A review on weeds as source of novel plant growth promoting microbes for crop improvement

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Abstract: In the context of increasing international concern for food security and environmental quality, the use of bioinoculants like diazotrophs and plant growth-promoting rhizobacteria (PGPR) for reducing chemical inputs in agriculture is a potentially important issue. The improvement in agricultural sustainability requires optimal use and management of soil fertility and soil physical properties, where both rely on soil biological processes and soil biodiversity. Biological nitrogen fixation by plant-associated bacteria is eco-friendly and has been effectively exploited for crop plants including legumes. Although associations of rhizobacteria with non-leguminous plants such as grasses have been known for decades, they have been poorly - studied. Weedy grass species normally thrive in adverse conditions and act as potential habitats for the diverse groups of elite bacteria with multiple beneficial characters remains unexplored. A more complete understanding of the diversity and functioning of rhizobacterial microorganisms, especially those that have symbiotic relationships with grass species is of great value for agricultural research and application.

Keywords: Agriculture, Bioprospecting, Plant growth, Rhizobacteria,Weeds

INTRODUCTION

Agriculture manages plant communities to obtain useful materials from small set of species called crops. Weeds comprise the other set of plant species found in agro-ecosystems. Although they are not intentionally sown, weed species are well adapted to environments dominated by humans and have been associated with crop production since the origin of agriculture (Peterson and Peterson,1999). The ecological role of weeds is seen in different ways depending on one's perspective and most commonly perceived as unwanted intruders into agro-ecosystem since they compete for resource, reduce crop yields and force the use of large amounts of human labour and technology to prevent greater crop losses (Fickett *et al*., 2013). At the other end of the spectrum, weeds can be viewed as valuable agroecosystem components. In Indian subcontinent and Mexico, farmers consume *Amaranthus*, *Brassica* and *Chenopodium* species as nutritious foods before the crop attains maturity. In western Rajasthan, yields of sesame and pearl millet can be increased by allowing the crops to grow in association with the leguminous weed *Indigofera cordifolia* (Bhandari and Sen, 1979). Certain weeds limit insect damage to some crops by interfering with pest movement or by providing habitat for natural enemies of pests. Weed species also reduce soil erosion (Walker, 1992), serve as important source of fodder, medicine and provide habitat for game birds and other desirable wild life species. Spahillari *et al*. (1999) re-examined the value of weeds as genetic resources for food agriculture and pharmaceutics and as indicators of agro-ecosystem biodiversity. These types of beneficial effects indicate that weeds are not just agricultural pests, but can also play beneficial roles in agroecosystems. However, little consideration has given to the soil conditioning properties of weeds, especially with regard to their influence on soil microbial diversity and subsequent soil health and quality. Soil health is a relative term used to define the efficiency of the soil functional processes (e.g. nutrient cycling, energy flow) are able to support viable, self-sustainable (micro) faunal and microfloral ecosystems, which constitute the living soil. It is often considered that soil microbial biodiversity is critical to the integrity, function and long-term sustainability of soil ecosystems. While the rhizosphere of crop plants have been well studied with the objective of screening PGPR, weeds which play an important role in maintaining ecological balance have largely been ignored and therefore a more complete understanding of the diversity and function of diazotrophic microorganisms is required. Especially, those that have symbiotic relationship with weed species particularly

experiencing abiotic stress, is of great value for agricultural application. Some recent progress in this field of plant growth promoting microbes associated with different weeds has been discussed in this review.

BIOPROSPECTING IN WEED RHIZOSPHERE

The rhizosphere is characterized as a zone of intense microbial activity and represents the close interaction among the plants, soil and soil microorganisms. The rhizosphere is enriched with energy rich carbon compounds, leaked photosynthates from plant roots including sugars, amino acids and organic acids. The composition of plant exudates is unique to the plant species, which determines the microbial community of that rhizosphere (Berg and Smalla, 2009).

Plant roots can stimulate or inhibit microbial populations and their activities through the exudation of different compounds. Root exudates are water-soluble organic compounds, mainly carbohydrates, organic acids and amino acids, released from the root cells along concentration gradients in the rhizosphere soil. For microorganisms, these exudates represent a convenient source of carbon (and possibly nitrogen) since they are readily assimilated without the need to synthesize exo-enzymes (Brimecombe *et al.*, 2001). Due to this large availability of substrates in the rhizosphere, microbial biomass and activity are generally much higher in the rhizosphere than in the bulk soil. The release of carbon in form of root exudates may account for up to 40% of the dry matter produced by plants. Even if the C-transfer to exudation was 10-20% of total net fixed carbon other microbial symbionts such as mycorrhizae or N_2-fixing microorganisms may each consume another 10-20 % of total net fixed carbon, so that plants would still release up to half of their total fixed carbon to fuel microbial interactions in the rhizosphere. Supporting microbial interactions in the rhizosphere must be of fundamental importance for plants to justify this significant input of carbon, which could otherwise be used (Doty *et al.,* 2009).

