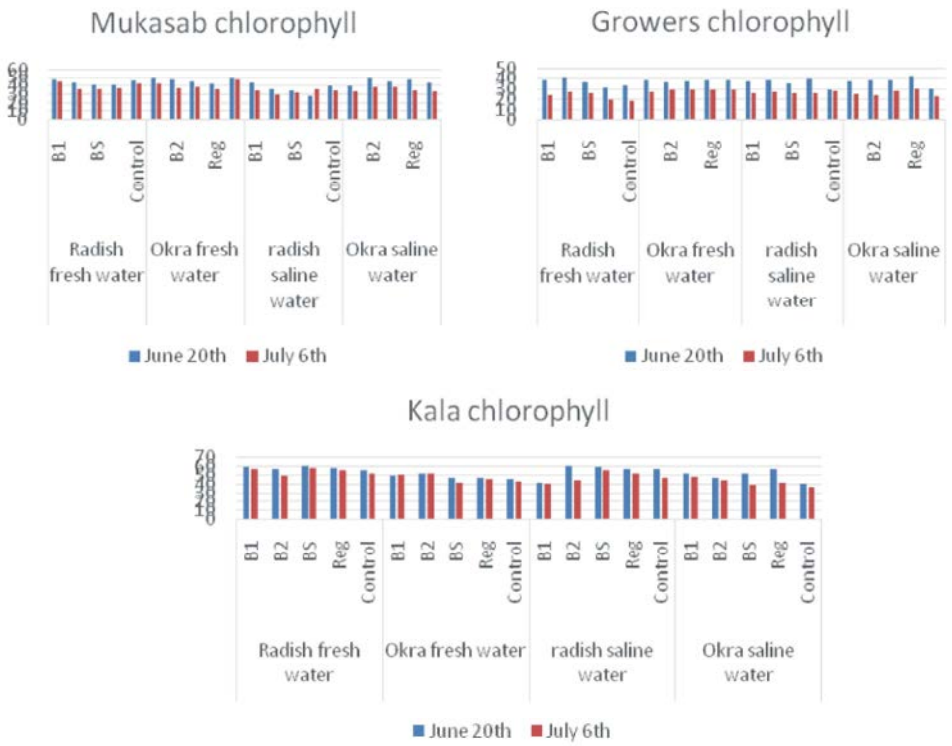

Fig. 4: Chlorophyll content as affected by different treatments

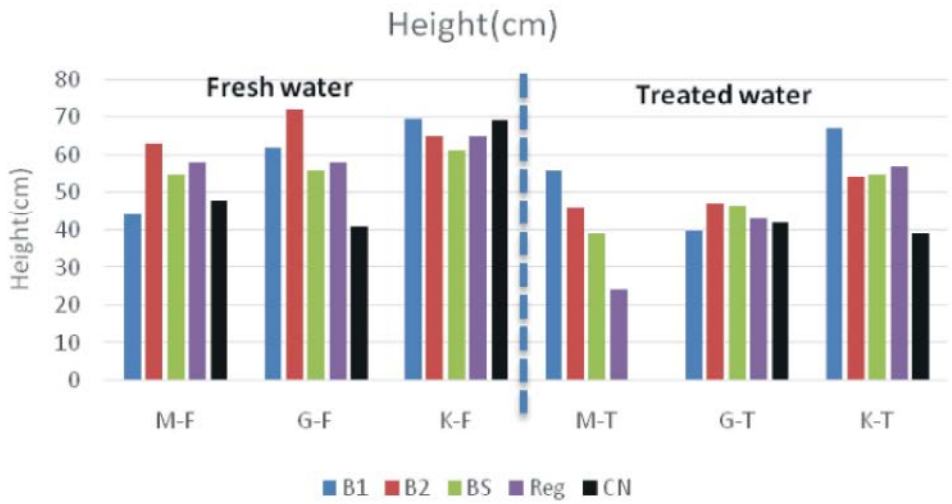

Fig. 5: Okra height as affected by different treatments

compared to other composts.The most interesting thing that Bacteria 1&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 to freshwater irrigation. Whereas, stimpo, bacteria1 and bacteria2 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 it productivity and reducing soil and water stresses.

