

Review Article

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Review on PGPR: An Alternative for Chemical Fertilizers to Promote Growth in *Aloe vera* Plants

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ABSTRACT

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Abiotic and biotic factors of the rhizosphere influence the quality of medicinal plants. Medicinal values of medicinal plants play an important role in improving the rhizosphere microbes. There are increasing interests in the research of the interaction between medicinal plant and their rhizosphere microbes for the improvement of medicinal plants. This review demonstrates the role of microbes in plant growth, nutrient availability, yield and quality of medicinal plant *Aloe vera*.

Introduction

Demand for medicinal plants is increasing worldwide due to growing recognition of natural products. Allopathic medicine also owes a tremendous debt to medicinal plants: one in four prescriptions filled in a country like India is either a synthesized form of or derived from plant materials. Habitat loss and deforestation coupled with over harvesting has resulted in dwindling population of important medicinal plants. Therefore, direct extraction of natural products from wild medicinal plants to satisfy the current

requirement is fast becoming an unrealistic goal. Domestic cultivation of medicinal plants is thought as a viable alternative. But, certain drawbacks, including variability in yield and difference in phytochemical profile over wild one are making it as a last resort. Mediculture, the scientific cropping of industrially important medicinal plants, has become the need of the day to improve the productivity of the medicinal important plants such as *Aloe vera*. *Aloe vera* is a unique medicinal plant having large applications in medical and cosmetic industries. *Aloe vera* gel includes more than 75 biologically active substances

such as vitamins, anthraquinones, minerals, enzymes, sugars, lignin, saponins, sterols, amino acids and salicylic acid. The gel present in the leaf pulp of *Aloe vera* is used for curative purposes and yellow latex present in bundle sheath cell is used for cathartic purposes. Thus, demand for this miraculous plant is increasing in both domestic and international markets (Rodríguez and Fraga, 1995). Hence, the quest to find a mechanism to increase its production is fundamental. Although much research has been conducted on the effect of PGPR on the crops, very little work has been done with medicinal plants. This field constitutes a largely unexplored method to increase productivity of medicinal plants.

Aloe barbadensis Miller (*Aloe vera*) is a perennial plant of the lily (*Liliaceae*) or *Aloeaceae* family. It is a stemless or very short-stemmed succulent plant growing to 80-100 cm tall, spreading by offsets and root sprouts. *Aloe* gel is the colourless gel contained in the inner part of the fresh leaves (Reynolds and Dweck, 1999). The gel consists primarily of water (>98%) and polysaccharides (pectins, cellulose, hemicellulose, glucomannan, acemannan and mannose derivatives). Acemannan is considered the main functional component of *Aloe vera* and is composed of a long chain of acetylated mannose (Femenia *et al.*, 1999; Djeraba and Quere, 2000; Lee *et al.*, 2000). It contains almost 95% of water, more than 70 essential medicinal ingredients including mineral, enzymes, proteins, amino acid, vitamins, vitamin B₁₂ and polysaccharides. These all combines and make *Aloe vera* plant really beneficial. *Aloe vera* juice is used in relieving digestive problems. *Aloe vera* acts as an antibacterial agent and protects the skin of a person against the sun's ultraviolet rays. It increases the flow of blood to the areas of wound and enhances fibroblasts. Gel is the pulp of the leaf and juice is obtained by

homogenizing and diluting the gel. *Aloe* gel is the new wonder anti-ageing agent. Gel is widely used in various medical, cosmetic and nutraceutical applications (Ni *et al.*, 2004). *Aloe vera* gel is helpful in case of minor cuts, scrapes and bruises and provides relief to a person rapidly. *Aloe vera* gel has provided a number of benefits to a person such as it helps in healing the sores and blisters and also helps people suffering from Psoriasis by reducing the itching and pain. It has shown considerable improvement in the reduction of lesions. Ample of study has been done for *Aloe vera* which aid in fighting against the cancer. It has also been confirmed that *Aloe vera* gives relief to the people suffering from liver problems, gastric problems and inflammatory bowel disease. *Aloe vera* gel is used both, topically (treatment of wounds, minor burns, and skin irritations) and internally to treat constipation, coughs, ulcers, diabete, headaches, arthritis, immune-system deficiencies (Vogler and Ernst, 1999; Eshun and He, 2004).

In addition to pharmaceutical importance, *Aloe vera* is widely used in food beverage and cosmetic industry. In the food industry, *Aloe* is being used as an ingredient for functional foods, mainly as food supplements the development of health drinks, desserts and beverages. In the recent past, the plant has emerged as an important commercial item. *Aloe vera* gel is used as an ingredient in commercially available yogurt, beverages and some desserts (Reynolds, 2004).