Soil microorganisms play an important role in soil processes that determine plant productivity. Diversity and community structure in the rhizosphere is however influenced by both, plant and soil type (Cocking, 2005). Plant-species-specific selective enrichment of microflora in the rhizosphere milieu has been exploited in legumes from the point of view of N_2-fixation under nitrogen limiting conditions (Coutinho *et al.,* 1999). Likewise, non-leguminous crops also favour specific bacterial groups in its rhizosphere. Nitrogen fixation is one of the essential beneficial biological processes for the economic and environmental sustainability of agriculture worldwide. Globally, annual inputs of fixed nitrogen from crop legume–rhizobia symbioses are estimated as 2.95 million tonnes for pulses and 18.5 million tonnes for oilseed legumes (Howieson, 2005). In spite of the in-depth knowledge about the biochemical and molecular steps involved in legume-rhizobium

symbiosis, the holy grail of N_2 fixation by other plants especially, weedy plants are yet to be realised. It is essential to enhance the activities of microbes that benefit plant nutrition, control diseases and assist plants to cope with a variety of abiotic stresses to sustain and improve global food production in future climate scenarios while maintaining environmental health (Minorsky, 2008) . A diverse range of beneficial microorganisms have been found but their reliable use in field environments is yet to be fully realised. New knowledge on soil microbial diversity can lead to the discovery of new generation inoculants as well as improve survival and performance of beneficial microbes in situ following their introduction into foreign environments. The association of weeds with plant growth promoting rhizobacteria in Indian soil is poorly understood.

Sturz *et al*. (2001) studied the influence of plant growth promoting (PGP) activity of bacterial communities recovered from each of six weed species (barnyard grass (*Echinochloa crusgalli*), corn spurrey (*Spergula arvensis* L.), goldenrod (*Sonchus* sp.), Italian ryegrass (*Lolium multiflorum* L.), lamb's-quarters(*Chenopodium album* L.), and quack grass (*Agropyron repens*) was examined in relation to the effect it had on the growth of the potato. Bacterial species composition and community structure were compared, species-abundance relationships were determined, and those members conferring positive benefits for potato growth and development were identified. Of the genera identified, *Bacillus, Arthrobacter, Stenotrophomonas, Acinetobacter* and *Pseudomonas* were the most common, and *Stenotrophomonas maltophilia* was the most frequent species recovered across all sources. It considered that complementary crops and soil conditioning treatments should not preclude the examination of weed species as possible beneficial, as alterations in rhizobacterial biodiversity and functional versatility can influence the numbers and types of PGP bacterial strains, and consequently may serve to improve soil quality.

WEED AS SOURCE OF PLANT GROWTH PROMOTING RHIZOBACTERIA IN AGRICULTURAL SOIL

Plant growth promoting rhizobacterial have the potential to contribute to sustainable plant growth promotion. Generally, PGPR function in three different ways: synthesizing particular compounds for the plants, facilitating the uptake of certain nutrients from the soil, and lessening or preventing the plants from diseases. Plant growth promotion and development can be facilitated both directly and indirectly. Direct plant growth promotion includes symbiotic and non-symbiotic PGPR which function through production of plant hormones such as auxins, cytokinins, gibberellins, ethylene and abscisic acid. Production of indole-3-ethanol or indole-3-acetic acid (IAA), the

compounds belonging to auxins, have been reported for several bacterial genera. Some PGPR function as a sink for 1-aminocyclopropane-1-carboxylate (ACC), the immediate precursor of ethylene in higher plants, by hydrolyzing it into α-ketobutyrate and ammonia, and in this way promote root growth by lowering indigenous ethylene levels in the micro-rhizo environment. PGPR also help in solubilization of mineral phosphates and other nutrients, enhance resistance to stress, stabilize soil aggregates, and improve soil structure and organic matter content. PGPR retain more soil organic N, and other nutrients in the plant–soil system, thus reducing the need for fertilizer N and P and enhancing release of the nutrients. Indirect plant growth promotion includes the prevention of the deleterious effects of phytopathogenic organisms. This can be achieved by the production of siderophores, *i.e.* small metal-binding molecules. Biological control of soil-borne plant pathogens and the synthesis of antibiotics have also been reported in several bacterial species. Another mechanism by which PGPR can inhibit phytopathogens is the production of hydrogen cyanide (HCN) and/or fungal cell wall degrading enzymes, e.g., chitinase and ß-1,3-glucanase.

