R-2383
[1-5]

REVIEW ARTICLE

Agricultural Reviews, Volume Issue : ()

The Biofertilizer Production for Salinity Stress in Plants: A Review

Shivangi Agnihotri, Ashwini A. Waoo

10.18805/ag.R-2383

ABSTRACT

Biotic and abiotic factors are environmental factors that play a vital role in plant growth and productivity. Abiotic stress like drought, salinity environmental pollution has done major damage to the productivity of crops. According to the study by the United Nations Environment Program approximately 20% of agricultural land and 50% of cropland in the world is under the salt-stress. Salinization of soil converts agricultural land to barren land. There is an estimate that every year 1-2% decrease in agricultural land. Salinity affects plant photosynthesis, protein synthesis, lipid metabolism. The growing population in the whole world demands a simple low-cost method to reduce the effect of salinity on lands. The tremendous use of chemical fertilizers has created environmental problems such as deterioration of soil quality and surface as well as groundwater quality. Reduced biodiversity and suppressed ecosystem function are side effects of using chemical fertilizers. Thus, to overcome this ecological crisis, microorganisms that allow more increased nutrient availability in soil, can provide sustainable solutions for current and future agricultural scenarios. Microorganisms that are native in saline soil are having inherent properties such as tolerance to saline conditions and beneficial interaction with the plants, by synthesis of compatible solutes, production of plant growth-promoting hormones. Such microorganisms help in the growth of plants by mechanisms direct or indirect. Some mechanisms are phosphate solubilization and ammonia production, these chemicals act as macronutrients. The bacterial chitinase, siderophores, HCN, production in the rhizosphere suppress hazardous effects resulting from biotic stress thus helping indirectly on plant growth. The isolation of novel microorganisms can be a useful tool to deal with the salinity stress and thus these organisms should be examined further to have a greater understanding of the stress management mechanism by PGPR and also their role in biodiversity. This competent microorganism can be converted to biofertilizers and the local farmers can be helped by educating about this efficient environment safe biofertilizers.

Key words: Agriculture, Biofertilizer, Environment, Eco-friendly, Ecosystem, HCN, PGPR, Salinity, Soil.

Today's world is facing a global water crisis due to a lack of water resources, environmental pollution and the salinization of soil and water has also increased. Agricultural sustainability has been badly affected by today's increasing human population which has reduced the land for cultivation. (Shahbaz and Ashraf, 2013). Environmental stresses like high winds, extreme temperatures, soil salinity, drought and flood have severely affected agricultural productivity and soil salinity has greatly reduced cultivated land area, crop productivity, quality. (Yamaguchi and Blumwald, 2005; Shahbaz and Ashraf, 2013). A soil is said to be saline when the electrical conductivity (EC) of the saturation extract (ECe) in the root zone exceeds 4 dS m^{-1} (approximately 40 mM NaCl) at 25°C and sodium that can be exchanged to 15%. The productivity of most crop plants is found to be greatly reduced at this ECe and many crops show reduction at much lower ECe values (Jamil *et al*., 2016). It is expected that 50% of the arable land would be salinized by the year 2050 (Jamil *et al*., 2016).

Various salinity in the soil causes degradation of chemical and physical properties of the soil, groundwater quality is diminished and plant growth. is impaired. Thus, agricultural and economic degradation can be observed and also agricultural sustainability is affected which degrade the living of farmers (Qadir *et al.* 2014). The accumulation of salt often occurs in soils due to crop irrigation and thus this issue is created by human beings (Qadir *et al.,* 2014). The water used for irrigation tends to have high concentrations of calcium, magnesium and sodium ions (Carillo *et al.,* 2011).

Department of Biotechnology, A.K.S University, Satna-485 001, Madhya Pradesh, India.

Corresponding Author: Shivangi Agnihotri, Department of Biotechnology, A.K.S University, Satna-485 001, Madhya Pradesh, India. Email: shivangiagnihotri12@gmail.com

How to cite this article: Agnihotri, S. and Waoo, A.A. (2022). The Biofertilizer Production for Salinity Stress in Plants: A Review. Agricultural Reviews. DOI: 10.18805/ag.R-2383.

