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Plant Growth Promoting Rhizobacteria for Sustainable Production of Sugarcane and Rice

P. P. Khandagale [a++*], S. S. Kansara [a#], Jay Padsala [a++] and P. R. Patel [b†]

[a] Department of Plant Pathology, N. M. College of Agriculture, NAU, Navsari, India
[b] Department of Plant Protection, ASPEE College of Horticulture, NAU, Navsari, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Sugarcane (*Sacchraum officinarum* L.) and rice (*Oryza sativa* L.) are important cash and staple crop in the world respectively. In today's population explosion the lots of pressure on cropping land to mitigate the feed need of consumers with judicious use of chemical fertilizers without considering the health of soil and its sustainability. The rhizobacteria live region around roots (2-80 mm) of crop with divers, dynamic and complex microflora having capacity with direct and indirect beneficial effects on crop health by availability of different nutrient, siderophores, rhizo deposits, auxins and role with bioremediation. There are different types of bacteria is isolated from rhizosphere of sugarcane and rice having Bacillus, Rhizobium, comamonas, cyanaobacteria, Nodosilinea, Levinella and Pseudomonas genera with most efficient nitrogen producer, solubilizers of inorganic

[++] *Ph.D. Research Scholar;*
[#] *Assistant Professor;*
[†] *Associate Professor and Head;*
**Corresponding author: E-mail: p2khandagale@gmail.com;*

phosphate, potash and other macro and micronutrient. In rice microbiome as Levinella, Psudomonas Anaeromyxobacter, Arenimonas, Arthrobacter, Bacillus, Bellilinea Proteobacteria, Chloroflexi, Actinobacteria, Acidobacteria and cyanobacteria with strains of Nitrosomonas and Nitrobacter are further divided in vegetative and reproductive growth stage of rice crop. The article give brief idea about the large arena of them.

Keywords: Rhizobacteria; sugarcane; rice; sustainable production.

1. INTRODUCTION

Rhizosphere give the term by Hiltner (1904) as narrow soil region near root zone having different secretion and associated soil microorganism as root microbiome communication .They feed on sloughed off plant cells called rhizodeposition and vice versa root released protein called root exudates. This symbiosis influence plant growth providing space to produce some *allochemicals* to control neighbors. Having the *rhizospheric* effect enhance the redox potential, ionic balance, osmatic pressure with formation of soil aggregates and prevent the crop roots from desiccation in abiotic stress . Sugarcane (*Sacchraum officinarum* L.) and rice (*Oryza sativa* L.) are important cash and staple crop in the world respectively. Sugarcane gives us tea sugar, brown sugar, alcohol, spirit, bagasse, press mud cakes, molasses with renewable energy sources for community transport with methanol blending in petrol. Every sugar factory enhances the socio economic status of the producing farmer in their locality with direct indirect employments opportunity generated by them. Now a days bio electricity generated by using the sugarcane wastes. For its sustainable production with soil management required use of different biofertilizers with bacterial inoculations consortia. “In sugarcane various kinds of bacterial endophytes such as *Glucano acetobacter, Psudomonas, Azospirillum, Burkholderia, Raoultella, Ralstonia Mesorhizobium, Ochrobactrum, Sphingomonas, Novosphingobium, Pantoea* and *Bacillus* were found and they are perform various role like promote growth, biological nitrogen fixation, production of phyto stimulants like - IAA, GA, Ethylene and cytokinin, phosphate mineralization, potash solubilization, iron carrier formation, saponin and glycosidase production, production of 1-amino-cyclopropane-1-carboxylic acid deaminase as the antibiotics and development of ISR and SAR throughout its life period sustain the crop in biotic and abiotic stress environmental condition” .