BIOLOGICAL NITROGEN FIXATION (BNF):

Nitrogen fixation is an ancient microbial process which evolved early in the history of our planet and is of central importance to the biosphere. All known forms of life require fixed nitrogen for biosynthesis and microbial nitrogen fixation provides the largest natural source of fixed nitrogen in the biosphere, accounting for the production of 100 to 290 t N yr^{-1} in terrestrial systems alone (Cleveland *et al.,* 1999). Free-living diazotrophs in soils provide the dominant natural source of fixed nitrogen in many of these terrestrial systems and yet we still have much to learn about the ecology and evolution of these organisms.Non-rhizobial N$_2$ fixing bacteria can grow as endophytes in a number of grasses, for example, in a recent study in South Australia *Pseudomonas* species were the most dominant group of *nifH* carrying bacteria found in the rhizosphere of perennial native grasses (Gupta *et al.*, 2003). Evidence suggests the *nifH* gene is present in a number of non-Frankia actinobacteria (for example, *Agromyces, Microbacterium, Corynebacterium* and *Micromonospora*). Thus the challenge is to identify (i) functionally significant N$_2$ fixing genera/species specific to biomes and crops, and (ii) key edaphic and environmental drivers regulating the genetic diversity and free living N$_2$ fixation in order to maximise benefits from these beneficial microbes both for sustainable primary production and climate change adaptation.

Nitrogen fixation in *Prosopis* sp. under natural conditions has been reported by a few researchers (Virgina *et al.,* 1981; Rundel *et al.,* 1982; Shearer *et al.,* 1983), In *Prosopis,* nitrogen fixation values have been estimated to vary between 23-30 kg N ha^{-1} year^{-1} in the Sonoran Desert habitat (Rundel *et al.,* 1982). These values could be higher if tree density was increased or the symbiotic association were improved. However, the deep *Prosopis* root system (Felker and Bandurski, 1979) makes it difficult to find the root nodules and therefore to isolate the symbiont. Felker and Clark (1980) found that *P. glandulosa* bears active root nodules deep into the soil, and as soil humidity shifts in the soil profile, both nodule presence and nodule activity change. The genus *Prosopis* occurs predominantly in tropical environments (Norris, 1958) and, according to Allen and Allen (1981), 84 per cent of its species nodulate. The capability of *Prosopis* to fix nitrogen can be firmly established from the results of study conducted by Felker and Clark (1980) where they reported that 12 *Prosopis* sp. became nodulated when inoculated with rhizobia strain isolated from a North American *Prosopis*, grew on a nitrogen free nutrient media, reduced acetylene to ethylene and had a positive significant correlation between the acetylene reduction rates and above ground dry matter. Subba Rao *et al.* (1982) reported that a strain isolated from *P. juliflora* nodulated peanut plants and classified the *Rhizobium* nodulating *P. juliflora* as belonging to the cowpea group; the same occurred for *Rhizobium* isolated from 5 species of the genera *Acacia* and *Albizzia* (Basak and Goyal, 1975).

In Brazil, a number of tropical weedy grasses, including *Brachiaria humidicola*, *B. decumbens*, *Paspalum notatum* and *Panicum maximum* have shown relatively high N$_2$ fixation rates in ^{15}N isotope dilution studies, and may derive up to 40% of their N-needs from fixation (Olivares *et al.,* 1996). High nitrogen fixation by kallar grass in Pakistan has also been reported by Malik *et al.* (1997). In another work, nitrogen fixing activities were also found Vettiver. Moreover, the variation in nitrogenase activity among the 102 isolates tested (0.01-2.15 n mole C$_2$H$_4$ mg^{-1} protein h^{-1}) with the average activity at 0.20 n mole C$_2$H$_4$ mg^{-1} protein h^{-1}. There were 31 isolates (30.4%) having higher activity than the average activity (Bhromsiri, 2009).