Plant Growth Promoting Rhizobacteria

Plant Growth - Promoting Rhizobacteria (PGPR) are a group of microorganisms that are able to colonize the rhizosphere or roots of many plant species, conferring beneficial effects on their host (Kloepper *et al.*, 1981). The PGPR present around the roots of the plants encourages beneficial effects on plant

health and growth, suppress disease-causing microbes and accelerate nutrient availability and assimilation. The use of microorganisms with the aim at improving nutrient availability for plants is an important practice and is necessary for agriculture (Kloepper *et al.*, 1981; Backman and Sikora, 2008). During the past couple of decades, the use of PGPR for sustainable agriculture has increased tremendously to various parts of the world. Significant increase in growth and yield of agronomical important crops in response to inoculation with PGPR has been repeatedly reported (Amara and Dahdoh, 1997; Chanway, 1998; Pan *et al.*, 1999; Bin *et al.*, 2000; Gupta *et al.*, 2000; Asghar *et al.*, 2002; Vessey, 2003; Silva *et al.*, 2004; Araujo *et al.*, 2005; Figueiredo *et al.*, 2007; Zhang *et al.*, 2010). In accordance with Vessey (2003), soil bacterial species burgeoning in the plant rhizosphere which grows in, on, or around plant tissues, stimulate plant growth by a plethora of mechanisms is collectively known as PGPR.

Bioactive factors produced by PGPR

Bioactive factors are substances that impact on growth of plants such as root exudates, vitamins, amino acids and phytohormones. Such products can affect rhizosphere properties and hence availability of soil nutrient by altering rhizosphere pH and the activity of microbes including PGPR.

Isolation of bacteria from *Aloe vera* PGPR

Herminiimonas obsidens was isolated by Nongkhaw and Joshi in 2013 from subtropical forests of Meghalaya, India. Their study was an attempt to explore plant associated bacteria which are beneficial to host plants, and thus aid in the conservation of ethnomedicinal plants of the studied subtropical forests, which are dwindling due to exploitation. Rai *et al.*, 2017 isolated three

hundred seven fluorescent *Pseudomonas* isolates from the *Aloe barbadensis* (Miller) rhizosphere. Mamta *et al.*, 2013 isolated four phosphate solubilizing bacteria identified as *Pseudomonas synxantha* AM 12356 for A1; *Burkholderia gladioli* R406 for A6 *Enterobacter hormaechei* EN 314 for A20 and *Serratia marcescens* A3 for A51 isolate. Meena *et al.*, 2013 isolated four plant growth promoting rizobacteria from *Aloe vera* rhizosphere as *Acinetobacter radioresistens* SMA4, *Bacillus thuringiensis* SMA5, *Brevibacterium frigiditolerans* SMA23 and *Pseudomonas fulva* SMA24.

Phosphorus solubilization

Phosphorus is an essential macronutrient for growth and development of plants involved in important metabolic pathways like photosynthesis, biological oxidation, nutrient uptake and cell division (Illmer and Schinner, 1992). Mamata *et al.*, 2013 found the amount of P-solubilization by PSB varied from 150 to 340 $\mu\text{g ml}^{-1}$.

Maximum P solubilization was observed by A1 (340 $\mu\text{g ml}^{-1}$) followed by A6 (276 $\mu\text{g ml}^{-1}$), A51 (212 $\mu\text{g ml}^{-1}$) and A20 (150 $\mu\text{g ml}^{-1}$). Karthikeyan *et al.*, 2010 observed that the microbial population is more in the rhizosphere soil compared to non-rhizosphere soil of the medicinal plants.

Meena *et al.*, (2017) observed phosphorus solubilization in range of 82.9 mg L^{-1} -135.6 mg L^{-1} isolated from *Aloe vera* rhizosphere. Radhika and Rodrigues (2010) isolated *G. maculosum*, *G. multicaule*, *G. geosporum* from *Aloe vera* which were potent phosphate solubilizer. Based on partial 16S rRNA gene sequencing PSB were identified as *Pseudomonas putida*, *Pseudomonas* sp. and *Pseudomonas plecoglossicida* with highest phosphate solubilization ability (Rai *et al.*, 2017).

