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PLANT GROWTH PROMOTING RHIZOBACTERIA: A RAY FOR SUSTAINABLE CROP PRODUCTION UNDER DROUGHT PRONE DRYLAND CONDITIONS

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ABSTRACT

Globally, drylands, covering 42.3% of croplands, are crucial for food security. Approximately 72% of these drylands are in developing nations such as India and Africa, which face severe weather challenges, including prolonged droughts and frequent famines. Climate change exacerbates drought stress, leading to increased crop failures and a 9-10% reduction in global crop production, threatening food security. To address this, eco-friendly practices like PGPR (Plant Growth-Promoting Rhizobacteria), VAM (Vesicular-Arbuscular Mycorrhiza), and other bio-stimulants are essential. PGPR, in particular, offers a cost-effective and sustainable method for enhancing plant growth and crop productivity in dryland agriculture.

KEYWORDS: Drought stress alleviation, Eco-friendly, PGPR, Sustainable agriculture

INTRODUCTION

The escalating global population, water scarcity, poor moisture retention capacity, low soil fertility, low SOC, and climate change threaten dryland farming through increased vulnerability to droughts and other extreme weather events. Among a group of abiotic stresses (moisture stress, salinity, heat stress, heavy metal stress, etc.) drought/moisture deficit stress is the single most stressful environmental factor threatening successful crop production under dry land tracts of the world. It has been projected that drought stress may cause serious plant growth problems on more than 50% of the earth's arable lands by 2050. Further, the increased drought frequency resulted in 9–10 % reduced crop production which threatens global food security.

Drought has multi-dimensional effects that alter various physiological and morphological characteristics in plants (Figure 1). The shortfall of soil moisture produced by drought, decreases soil water potential, causing cell dehydration, reduced cell division, expansion, production of reactive oxygen species (ROS), and reducing plant water use efficiency (WUE) and crop yields. Thus, it is necessary to find solutions that enhance plant tolerance to drought stress and allow crop productivity that satisfies the increasing food demands.

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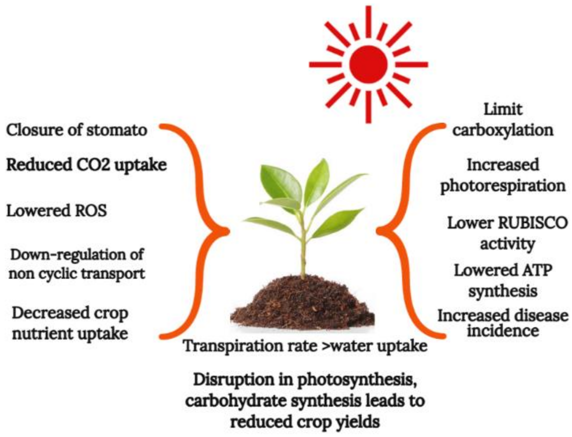

Fig.1 Effect of drought on plant

The technical, economic, and ecological limitations of conventional breeding strategies have sparked interest in the exploration of alternative low-cost, natural, and ecologically friendly initiatives, viz., plant growth-promoting rhizobacteria (PGPR). PGPR are free-living soil bacteria that colonize root systems and support plant growth by modifying the defence response of plants under moisture stress.

PLANT-ASSOCIATED BENEFICIAL BACTERIAL BIOMES

The microbes are ubiquitous and survive from a favourable system to extremely unfavourable/harsh conditions. A gram of rhizospheric soil contains nearly 9×10^7 bacteria, 4×10^6 actinomycetes, 2×10^5 fungi, 3×10^4 algae, 5×10^3 protozoa, and 3×10^1 nematodes (Glick 2014). Bacteria are the most common rhizospheric microbiomes and control various physiological and biochemical functions in plants. The beneficial bacterial communities associated with plant ecosystems have been classified into three types (a) phyllosphere, (b) endophytic, and (c) rhizospheric.

Table 1. Classification of beneficial bacterial communities

Phyllospheric Bacteria			**Endophytic Bacteria**
Stem (caulosphere)	Leaves (phylloplane)	Fruits (carposphere)	Interact with internal tissues of root, stem flower, fruits or seeds
Genera	*Achromobacter, Acinetobacter, Agrobacterium, Arthrobacter, Bacillus, Delftia, Methylobacterium, Pantoea, Pseudomonas, and Xanthomonas*		*Azoarcus, Achromobacter, Burkholderia, Nocardioides, Herbaspirillum, Pantoea, Klebsiella, Gluconoacetobacter, Enterobacter,*

The bioaugmentation of plants with PGPR is considered one of the critical methods to overcome the adverse effects of drought. Generally, plants release root exudates into the rhizosphere to attract soil microbiome. A large number of rhizospheric microbes from various genera, including *Methylobacterium*, *Pseudomonas*, *Serratia*, *Rhizobium*, *Paenibacillus*, *Erwinia*, *Enterobacter*, *Flavobacterium*, *Bacillus*, *Azospirillum*, *Burkholderia*, *Arthrobacter*, *Alcaligenes*, and *Acinetobacter*, have been identified for plant growth promotion (Tsadik et al., 2020; Yadav, 2021). These plant-beneficial microbiomes will support plant growth either directly or indirectly by promoting a favourable environment in the rhizosphere (Figure 2). Thus, plant-microbial interaction is thought to be imperative for improving soil fertility, plant growth, and production for agricultural sustainability.