Submitted: 23-09-2021 **Accepted:** 16-03-2022 **Online:** 24-05-2022

The use of this brackish water, without adequate drainage management, results in the accumulation of salts in the rooting zone of plants due to evapotranspiration (Qadir *et al.*) The Calcium and magnesium of water used tend to precipitate into carbonates and sodium is left as the most prevalent ion in the soil and this negatively impacts plant growth and soil structure. Soil salinization affects 20% of irrigated land worldwide, which equates to an area approximately the size of France (62 million ha) (Bazvand and Ghassemi *et al.,* 2020).

In India, the area under salt-affected soils is about 6.73 million ha (Dagar 2005). The first-ever case of salinity was reported in 1855 from village Moonak in Haryana. Western Haryana and Uttar Pradesh lack freshwater availability.

The rainfall in this area is very less and evapotranspiration is very high and their only source of water in such areas is highly saline groundwater (or seawater in coastal areas) (Dagar, 2005).

Salinity has increased due to continued recirculation and reuse of marginal quality of water without any disposal of saline water from an outside system. Kannauj, Auraiya, Raebareli, Unnao and Manipuri are suffered from salinity to a great degree (Priya 2015). The irrigation with alkaline water has made topsoil very low fertile.

The middle area of Uttar Pradesh in the Gangetic plain is extremely affected by salinity and alkalinity. The 5 districts that are extremely affected by salinity are; named Mainpuri, Kanpur, Unnao, Raebareli and Pratapgarh (Priya 2015).

Problems of salinization

The plants growing in salt-affected soils exhibit two distinct phases- osmotic (water) stress and salt stress- of growth inhibition. The water potential in surrounding soils is less than water potential in root cells of plants this osmotic stress inhibits water uptake. which results in water deficit causing many physiological and biochemical abnormalities that adversely affect plant growth (Hauser and Horie, 2010).

The plants maintain a higher cytosolic K+ /Na+ ratio via ion homeostasis but this ionic equilibrium is disturbed in salinity. The similar radius of Na+ and K makes transporting channels difficult to distinguish between these two ions. This creates an ionic imbalance as K+ transporting channels take up toxic Na+ ions which negatively affect plant growth. These elevated Na+ concentrations in the plant inhibit K+ absorption and thus affect important metabolic processes such as photosynthesis and protein synthesis by inhibiting the function of key enzymes involved in such processes. (Hauser and Horie, 2010). The salinity affects water and air movement, water holding capacity, plant root penetration, seedling emergence and tillage operations.

The efficient resource management and crop/livestock improvement for evolving better breeds can help to overcome salinity stress but these methods are costly. The rhizobacteria present in saline soil directly or indirectly influence plant growth and development. The enhanced microbial biomass and activities are important to ecosystem functioning and pollutant degradation and also improve plant health as well as in contaminated environments.

PGPR: Modes of action to improve plant growth

In developing countries, efficient and sustainable practices are needed to allow cost-efficient production of adequate nutrition for the growing populations. The costly chemical fertilizers degrade the soil productivity with and also plant nutrients are degraded and thus microscopic organisms come into the role as they allow more efficient nutrient use and increase nutrient availability are the sustainable solutions for present and future agricultural practices.

When microorganisms face a high osmolality environment the water from their cell is drawn out which reduces turgidity and causes dehydration of the cell but microbes have developed various adaptations to counteract the outflow of water. The cells try to accumulate high salt to maintain ionic concentration with the surrounding. The first response to osmotic imbalance and the resulting efflux of cellular water is an uptake of K+ and also cells start to accumulate compatible solutes (Whatmore *et al*. 1990). In one of the studies, the combined application of salt-tolerant microorganisms and organic amendment resulted in alleviating rice plants' salt stress and improving plant growth (Bhambure and Mahajan 2018). Paul and Nair (2008) reported that Pseudomonas fluorescence MSP-393, a PGPR strain, as a means of salt tolerance, de novo-synthesized, the osmolytes, alanine, glycine, glutamic acid, serine, threonine and aspartic acid in their cytosol. Several microorganisms like *Rhizobium*, *Bradyrhizobium*, *Azotobacter, Azospirillum, Pseudomonas, Bacillus*, *etc*. have been isolated from stressed environments like desert, acid soils, saline and alkaline areas (Upadhyay *et al.* 2010) and these are found to be involved in natural remediation of soil. Some PGPR assists directly in plant growth and development by providing plants with fixed nitrogen, phytohormones, iron that has been sequestered by bacterial siderophores, soluble phosphate and PGPR even provide resistance to plants for several diseases (Hyatt *et al* 2010).