“Rice the main staple food for about half of the world’s population, microorganisms exert positive influences on plant growth, yield potential - production, and health of rice. A variety of microbial species as actinomycetes and Gram-positive bacteria reside in the rhizosphere and the phyllosphere of plants and also have multiple roles as symbiotic endophytes. They alter the morphology of host plants, enhance their growth, health, and yield, and reduce their vulnerability to biotic and abiotic stresses. Bacterial communities are usually dominated by the *Anaeromyxobacter*, *Arenimonas*, *Arthrobacter*, *B acillus*, *Bellilinea Proteobacteria, Chloroflexi, Actinobacteria, and Acidobacteria, and cyanobacteria* which help in uptake of nitrogen and other growth promoting role in rice” [1].

2. SUGARCANE

2.1 *Azosprillum* and sugarcane

“Azospirillum is facultative endophytic, polymorphic, obligate can grow under low PO_2 soil condition . Are micro-aerophilic, gram-negative rods and often associated with interior and surfaces roots of cereals and grasses” [2]. “It is very well known for its nitrogen-fixing ability and can fix at least 10 mg N g1 of carbohydrate and higher production of indole acetic acid. Three species of this genus namely, *Azospirillum amazonense, A. brasilense*, and *A. lipoferum* have been isolated from sugarcane roots .Microbial consortia containing the species, *Azospirillum brasilense*, and *Bacillus subtilis* have shown great potential to cycle nutrients from crop residues and restore soil fertility. The seed treatment enhances the root volume at 86% and 100% increase than untreated ones.The inoculation with *Azosprillum brasilense* + *B. subtilis* associated with 45 kg ha^{-1} of P_2O_5 also increases sugar yield, resulting in a savings of 75% of the recommended P_2O_5 rate” [2].

2.2 *Enterobacteriaceae* Family Bacteria and Sugarcane

"The members of *Enterobacteriaceae* a large family of bacteria are rod-shaped, gram-negative, facultative anaerobes, motile or non-motile and most of them reduce nitrate to nitrite the dominating nitrogen-fixing bacteria isolated from sugarcane rice, wheat, sorghum, grasses, and dicotyledonous plants roots. The three genera belong to the Enterobacteriaceae as *Enterobacter cloacae* and *Klebsiella pneumoniae* and *Pantoea were* isolated from all parts of the sugarcane. Three species of this genus, *Pantoea ananatis, P. herbicola*, and *P. stewartii* have been isolated from roots, stem, and leaves of Brazilian sugarcane plants" [3] capable of nitrogen fixation.

2.3 Gluconacetobacter and sugarcane

"This genus belongs to the family *Acetobacteraceae* to produce acetic acid and nitrogen fixing and usually acid-tolerant and grow well below pH 5.0. They are gram-negative, aerobic, and rod-shaped bacteria. This organism has lack of nitrate reductase and only partial inhibition of nitrogenase activity by ammonium ions, enables it to fix nitrogen in the presence of soil nitrogenease is also a phytohormone producer. In sugarcane endophytic *Gluconacetobacter diazotrophicus* and its abilities to fix nitrogen and disease resistance studied"[4]. *G. dizotrophicus* inhibit *Xanthomonas albilineans (*leaf scald disease) [5] .At Central Sugarcane Research Station Padegaon, Dist .Satara (Maharashtra)studied the effect of *Glucanoacetobacter diazotrophicus* @ 10kg/ha (Set treatment) with other six treatment was carried from year 2014-2018 on preseason sugarcane on CoM 0265 variety with (75% P_2O_5, 100% K_2O + Recommended FYM (Suru- 20 t/ha, Preseason- 25 t/ha) and PSB application common to all treatments except T1 RDF, found that treatment with 50% N+ *Glucanoacetobacter* set treatment recorded highest tillering count at 120 DAP (167.05 thousands/ha) and no. of mill liable cane .For cane yield same treatment recorded highest cane yield (57.54 t/ha).,CCS%,CCS yield and sucrose %.[6] .Same treand found in suru(Dec-Jan. Plantation) sugarcane as treatments with (50% N+ *Glucanoacetobacte*r set treatment)recorded highest (162.00) tillering count at 120 DAP,NMC (53.31 thousand /ha) and cane yield. (52.17 t/ha. As regards CCS yield highest (7.98 t/ha), highest purity (97.90),sucrose %(21.20) found with same trends.The endophytic bacterial count found in same tretment as in root (7.10x104, 11.20x104 and7.58x104), juice (16.53x104,29.63x104 and 18.96x104) and leaves (14.48x104, 30.01x104 and 16.35x104) at 4 months, 8 months and harvest stage of the crop, respectively.Having beneficial impact on sugar revcovery , NMC and other yield attributing parameters. Some scientist found that a new role for *G. diazotrophicus* induce systemic resistance against *Xanthomonas albilineans*-cause leaf scald disease of sugarcane [7].