PRODUCTION OF PLANT GROWTH PROMOTING SUBSTANCES

Phytohormones also called plant growth regulators (PGRs) are well known for their regulatory role in plant growth and development. PGRs are organic substances that influence physiological processes of plants at extremely low concentrations. Because the concentration of hormonal signals is critical to the regulation of various physiological processes in plants, local changes of phytohormone levels can lead to characteristic changes in plant growth and development. In 1979, production of auxins, cytokinin -like and gibberellin-like substances was proposed for *A. brasilense*, since the increased number of root hairs and of lateral roots observed after inoculation with this bacterium could be mimicked by the application of a mixture of indole- 3–acetic acid, kinetin, and gibberellic

acid. Moreover, in several other studies the increased plant growth observed after inoculation with *Azospirillum* was proposed to be due to bacterial phytohormone production (Harari *et al.,* 1988). Eighty per cent of microorganisms isolated from the rhizosphere of various crops have the ability to produce auxins as secondary metabolites. Bacteria belonging to the genera *Azospirillum, Pseudomonas, Xanthomonas, Rhizobium, Alcaligenes, Enterobacter, Acetobacter* and *Bradyrhizobium* have been shown to produce auxins that help in stimulating plant growth (Glick *et al.*, 1998). The rhizosphere of a luxuriantly growing, medicinal weed, *Cassia occidentalis* was analysed by enumerating PGPR on N free media from the most diverse stage of plant. Each isolate was tested for other plant growth promotion assays including production of cellulase, indole acetic acid (IAA), ammonia, HCN, siderophore and chitinase to select for ones possessing multi-trait plant growth promoting (PGP) properties. In Thailand, first report about nitrogen fixing and IAA production abilities of plant growth promoting rhizobacteria isolated from rhizosphere of Vettiver grass. The isolates were identified as *Stenotrophomonas maltophilia, Aurantimonas altamirensis, Agrobacterium tumefaciens, Rhizobium bacillus, Paenibacillus polymyxa, Serratia marcescens, Klebsiella, Alcaligenes faecalis* and *Azospirillum* sp. (Bhromsiri and Bhromsiri, 2010). Similarly in India, from rhizosphere of bermuda grass, all the rhizobacterial isolates shows the ability to produce phytohormones such as indole-3-acetic acid and Gibberellic acid (Sarathambal *et al.*, 2013).

SYNTHESIS OF ENZYMES THAT CAN MODULATE PLANT GROWTH AND DEVELOPMENT

Ethylene is a potent plant growth regulator that affects many aspects of plant growth, development and senescence. In addition to its recognition as a "ripening hormone", ethylene promotes adventitious root and root hair formation, stimulates germination, and breaks the dormancy of the seeds. However, if the ethylene concentration remains high after germination, root elongation (as well as symbiotic N_2 fixation in leguminous plants) is inhibited (Jackson, 1991). It is widely believed that many plant growth promoting bacteria may promote plant growth by lowering the levels of ethylene in plants. This is attributed to the activity of the enzyme 1–aminocyclopropane-1–carboxylate deaminase, which hydrolyzes ACC, the immediate biosynthetic precursor of ethylene in plants. The products of this hydrolysis, ammonia and α-ketobutyrate, can be used by the bacterium as a source of nitrogen and carbon for growth (Honma and Shimomura, 1971). In this way the bacterium acts as a sink for ACC and as such is lowering the ethylene level in plants, preventing some of the potentially deleterious consequences of high ethylene concentrations (Glick, 1995). The diazotrophs containing ACC deaminase are present in various soils and offer promise as a bacterial inoculum for improvement of plant growth, particularly under unfavourable environmental conditions such as flooding, heavy metals, phytopathogens, drought and high salt. Inoculation of crops with ACC deaminase-containing PGPR may assist plant growth by alleviating deleterious effects of salt stress. In nature, ACC deaminase has been commonly found in soil bacteria that colonize plant roots (Belimov *et al..,* 2001). Many of these microorganisms are identified by their ability to grow on minimal media containing ACC as its sole nitrogen source. Similar findings by Sarathambal (2013) reported that 43% of rhizosphere diazotrophs from different weedy grasses (*B. subtilis, K. pneumoniae, Serratia* sp.*, B. licheniformis, S. Marcescens* and *Bacillus* sp.) are all found to use ACC as the sole nitrogen source for growth.