PGPR: A recent boon to sustainable agriculture

The PGPR strain, *P. fluorescence* IISR-6, significantly enhanced the root biomass of black pepper vines. Rhizobacteria-mediated root proliferation has been well proven and it also works in stressed soils (Diby *et al*. 2014). The root growth was enhanced by increasing the root surface thus will absorb more water and nutrients (Diby *et al*. 2014; Paul and Sarma, 2006). The chlorophyll content in maize was increased by inoculating Azotobacter strains, thus promoting plant growth (Rojas-Tapias *et al*. 2012) and the same observation was made in maize and canola (Glick *et al*. 2014).

The PGPR improves plant growth by secreting certain hormones like indole acetic acid, gibberellins and other growth regulators and this will increase root length, root surface area and the number of root tips, leading to enhanced uptake of nutrients thereby improving plant health under stress conditions (Egamberdieva 2009).

The level of 1-aminocyclopropane-1-carboxylate (ACC) increases, in the plants growing in saline soil, which results in increasing ethylene concentration resulting in plant damage (Botella *et al.,* 2007). The chemicals like cobalt ions and amino etoxyvinyle, glycine is observed to inhibit the issue raised by salt stress. The usage of these chemicals to alleviate salt stress causes environmental hazards and also, they are costly. The Rhizobacteria are found to hydrolyze 1-aminocyclopropane-1-carboxylate (Saleem *et al.,* 2007), hydrolyzing to ammonia and a-ketobutyrate and thus lowering the levels of ethylene in stressed plants. The presence of enzyme 1-aminocyclopropane-1-carboxylate deaminase in bacteria, degrade it to supply nitrogen and energy (Mayak *et al*. 2004), facilitating plant growth under the salinity stress condition.

The nutritional requirements of plants should be fulfilled as it is a very important factor in combating stress. The nutritional deficiency is caused by different factors like salinity competition in nutrient uptake. This nutritional deficiency caused due to salinity in soil affects plant growth parameters. Nitrogen, is present in many forms in plants and 80% of the total mineral nutrients absorbed by plants is Nitrogen and inadequate nitrogen is often growth-limiting nutritional stress.

There is a study performed on coastal saline soil where three microbes *Pseudomonas multiresinivorans*, *Microbacterium esteraromaticum* and *Bacillus subtilis* individually and their consortium with farmyard manure (FYM) were compared against untreated control and FYM without the microbial inoculants. (Bhambure and Mahajan 2018). The seed dormancy is also alleviated by inoculating PGPR strains. A study in 2009 has proved this property of PGPR. The strains inoculated were *Pseudomonas aureantiaca* TSAU22*, Pseudomonas extremorientalis* TSAU6 and *Pseudomonas extremorientalis* TSAU20. (Egamberdieva 2009).

There is another study in the Kutch region of Gujarat for the Isolation and characterization of halotolerant bacteria and its effects on the wheat plant as PGPR. The bacteria isolated are showing a positive response for IAA significant role in phosphate solubilization, HCN production and nitrogen-fixing capacity (Marakana *et al.,* 2018).

B. halotolerant strain FAB3 was found to reduce salt stress in wheat by significantly decreasing various biochemical stress markers such as catalase (CAT), glutathione reductase (GR), superoxide dismutase SOD), proline and malondialdehyde (MDA), (Ahmad *et al* 2014).

In another study osmoadaptive salt-tolerant *Azotobacter chroococcum and Azotobacter vinelandii*, which were isolated from salt-affected soils were seen to facilitate plant growth in saline soil of wheat (Allam 2018).

The PGPR bacteria were observed to increase growth in Chickpea in saline soils of Gujarat, India, that is, Bhavnagar and Khambat. The strains identified were as *Pseudomonas putida* and *Pseudomonas pseudoalcaligens*. (Patel *et al* 2012).

The study of PGPR ability to enhance the growth of oats and barley in saline soil was studied in Canada. Plant growth-promoting bacteria (PGPB) strains that contain the enzyme 1-aminocyclopropane-1-carboxylate (ACC) deaminase can lower ethylene levels and improve plant growth. (Chang 2014).

The Endophytic bacteria was also found to help the plant growth under salt stress. These bacteria were isolated from date palm seedling roots (Mahmoud *et al.,* 2015).