IAA production

Phytohormone production is one of the important trait of PGPR. Among the phytohormones, indole-3-acetic acid (IAA) is the naturally occurring and most physiologically active auxin found in plants. IAA is released as a secondary metabolite because of the rich supplies of substrates exuded from the roots (Srrzelczyk and Pokojnska, 1984; Ahmad *et al.*, 2005). Microbial biosynthesis of IAA in soil are enhanced by tryptophan secreted from roots or decaying cells (Benizri *et al.*, 1998) and its positive effect on root growth and morphology is believed to increase the access to more nutrients in the soil and enhancing other beneficial bacteria or fungi, controlling fungal diseases, controlling bacterial diseases (Bioprotectant). Mamta *et al.*, 2011 observed Isolate A6, A20 and A51 produced IAA 6.93 $\mu\text{g ml}^{-1}$, 4.33 $\mu\text{g ml}^{-1}$, 28.2 $\mu\text{g ml}^{-1}$ respectively). Whereas, isolate A1 produced no IAA. Meena *et al.*, (2017) observed Maximum IAA production was shown by isolate SMA24 (80.2 $\mu\text{g mL}^{-1}$) followed by SMA23 (66.4 $\mu\text{g mL}^{-1}$), SMA5 (53.8 $\mu\text{g mL}^{-1}$) and SMA4.34.6 $\mu\text{g mL}^{-1}$. Malleswari. D and Bagyanarayana, 2013 observed that isolate Av 30 isolated from Aloe vera rhizosphere produced 60.0 $\mu\text{g mL}^{-1}$ IAA.

Siderophore production

Siderophore are iron chelating compounds produced by plant growth promoting bacteria having high association constants for complexing iron. Meena *et al.*, 2017 observed quantitative estimation, maximum siderophore percentage units were observed in case of SMA5 followed by SMA24, SMA23 and SMA4. SMA23 and SMA24 has shown maximum siderophore production (38.6% Siderophore units and 41.6% Siderophore units) after an incubation time of 36h and 48 h respectively while in case of SMA4 maximum siderophore production (21.6% Siderophore units) was observed after incubation time of 72h. Isolates, A1, A6, A20 and A51 produced siderophore 94.47%, 95.22%, 27.86% and 86.67% respectively.

Effect of PGPR on Aloe growth

Mamta *et al.*, 2013 observed that PGPR significantly ($P \leq 0.05$) increased leaf length by 39.5%, root length by 31.1%, total number of leaves by 48.1%, total gel volume by 143%, dry gel weight by 147% and dry rind weight by 95.2% as compared to the control plants. Maximum stimulatory effects on various biometric parameters were obtained by *P. synxantha* followed by *S. marcescens*, *B. gladioli* and *E. hormaechei*. Compared to control plants, an increase of over 243% in total gel volume was observed in plants treated with the PSB consortium. Maximum increase in leaf length (21.0%) and dry rind weight (51.8%) was shown by *P. synxantha* treated plants. Whereas, in case of root length, total gel volume and dry gel weight, maximum stimulatory effects were shown by *S. marcescens* treated plants. The plants treated with *B. gladioli* and *E. hormaechei* showed smaller increases in growth parameters than *P. synxantha* and *S. marcescens* treated plants. Meena *et al.*, 2017 observed that PGPR SMA5 significantly ($P \leq 0.05$) increased Plant biomass by 105.72%, root weight by 111.67%, shoot weight by 137.23%, total number of leaves weight by 63.23%, total gel volume by 193% as compared to the control plants. Compared to control plants, an increase of over 213% in total gel volume was observed in plants treated with the consortium.

Effect of PSB on aloin-A content

The increase in the aloin-A content was due to both the increase in biomass of Aloe plants and the increased biosynthesis of aloin-A as compared to control plants. The increases were 159% and 673% based on g^{-1} dry gel weight basis and plant^{-1} dry gel weight basis, respectively. Amongst individual PSB treatments, a maximum increase (90.4–111%, g^{-1} dry gel weight and 245–293%, plant^{-1} dry gel weight) was observed with *P. synxantha* treated plants in both soil. Meena *et al.*, (2017) observed that Amongst individual PGPR treatments, a maximum increase 184% was

observed with *P. fulva* treated plants followed by *Bacillus thuringiensis* SMA5 (152.6%).

The present review clearly indicates the potential of plant growth promoting rhizobacteria on *Aloe* plant growth and aloin-A content. The effect of an inoculation by a consortium was more pronounced than individual inoculations. This review also demonstrates that increased nutrient uptake in plants directly correlates with enhanced aloin-A production. This review emphasizes the potential of an economical and eco-friendly means of achieving higher levels of aloin-A by using plant growth promoting bacteria. However, further research is needed to understand the specific mechanisms involved in the positive effects of PGPR on the biosynthesis of aloin-A contents

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