ANTAGONISTIC ACTIVITY

Rhizobacteria can suppress the growth of various phytopathogens in variety of ways like competing for nutrients and space, limiting available Fe supply through producing siderophores, producing lytic enzymes and antibiosis (Jing *et al.*, 2007). Among PGPRs, fluorescent pseudomonads are widely reported for their broad spectrum antagonistic activity against number of phytopathogens. Recently different PGPR isolates from weedy grass (Sarathambal, 2013) to control the rice plant pathogens such as *P. oryzae, R. solani* and *S. oryzae*. Many rhizospheric and endophytic bacteria are reported to have antagonistic activity against a variety of plant pathogens. Cibichakravarthy *et al.* (2011) reported that *Bacillus subtilis* isolated from the *Parthenium* rhizosphere has the ability to suppress the plant pathogens such as *Macrophomina phaseolina, Sclerotium rolfsi, Lasiodiplodia theobromae, Colletotrichum gloeosporioides* and *Alternaria solani.*

MINERAL SOLUBILZATION

One of the various mechanisms by which rhizobacteria promote plant growth is by solubilization of insoluble minerals. Phosphorus is the second most important macronutrient next to nitrogen in limiting crop growth. More than 40% of the world soils are deficient in phosphorus and the acid weathered soils of tropical and sub - tropical regions of the world are particularly prone to phosphorus deficiency (Vance, 2001). A survey of Indian soils revealed that 98 per cent of these need phosphorus fertilization either in the form of chemical or biological fertilizer. Application of chemical phosphatic fertilizers is practised though a majority of the soil P reaction products are only sparingly soluble. Under such conditions, microorganisms offer a biological rescue system capable of solubilizing the insoluble inorganic P of soil and make it available to the plants. P solubilization by plant-associated bacteria has been well documented in a number of studies. This group covers bacteria, fungi and some actinomycetes. These organisms solubilize the unavailable forms of inorganic-P like tricalcium,

iron, aluminum and rock phosphates into soluble forms by release of a variety of organic acids like succinic, citric, malic, fumaric, glyoxalic and gluconic acids (Venkateswarlu *et al.*, 2007).

Apart from phosphorus, micronutrients like Zn, Fe and Mn are found to be deficient in most of the soils with Zn as a foremost nutrient throughout the world (Alloway, 2001). Zinc, the micronutrient required for plant growth, is an essential component of over 300 enzymes and play catalytic, co-catalytic or structural roles in many plant systems (Christie *et al.*, 2004). For alleviation of Zn and other micronutrients important for crops, their application is done mainly in soluble form as zinc sulphate the soluble form of Zn applied to the soil get transformed into different unavailable forms due to the soil reaction. These transformations are based on the type of soil and other nutrients available. Zn is mainly transformed into zinc carbonate in highly calcareous soils, reacts with Fe and Mn oxide minerals, and while converted into zinc phosphate in higher P fertilizing soils. Inclusion of a bacteria solubilizing zinc, as a bioinoculant in crop production technology is really beneficial for a country like India having high incidence of zinc deficiency (more than 70 per cent). A term called zinc solubilizing bacteria (ZSB) was coined for those bacteria that are capable of solubilizing the insoluble zinc compounds / minerals in agar plate as well as in soil (Saravanan *et al.,* 2007). Potassium solubilizing bacteria such as *Bacillus mucilagenosus* and *Bacillus edaphicus* are example of microorgassium that used in bio inoculants. Potassium solubilizing bacteria are able to solubilize potassium rock through production and secretion of organic acids. Potassium solubilizing bacteria is a heterotrophic bacterium which is obtaining all their energy and cellular carbon from pre-existing organic material. Besides, Potassium solubilizing bacteria are aerobic bacteria which play an important role in maintaining soil structure by their contribution in the formation and stabilization of water-stable soil aggregates. It is observed that, inoculants such as, *Enterobacter* sp. CG1, *Bacillus* sp. CG5, *Serratia* sp. CB2, *K. pneumoniae* CR3, *Klebsiella* sp. OR7 and *S. marcescens* CD1 from different weedy grasses showed that solubilize phosphorus, zinc and mineralize potassium with varying ability (Sarathambal, 2013). In another study, the isolates of *Parthenium* (*B. subtilis*, *Azospirillum* sp., *A. brasilense* and *Bacillus* sp.) has the ability to solubilise the minerals such as phosphorus, potassium and zinc (Cibichakravarthy *et al.*, 2011).