The research was conducted to study the effect of tomato and pepper inoculation with salt-tolerant PGPR strains (*Pseudomonas fluorescence, Bacillus pumilus* and *Azospirillum lipoferum*) for tomato while, (*Bacillus megaterium, Paenibacillus alvie* and *Azospirillum lipoferum*) for pepper in combination with humic acid and organic manure (compost) the inoculation with PGPR increased the content of oxidative enzymes such as nitrate reductase, peroxidase and polyphenol oxidase and so improve plant defense against saline stress conditions (Akhal *et al.,* 2013).

The effect of biofilm-forming plant growth-promoting rhizobacteria on salinity tolerance in barley was studied. Thus, we can conclude the bacterial activity of biofilm formation helps improve salt stress tolerance of barley.

It was found that PGPR when formulated with sugarcane husk and maize straw \increase 20-30% plant growth, by enhancing chlorophyll, sugar, protein contents and antioxidants activities (Bano and Hassan 2016).

A field experiment was conducted during the Rabi season of 2010-2011 at Crop Research Centre of SVPUAT Meerut to study the impact of Bio-fertilizers with different NPK levels on growth and yield of wheat (*Triticum aestivum* L.) (Singh *et al.* 2016).

PGPR: A competent biofertilizer

N is the most limiting nutrient to plant growth as the atmospheric N is not readily available for plant uptake. Some bacteria are capable of N2 fixation from the atmospheric N pool and they are termed as The most exploited and known symbiotic N2-fixing bacteria are those belonging to the family Rhizobiaceae (Rhizobia) and include the following genera: *Rhizobium, Bradyrhizobium, Sinorhizobium, Azorhizobium, Mesorhizobium* and *Allorhizobium* (Vance, 2001; Graham and Vance, 2001).

Phosphorus is the second most limiting plant nutrient after N. The total P concentration in soil is usually high, but most of this soil Phosphorus is not readily available for plant uptake. Some bacteria were found to mobilize P from unavailable soil pools and increase P availability to plants. These bacteria are termed phosphorus-solubilizing bacteria (PSB) and belong to the genera Bacillus and Pseudomonas (Richardson, 2001).

Arbuscular Mycorrhizal Fungi can be used as biofertilizers. This inoculum can be applied as spores, fragments of roots colonized by AM fungi, or a combination of the two and incorporated soil mycelium. AM spores and hyphae can be isolated from the soil substrate and mixed with carrier substrate. Commonly used carriers include pumice or clay, sand, perlite, vermiculite, soil rite and soil or glass pellets (Redecker *et al*., 2000; Gaur and Adholeya, 2000).

The microorganisms identified can be used to increase the yield of crops in the salt-affected area. The microbial strains converted to biofertilizers will be an eco-friendly and healthy and safe alternative to the present chemical fertilizers. It will help to convert barren land to fertile and will help to lessen the use of chemical fertilizers and thus will further help to save the environment.

CONCLUSION

The saline soil has affected crop productivity to a large extent. Thus, it has become a global issue that is needed to be addressed. Salinity is one of the key factors which hinder the growth and productivity of crops, thus there is a need to develop simple and low-cost biological methods for managing salinity stress.

The costly chemical fertilizers degrade the soil productivity with and also plant nutrients are degraded and thus microscopic organisms come into the role as they allow more efficient nutrient use and increase nutrient availability are the sustainable solutions for present and future agricultural practices. This PGPR assist directly in plant growth and development by providing plants with fixed nitrogen, phytohormones, iron that has been sequestered by bacterial siderophores, soluble phosphate and PGPR even provide resistance to plants for several diseases.

Thus, microorganisms with properties such as tolerance to saline conditions, genetic diversity, compatible solutes synthesis, plant growth-promoting hormones production and interact differently with crop plants. These PGP can be inoculated with the desired crop and seedlings. These microorganisms improve plant growth either by direct or indirect mechanisms. These microbes assist plant growth by solubilizing phosphate and produce ammonia, act as macronutrients, producing siderophores, HCN and also protecting plants from hazardous effects of biotic stresses. The isolation of novel microorganisms may provide an effective way to deal with the problem of salinity and such organisms should be studied to understand the mechanism of action and also for biodiversity. This competent microorganism can be converted to biofertilizers and the local farmers can be helped by educating about this efficient environment safe biofertilizers.

Conflict of interest: None.

REFERENCES

Allam, N.G., Ali, W.Y., Kinany, R. and Refai, E.E. (2018). Potential use of beneficial salt tolerant bacteria for improving wheat productivity grown in salinized soil. Journal of Microbiology Research. 8(2): 43-53.