2.4 *Pseudomonas spp*. and Sugarcane

"The genus belongs to the family *Pseudomonadaceae* with gram negative, rod shaped bacteria secreted soluble greenish fluorescent pigment called *fluorescein* in low availability of iron are facultative anaerobic require NO_3 without O_2 and some with O_2 with multiple polar flagella as they are *chemolithotrophs.* Haning large number of species with very well-known PGPR bacteria due to its ability to produce phytohormones, siderophores, antibiotics, phosphate solubilization and production of antifungal compounds. Some species also fix nitrogen in addition to above-mentioned characteristics. *Pseudomonas fluorescens*, *Pseudomonas putida* for PGPR and *Pseudomonas aurantiaca, Pseudomonas chlororaphis* for biocontrol agents in foliar spray due to the production of antifungal phenazine compounds. *Pseudomonas* spp. have been isolated from stem, root, leaves, and rhizosphere of sugarcane growing in Australia, Brazil, India, Pakistan, and South Africa. They are among most efficient solubilizers of inorganic phosphate" [8]. They produces phytohormones like indoleacetic acid, gibberellins, and cytokinin, iron-sequestering siderophores, phosphate-solubilizing enzymes, and 1-aminocyclopropane-1-carboxylate (ACC) deaminase [9]. Growth hormones produced by the bacteria enhance the development of lateral roots and improve the plant's nutrient uptake from the rhizosphere.

2.5 PGPR and Biocontrol agents in Sugarcane

PGPR induce resistance in plants against fungal, bacterial, viral diseases and insects and nematodes attacks. PGPR bring about Induced resistance through fortifying the physical and mechanical strength of the cell wall as well as changing the physiological and biochemical reaction of the host leading to the synthesis of defense chemicals against the challenge pathogen. PGPR provide different mechanisms for suppressing plant pathogens having pre and post biochemical and cellular modification to suppress the invasion of disease pathogen. They include competition for nutrients and space, antibiosis by producing antibiotics *viz*., pyrrolnitrin, pyocyanin, 2,4-diacetyl phloroglucinol and production of siderophores, *viz*., *Pseudobactin* which limits the availability of iron necessary for the growth of pathogens.

"The *P. fluorescens* strains from sugarcane reported antifungal activity against *Fusarium oxysporum* and *Rhizoctonia bataticola"* [10]. "The strains *P. putida, B. subtilis*, and *Stenotrophomonas maltophilia* found control against local strains of red rot -*Colletotrichum falcatum"* [11] [12] checked the antifungal activity of *Burkholderia isolates* from the sugarcane rhizosphere, against *U. scitaminea* (sugarcane smut) and *Fusarium spp.* (stalk rot) [13] .

3. RICE

In rice different growth stages with availability of water the PGPR having different species and its population. As vegetative stage bacterial population are differ from their reproductive stage**.** The ponding standing water in rice field rich in of Gram-negative bacteria plus algae. while in percolating water having only Gram-negative bacteria dominated by the *Anaeromyxobacter*, *Arenimonas Arthrobacter*, *B acillus*, *Bellilinea, Proteobacteria, Chloroflexi, Actinobacteria, and Acidobacteria, and cyanobacteria .*

3.1 Rice and *Pantoea* inoculant

"Bacteria belonging to the genus *Pantoea* are gram negative, highly diverse, aerobic or facultative anaerobic with peritrichous flagella in *Enterobacteriaceae* family though they are infecting rice with diseases some strains are till beneficial (*P. ananatis , P. agglomerans* ,*P .rodosii*) showing a promising capacity to mediate the negative effects of arsenic stress as bioremediation and also act as phyto stimulants . They act as potential P solubilizes, N fixer ,IAA and salt tolerance with siderophore production capacity. The rice endophyte *Pantoea agglomerans* (YS19) showed nitrogen-fixing activity *in vitro* produced four different phytohormones, including IAA and promoted plant growth [14] "They found ubiquitous in roots and reduced at the time of tillering with subsequent stages" [15].