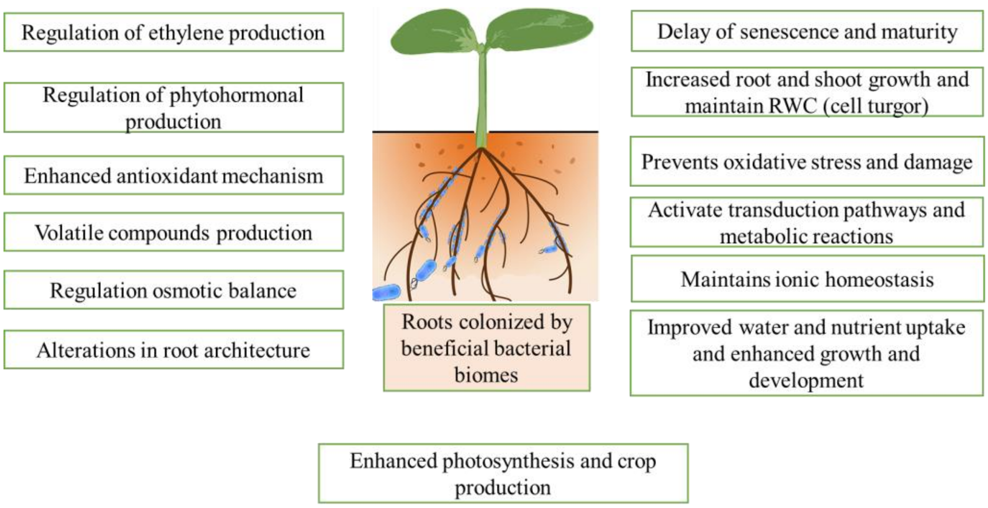

Fig.2. Mechanisms of drought stress tolerance as mediated by beneficial rhizobacterial biomes

MECHANISMS OF DROUGHT STRESS ALLEVIATION BY RHIZOBACTERIA

Adaptation by rhizospheric bacteria towards moisture-stress environments helps in improving health and drought stress tolerance in crop plants. Plant-associated bacterial microbes can function as drought stress tolerance by altering plant morpho-physiological processes, plant hormonal balance, and plant biological processes as shown in figure 2.

Several scientific investigations have well documented that drought can be counterbalanced by inoculating the plant with plant growth-promoting rhizobacteria (Table 2).

Table 2. Scientific research evidence

PGPR	**Host plant**	**Effect**	**Reference**
Bacillus velezensis	Maize	Enhanced drought tolerance through ACC deaminase and EPS-producing activity	Nadeem et al. (2021)
B. amyloliquefaciens	Pearl millet	Reduced the ethylene production through ACC deaminase activity and thereby increased the plant survival rate and growth under moisture stress	Murali et al. (2021)
Ochrobactrum sp. (EB-165) and *Microbacterium sp. (EB-65)*	Sorghum	Increased plant relative water content by regulating stomal closure.	Govindasamy et al. (2020)
Pseudomonas fluorescens (S3X)	Maize	Increased root and shoot growth by increased production of IAA which enhanced drought tolerance.	Notununu et al. (2022)
Bacillus pumilis (DH-11) and *Bacillus firms* (40)	Potato	Increased accumulation of enzymatic antioxidants *viz.*, ascorbate peroxidase helps to reduce ROS damage under moisture stress.	Ullah et al. (2019)
Streptomyces sp. (IT25 and C-2012)	Tomato	An increase in total sugar (sucrose and fructose) enhanced osmotic adjustment to overcome moisture stress.	Abbasi et al. (2020)
Alcaligenes faecalis (AF3)	Maize	10% increased root length under moisture stress conditions.	Pereira et al. (2020)
Streptomyces strain IT 25 or C-2012	Tomato	Increased the fruit weight by 25-35 % by regulating shoot growth.	Abbasi et al. (2020)

CONCLUSION

Taken together the co-inoculation of plants with beneficial rhizobacteria is a potential way forward to alleviate drought stress naturally. As rhizobacteria adopt multiple approaches such as regulation of ethylene production, phytohormonal balance, osmotic adjustment, enhanced morpho-physiological factors etc help to ameliorate drought stress effectively and will also solve the food security problem. Moreover, rhizobacteria can provide a better and more cost-effective alternative for drought tolerance in crop plants.

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