Ahmad, M. and Kibret, M. (2014). Mechanisms and applications of plant growth-promoting rhizobacteria: Current perspective. Journal of King Saud University Science. (26): 1-20.

Bazvand, F., Ghassemi, F. (2020). Artifacts in macular optical coherence tomography. J. Curr. Opthalmol. 32: 123-31.

Bhambure, A.B., Kerkar, S. and Mahajan, G.R. (2018). Salt Tolerant Bacterial Inoculants as Promoters of Rice Growth and Microbial Activity in Coastal Saline Soil. Proceeding of the National Academy of Sciences, India. Section B: Biological Sciences. 88(4). DOI:10.1007/s40011-017-0901-9.

Botella, Miguel, Rosado, Abel, Bressan, Ray, Hasegawa, Paul. (2007). Plant Adaptive Responses to Salinity Stress. Plant Abiotic Stress. 10.1002/9780470988503.ch3.

Carillo, P., Annunziata, M.G., Pontecorvo, G., Fuggi and Woodrow, P. (2011). Salinity Stress and Salt Tolerance. In: Abiotic Stress in Plants-mechanisms and Adaptations. [Shanker A (ed)], InTech Europe, Rijeka, Croatia, pp (21-38).

Chang, P., Gerhardt, K.E. *et al.*, (2014). Plant growth-promoting bacteria facilitate the growth of barley and oats in salt impacted soil: Implications for phytoremediation saline soils. International Journal of Phytoremediation. 16(7-12): 1133-47.

Dagar, J.C. India Salinity Research in India: An Overview. Central Soil Salinity Research Institute, Karnal.

Diby, P., Lade, Harshad. (2014). Plant growth promoting rhizobacteria to improve crop growth in saline soils: A review. Agronomy for Sustainable Development. DOI:10.1007/s13593-014-0233-6.

Egamberdieva, D. (2009). Alleviation of salt stress by plant growth regulators and IAA producing bacteria in wheat. Acta Physiologiae Plantarum. 31: 861-864.

El-Akhal, M.R., Rincón, A., Coba de la Peña T., Lucas, M.M., El-Mourabit, N., Barrijal, S., Pueyo, J.J. (2013). Effects of salt stress and rhizobial inoculation on growth and nitrogen fixation of three peanut cultivars. Plant Biol. 15(2): 415-21.

Gaur A. and Adholeya, A. (2000). Effects of particle size of soil-less substrates upon AM fungus inoculum production. Mycorrhiza. 10: 43-48.

Glick, B.R. (2014). Bacteria with ACC deaminase can promote plant growth and help to feed the world. Microbiological Research. 169(1): 30-39.

Ghassemi, F., Jakeman, A.J. and Nix, H.A. (1995). Salinization of land and water resources. CAB International, Canberra 21. United Nations University Institute for Water, Environment and Health. (UNU-INWEH).

Hauser, F. and Horie, T. (2010). A conserved primary salt tolerance mechanism mediated by HKT transporters: A mechanism for sodium exclusion and maintenance of high K (+)/Na (+) ratio in leaves during salinity stress. Plant Cell Environ. 33(4): 552-565.

Hingole, S.S. and Pathak, A.P. (2016), Saline soil microbiome: A rich source of halotolerant-PGPR. J.Crop Sci Biotech 13(3): (231-239).

Hyatt, D., Chen, G.L., Locascio, P.F., Land, M.L., Larimer, F.W., Hauser, L.J. (2010). Prodigal: Prokaryotic gene recognition and translation initiation site identification. BMC Bioinformatics. 11: 119. https://doi.org/10.1186/1471-2105-11-119.

Hassan, T. and Bano, A. (2016). Biofertilizer: A novel formulation for improving wheat growth, physiology and yield. Pak. J. Bot. 48(6): (2233-2241).

Jamil, M., Ashraf, M., Rehman, S.U. (2016). Salinity induced changes in cell membrane stability, protein and RNA contents. African Journal of Biotechnology. 11(24): 6476-6483.

Mayak, S., Tirosh, T. and Glick, B.R. (2004). Plant growth-promoting bacteria confer resistance in tomato plants to salt stress. Plant Physiology and Biochemistry. 42(6): 565-572.

Marakana, T. and Sharma, M. (2018). Isolation and characterization of halotolerant bacteria and its effects on the wheat plant as PGPR. Pharma Innovation. 7(7):102-110.