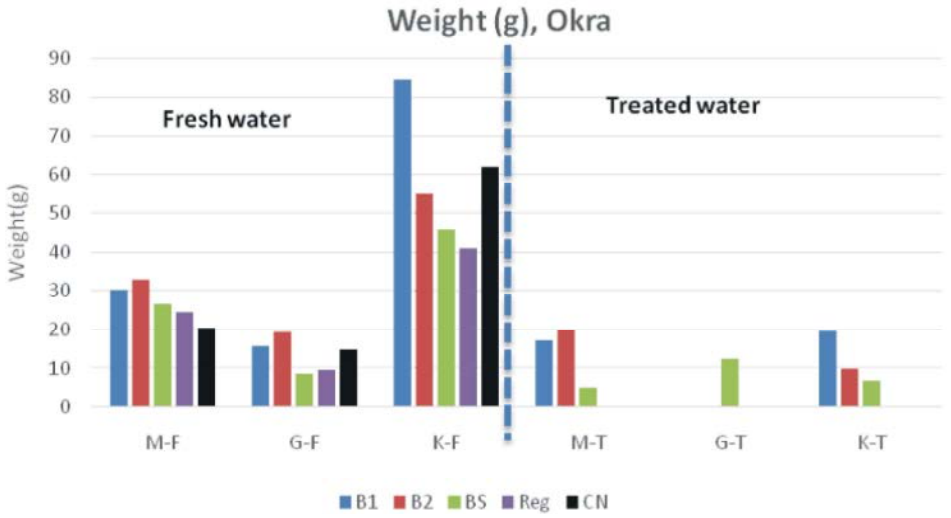

Fig. 6: Okra fruit weight as affected by different treatments

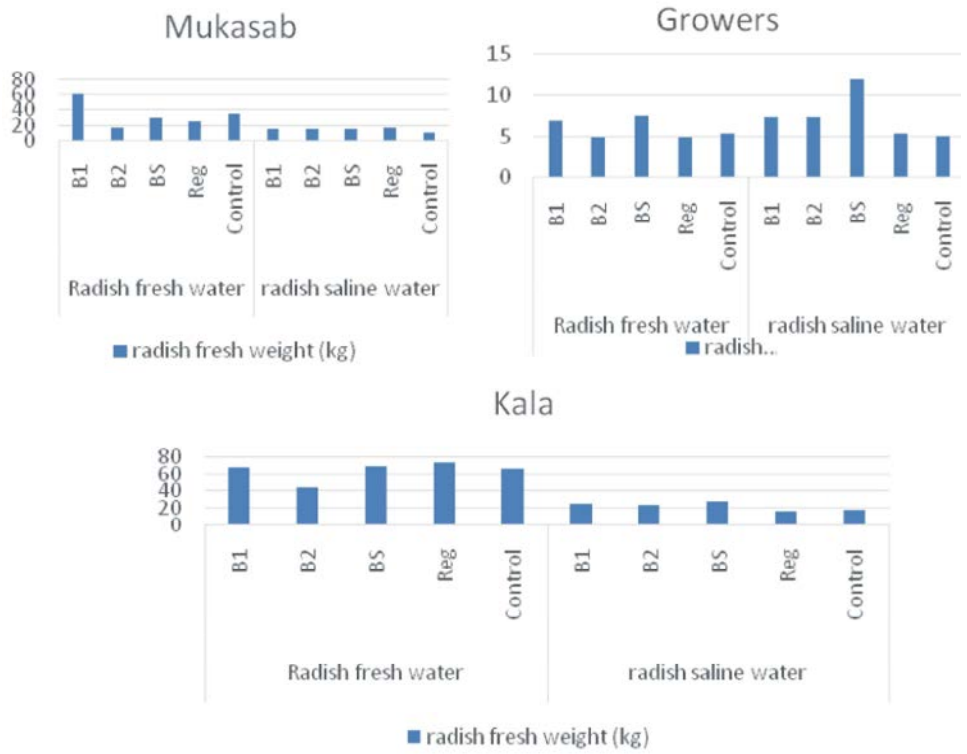

Fig. 7: Radish fruit weight as affected by different treatments

Radish Fresh Weight: Radish is short growing crops. 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 affected Radish productivity. There was a big difference in Radish productivity between three composts in which Kala got the highest values followed Mukassab and finally Grower. Moreover, there was a clear effect of water salinity within each compost where salts suppressed radish growth.

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 bactria 1 is the best for Oman saline conditions.

CONCLUSION

Plant growth can be affected by different parameters such as salts, organic matter and bacteria activities. From this study, it was found that soil salinity was the major parameter affected plant growth and productivity. Application of different composts and bacteria had a role in supporting plant growth and it 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 to Mukasab and Grower composts. In addition it was enhancing bacteria growth by providing almost all needed parameters for better bacteria growth.

Bacteria came 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 were vary and gave lower support for plant compared to native bacteria.

In general, regoplantwas a good agent under normal conditions but not in saline soils. Stimpo and plant growth promoting rhizobacteria (bacteria 1&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&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

1. Munees, A. and K. Mulugeta, 2014. Mechanisms and Applications of Plant Growth Promoting Rhizobacteria: Current perspective.Journal of King Saud University - Science, 26: 1-20.
2. Dutta, S. and A. Podile, 2010. Plant Growth Promoting Rhizobacteria (PGPR): The bugs to debug the root zone. Critical Reviews in Microbiology, 36(3): 232-244.
3. Suad Jaffar Abdul Khaliq, Ahmed Al-Busaidi, Mushtaque Ahmed, Malik Al-Wardy, Hesham Agrama and B.S. Choudri, 2017. The effect of municipal sewage sludge on the quality of soil and crops. International Journal of Recycling of Organic Waste in Agriculture, 6: 289-299.
4. Oman Salinity Strategy by Ministry Of Agriculture and Fisheries (MAF). 2012. Sultanate of Oman and International Center for Biosaline Agriculture (ICBA) Dubai, UAE. http://www.sciencedirect.com/ science/article/pii/S1018364713000293.
5. FAO, IFAD and WFP, 2013. The State of Food Insecurity in the World. 2013. The multiple dimensions of food security. Rome, FAO.
6. Andreas Buerkert, Maher Nagieb, Stefan Siebert, Iqrar Khan, Ahmed Al-Maskri, 2005. Nutrient cycling and field-based partial nutrient balances in two mountain oases of Oman. Field Crops Research, 94: 149-164.
7. Shahzad, S., A. Khalid, M. Arshad, J. Tahir and T. Mahmood, 2010. Improving nodulation, growth and yield of Cicer arietinum L. through bacterial ACC-deaminase induced changes in root architecture. European Journal of Soil Biology, 46(5): 342-347.