SIDEROPHORE PRODUCTION

In the case of iron uptake, it was suggested that plants can benefit from the siderophores produced by several plant growth promoting rhizobacteria. Although iron is one of the most abundant minerals on Earth, in the soil it is relatively unavailable for direct assimilation by microorganisms. Iron is an essential growth element for all living organisms. The scarcity of bioavailable iron in soil habitats and on plant surfaces foments a furious competition (Whipps, 2001). Under iron-limiting conditions PGPB produce low molecular weight compounds called siderophores to competitively acquire ferric ion. Siderophores (Greek: "iron carrier") are small, high-affinity iron chelating compounds secreted by microorganisms such as bacteria, fungi and grasses. Microbes release siderophores to scavenge iron from these mineral phases by formation of soluble Fe^{3+} complexes that can be taken up by active transport mechanisms. Rhizosphere bacteria of weedy grass (*Brachiaria reptans*, *Cenchrus glaucus*, *Saccharum spontaneum*, *Panicum repens*, *Cyperus rotundus*, *Dactyloctenium aegyptium,* *Chloris barbata,* *Cyanodon dactylon* and *Setaria verticillata)* was able to produce under *invitro* conditions (Sarathambal, 2013). Cibichakravarthy *et al.* (2011) mentioned that *A. brasilense* from *Prosopis julifera* was able to produce the siderophore.

CROP RESPONSE STUDY OF PGPR INOCULANTS ISOLATED FROM THE RHIZOSPHERE OF WEEDS

Seed bacterization with plant growth promoting rhizobacteria has emerged as a promising technique to induce enhanced growth of plants and simultaneously provide protection from deleterious and pathogenic micro organisms. Plants play an important role in selecting and enriching the type of bacteria by the constituents of their root exudates. The bacterial community developing in the rhizosphere has an efficient system for uptake and catabolism of organic compounds present in root exudates (Barraquio *et al.,* 2000).

Isolates of *C. occidentalis* were used for bacterization of *Vigna radiata* and *Vigna mungo* to evaluate their efficacy in promoting plant's growth in seedling germination and axenic pot conditions. A maximum increase of approximately 36 and 60 % was observed for shoot and root length, respectively in *V. radiata* in axenic pot culture over control plants (Arun *et al.*, 2012). Six plant growth promoting diazotrophs were isolated from the rhizosphere of selected weedy grass species (*C. glaucus*, *C. rotundus*, *C. barbata*, *O. rufipogon* and *C. dactylon*) and tested their efficiency in field conditions in rice (cultivar-ADT 43). The results of field experiment revealed that the strain *Serratia* sp. (CB2) increased the plant height (13%), number of effective tillers (10%) and grain yield (32%) compared to 100 percent recommended dose of fertilizer applied treatment (Sarathambal, 2013). In another study, the beneficial effects of multifaceted growth promoting isolates of bermuda grass for rice under two different salt concentrations in pot culture conditions were evaluated. Results revealed, plant growth (plant height, dry weight, and chlorophyll content) was promoted by bacterial inoculation with 2.9 and 5.8 g NaCl/kg soil. Uptake of nutrients (N^+, P^+,

and K^{+}) were found increased in regardless of NaCl concentration with inoculation of *Serratia* sp. and *Bacillus* sp Sarathambal and Ilamurugu (2013). Plant growth promoting rhizobacterial isolates from the rhizosphere of two arid weed plants *prosopis julifera* and *parthenium hysterophorus* were evaluated in aerobic rice (PMK 3). The elite strains showing multifaceted beneficial activities including nitrogen fixation, mineral solubilisation, phytohormaone production, against soil pathogens were inoculated to aerobic rice Cibichakravarthy *et al.* (2011)

Conclusion

The study opens up possibilities for utilization of this property of weeds in plant growth promotion, and subsequent enhancement of yield for agricultural crops. This study also emphasise the multifaceted plant growth promoting activity obtained from the weedy grass rhizosphere under stressed condition may be employed in nutrient deficient and problematic soils for stress mitigation and sustainable crop cultivation with fewer chemical inputs. The preliminary analysis has indicated that the rhizosphere of weeds is colonized by certain characteristic microbial communities, representing a good starting point for further analyses. It would be very interesting to investigate the molecular understanding between these plants and microbes in rhizosphere for further exploitation of these potential novel microbes in the nutrient management of crops growing under stress conditions. To further understand the highly complex nature of microbial adaptation and their response to alterations in the biological, chemical, and physical environment of the rhizosphere remains a significant challenge. Hopefully, new research will provide farmers with novel control strategies for the development of microbial strains that are more effective and have longer shelf-lives as a "plant growth stimulators" and "biocontrol" to supplement and/or complement chemical fertilizers and pesticides in agriculture.

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