3.2 Rice and *Bacillus spp***.**

Microorganisms in the endospheric *Bacillus* are aerobic, gram positive, soil bacterium affect the root morphology, tiller biomass when was applied as an inoculant biofertilizer. They synergists affects on chlorophyll content, plant height, number of tillers, tiller biomass and yield attributes in rice. The combination of TUAT-1 [13] (*Bacillus pumilus* strain) and 100% N (farmer recommended rate of N) resulted in the greatest tiller number and biomass at the maximum tillering stage, and positively affected other growth attributes and yield (4.89 ton ha^{-1}) and concluded that TUAT-1 promoted root development which increased nutrient uptake from the soil by promoting the growth and development of roots.

The strain *Bacillus subtilis sub sp. megatherium* acts as the PGPR and bio control agent in rice so that plant can overcome the negative effect of environmental stress. Plant increased micronutrients uptake affect Phyto hormone homeostasis, stabilized membrane integrity, decreased leaf transpiration ,increased nutrition and metabolic activity with maintaining cell turgor of rice leaves under drought stress because of production of hormone IAA [16,17].

3.3 Rice and Siderophore-producing bacteria

"The genera *Sphingomonas*, *Pseudomonas*, *Pantoea* , *Burkholderia* and *Enterobacter* are primarily detected in rice plant tissues during plants' vegetative stage acts as siderophores, giving them greater access to iron and other elements in the soil. The *Psudomonas fluroescens* at field application enhanced the number of tillers, plant height and biomass with yield increase at 20-26 % over control" [18]. Inoculation with *Beijerinckia indica* in field increased no. of tillers and plant height with 25-29% increased yield [19].

3.4 Rice and *Azospirilum* Inoculant

They are surface colonizing, gram negative, free living, nitrogen fixing, polar flagellar moment forming cyst in unfavorable climatic condition.

The inoculation of rice seedlings with *Azospirillum brasilense* promoted early tillering and the better reproductive performance of rice plants. It was found to significantly increase the grain-filling rate and the grain weight per plant at harvest time. [20] found that *Azospirillum* spp.(B510) strain in field condition enhanced no. of tillers and plant height with increased in yield at 17-25%.

3.5 Rice and *Psudomoans* Inoculation

"In rice the inoculation with *P. dispersa* significantly improves the morpho-biochemical characteristics of the plants such as increased enzymatic activities and reduced arsenic uptake into rice tissues" [21]. A study by , [22]and [23] indicates that "*Pseudomonas fluorescens* produces a volatile organic compound (pyrazine) that can suppress infection and physiological damage can give by *Magnoporthe oryzae* in rice".

3.6 Rice and *Rhizobium* bacterial inoculant

Though rice plants are not leguminous. So benefits of nitrogen not from N-fixation in nodules formed on plant roots because they can't have the *Sym* gene for endophytic colonization on rice root. However they having beneficial endophytic association [24,25] with *Rhizobium* different strains. They enhance crop health, yield and reduced the harmful effect of fungicides ,pesticides and synthetic chemicals. "In Egypt, it was found that the association of *Rhizobium leguminosarum* with rice plants could significantly increase the shoot and root growth, grain yield and nitrogen-use efficiency" [26] . "The growth and yield responses of rice plants to inoculation with two bacterial strains (*R. leguminosarum* (E11) and *Rhizobium* sp. (IRBG74) showed significantly increased grain and higher straw yields at the maturity stage" [27]. A multinational collaborative study with three field experiments in Egypt reported that the *Rhizobium* inoculation of rice plants significantly increased their biomass, nutrient uptake (due to more robust root architecture), grain yield, fertilizer efficiency, harvest index, and grain nutritional value. Further experiments of selected *rhizobiaum* endophytes on rice showed that they produced cell-bound cellulase and poly galacturonase enzymes that hydrolyze glycosidic bonds in plant cell walls plus certain bacteriocins that can inhibit the growth of undesirable microbes.