Mahmoud, W., Yaish., Irin Antony. and Bernard, R. Glick. (2015). Isolation and characterization of endophytic plant growth-promoting bacteria from a date palm tree (Phoenix dactylifera L.) and their potential role in salinity tolerance. Springer vol. 107: 1519-1532.

Patel, D., Jha, C.K., Saraf, M., Tank, N. and Saraf, M. (2012). Growth enhancement of chickpea in saline soils using plant growth-promoting rhizobacteria. J. Plant Growth Regulator. 31: 53-62.

Priya, R. (2015). Salinity status and its association with deforestation in Uttar Pradesh. Journal of the Indian National Cartographic Association. 35: 322-327.

Paul, D., Nair, S. (2008). Stress adaptations in a plant growth promoting rhizobacterium (PGPR) with increasing salinity in the coastal agricultural soils. Journal of Basic Microbiology. 48(5): 378-84.

Paul, D. and Sarma, Y.R. (2006). Antagonistic effects of metabolites of *Pseudomonas fluorescens* strains on the different growth phases of *Phytophthora capsici*, footrot pathogen of black pepper (*Piper nigrum* L.*).* Archives of Phytopathology and Plant Protection. 39(0): (1-6).

Qadir, M., Quillérou, E., Nangia, V., Murtaza, G., Singh, M. and Thomas, R.J. (2014). Economics of salt-induced land degradation and restoration. Nat. Resour. Forum. 38: 282-295.

Qadir, M. and Oster, J.D. (2002). Vegetative bioremediation of calcareous sodic soils: History, mechanisms and evaluation. Irrig Sci. 21: (91-101).

Qadir, M., Quillérou, E., Nangia, V., Murtaza, G., Singh, M. and Thomas, R.J. (2014). Economics of salt-induced land degradation and restoration. Nat Resour Forum. 38: 282-295.

Singh, M.P., Kumar, P., Kumar, A., Kumar, R., Diwedi, A., Gangwar, S., Kuma, V. and Kumar, N. (2016). Effect of NPK with biofertilizers on growth, yield and Nutrient uptake of wheat (*Triticum aestivum* L.) in Western Uttar Pradesh condition. Society for Recent Development in Agriculture Prog. Agric. 16 (1): 83-87.

Shahbaz, M., Ashraf, M. (2013). Improving salinity tolerance in cereals. Critical Reviews in Plant Sciences. DOI:10.1080/ 07352689.2013.758544.

Richardson, E.C., Kaiser, A.G., Piltz, J.W. (2001). The nutritive value of frosted wheat for sheep. Aust. J. Exp. Agric. 41 (2): 205-210.

Redecker, D. (2000). Specific PCR primers to identify arbuscular mycorrhizal fungi within colonized roots. Springer Mycorrhiza. 10: 73-80.

Saleem, M., Arshad, M., Bhatti, A.S. and Hussain, S. (2007). Perspective of plant growth-promoting rhizobacteria (PGPR) containing ACC deaminase in stress agriculture. J. Ind Microbiol Biotechnology. 34: 635-648.

Schachtman, Daniel, Reid, R. Ayling, S. (1995). Phosphorus uptake by plants: From soil to cell. Plant Physiology. 116(2): 447-453.

Tapias, D.R., Bonilla, R., Galván, A.M., Pardo-Díaz S., Obando, M., Rivera D. and Bonilla, R. (2012). Effect of inoculation with plant growth-promoting bacteria (PGPB) on amelioration of saline stress in maize (*Zea mays*). Applied Soil Ecology. 61: 264-272.

Vance, C.P. (2001). Symbiotic Nitrogen Fixation and Phosphorus Acquistion. Plant Nutrition in a World of Declining Renewable Resources. Update on the State of Nitrogen and Phosphorus Nutrition.

Thomas, L., Singh I. (2019). Microbial Biofertilizers: Types and Applications. Biofertilizers for Sustainable and Environment. (pp 1-19).

Upadhyay, Lama A., Tawata, J., Shinkichi. (2010). Utilization of pineapple waste: A review. Journal of Food Science and Technology. Nepal.

Whatmore, A., Chudek, J.A. and Reed, R. (1990). The effects of osmotic up shock on the intracellular solute pools of *Bacillus subtilis*. Journal of General Microbiology. 136. (2527-2535).

Yamaguchi, T, Blumwald, E. (2005). Developing salt-tolerant crop plants: Challenges and opportunities. Trends Plant Sci. 10(12): 615-20.