3.7 Rice and PGPR as Disease Control

"Antifungal compounds produced by *B. subtilis* show a strong synergistic inhibitory effect on the hyphal growth of *Pyricularia grisea* and *R. solani* the as causative agents for blast and sheath blight in rice" [28] . "Another study that employed a strain of endophytic bacterium *Bacillus* sp. (EBPBS4) and *Serratia macrcescens* used for managing sheath blight as antagonistic toward the fungal pathogen *R. solani* by decreasing its severity and incidences" [29-32]. *Bacillus oryzicola* reduced the bakanae disease (*Gibberella fujikuroi)* severity by 46-78% in field condition after its inoculation. The *Pseudomonas* spp. as biocontrol agents for resisting various soil-borne plant diseases [28] inhibits the mycelial growth of the sheath blight fungus *R. solani* by increasing chitinase and peroxidase activity in rice act as inducing systemic resistance [33]. A talc-based bioformulation reduce the incidence of sheath blight in rice by up to 62%, with 12–21% more grain yield because of trigger the ISR against the microbes [34,35].

3.8 PGPR and interference in Quorum sensing

The bacterial cell to cell communication system between themselves or external eukaryotes chemical cues coordinated the bacterial behaviors in response to fluctuation in cell population density called quorum sensing. The small chemical molecules like AHL and HAQs are acts as autoinducer the networking passage for their communication to enhance the concentration as a function of cell density .After their release several bacterial pathogen collectively express the traits like biofilm production ,virulence build up ,swarming motility to protect them against the harsh environmental condition or phagocytosis and hyperparasitism. Some bacterial strains act as interference in biofilm production like *Burkholderia glumae, Psudomonas aeruginosa and Bacillus cereus* in rice so pathogen virulence diminishes and they acts as the biocontrol agent for the crop [36].

4. CONCLUSION

From above all various information we concluded that in sugarcane and rice PGPR promote plant growth directly and in directly by increasing uptake and availability of macronutrients (N, P, K and essential minerals) and play a role by regulating plant hormone levels indirectly with reducing the inhibitory effects of various pathogens on plant growth and development in the form of biological control agents [33,34,35]. For future need of mankind with hygienic and residue free organic harvest we require careful management without burning the farm residue, mulching,heap management for harboring them in field. They are also act as the biocontrol agent against many disease in both the crop [37]. By active application of microbial consortia at different growth stages of crop eliminate the dependency of big imports of potassic and phosphatic fertilizers with saving the incredible foreign currency . The harmonize and symbiotic management of them must emphasized for *satat vikas lakshy in swarnim Bharat* with biosphere and ecological conservation having sustainability for our mankind [37,37-41].

5. FUTURE SCOPE OF STUDY

In today's climate changing scenario new hybrids varieties are developed only for quantitative higher yield without much bother about the devastating effect on the soil and its loss in productivity . By adopting the application of different PGPR bacterial inoculant in different crop as seed treatment ,seed priming, seedling drenching or spraying the endophytic bacterial culture on standing crop built them healthy and prosperous growth and development. They play pivot role as microbial control, nitrogen fixation, Phosphate solubilization, Potash mobilizing, siderophore formation, different enzymes and auxins formation leads to direct and indirect benefit to plants .By its application we save our foreign currency for importing the chemical fertilizers from international markets. Require better practical approach, wide extension programs, laboratory facility near the village area ,high shelf and transport life with better CFU count are essential for its wide adaptations. Scope for collecting much information about crop ecological and rhizosphere system with new strains availability of PGPR with their complex interactions in respective ecological and climatic region. They are helpful to farmer to reduce the indiscriminate application of fertilizers, fungicides with enhance the bio safety approach required for today's environment.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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