



# Rhizobacteria mediated seed bio-priming triggers the resistance and plant growth for sustainable crop production

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## ABSTRACT

Advanced technologies are commonly used in modern agriculture to break the yield barriers and increase crop productivity. Seeds treated with plant growth-promoting rhizobacteria (PGPR) are an effective bio-priming method to introduce beneficial microbial inocula into the rhizosphere or soil. Bio-priming is a type of seed treatment that employs biological entities, which involves the hydration of seeds and inoculation with beneficial microorganisms. Mainly, the seed bio-priming technique improves the seed quality, germination, viability, vigor index, growth promotion, production, and subsequent disease resistance by enhancing the uniform speed of germination and production of others growth regulators. In the majority of cases, bacterial inoculants mostly PGPR are used for seed bio-priming, it is an ecologically comprehensive strategy that uses selected PGPR to promote plant growth by producing regulatory substances, enhancing uptake of nutrients, protecting seedlings/plants from seed or soil-borne pathogens. Bio-priming methods using PGPR inoculants are becoming more common in modern agriculture as an alternative to chemical treatments. They are more environmentally sustainable and safer for future agriculture apart from improving plants and soil health.

## 1. Introduction

Harmful chemicals are used to protect crops against infections, however, they have a major adverse impact, such as human and cattle poisoning, environmental contamination and ecological disruption. Bio-priming may provide a revolutionary approach for plant growth, protection and sustainable development. Seed bio-priming is a technique for enhancing seed germination, stress management, plant growth regulation, and acting as a bio-control agent/inoculum by inducing plant immunity (Sarkar et al., 2021; Fig. 1). Beneficial or efficient microbes are applied directly to the soil, by seed bio-priming or seed inoculation, plant tissues treatment, or with different soil applications to protect the plants when there is a high risk of harmful microbial infection or inhibitors on the plant tissues (Mahmood et al., 2016). There are numerous studies about the beneficial attributes of PGPR, such as

increasing the bio-availability of various soil nutrients for plant growth, stimulating phytohormones for example auxins, cytokinins and gibberellins, abiotic and biotic stress management of plants by producing many metabolites including ACC-deaminase and biocontrol agents such as antibiotics, hydrogen cyanide, siderophore and lytic enzymes production, which in turn enhancing the speed and percentage of seed germination, proliferation of root growth, ability to withstand in contaminated soils, and soil structure (Basu et al., 2021).

## 2. Seed bio-priming and method of priming

Seed bio-priming, which involves soaking the seeds in liquid bacterial culture suspension for a particular period, initiates physiological developments/processes within the seed thereby preventing plumule and radicle emergence before the seed is sown (Bisen et al., 2015; Fig. 2).

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The onset of physiological processes within the seed boosts plant growth-promoting (PGP) levels in the spermosphere, which enhances the many fold proliferation of inoculated PGPR bacteria within the seeds and it protects the seed from pathogens attack, allowing the plant to withstand adverse conditions. Bio-priming is a coating process or seed treatment with beneficial PGPR under controlled hydration conditions, which improves the preparatory methods prior to germination without the emergence of the radicle (Sukanya et al., 2018). It's linked to increased hydrolytic enzyme activity, reactive oxygen species (ROS), detoxifying enzyme activity, and changes in internal plant hormone levels, as well as differential gene expression in plants, all of which lead to improved plant growth and resistance to stress viz. biotic and abiotic (Deshmukh et al., 2020). For a better understanding of the role of bio-priming with PGPRs in phyto-stimulation and nutrient enhancement, in-depth and innovative research studies at the biochemical, proteomics and transcriptome levels are needed.

### 3. Role of PGPR in bio-priming for plant growth promotion

Bio-priming of seeds with PGPR is one of the inexpensive and eco-friendly solutions to increase the growth in the early or primary stages of its growth (Raj et al., 2004; Deshmukh et al., 2020; Fig. 3). The use of beneficial PGPRs such as *Pseudomonas* spp. (Chitra and Jijeesh, 2021), *Enterobacter* spp. (Roslan et al., 2020), *Bacillus* spp. (Bidabadi and Mehralian, 2020; Panneerselvam et al. 2019; Li et al., 2021), *Azotobacter* spp. (Bidabadi and Mehralian, 2020), *Azospirillum* spp. (Gowthamy et al., 2017) and *Burkholderia* spp. (Ait Barka et al., 2006) as a

bio-inoculant or seed bio-priming agent has been well documented and utilized to improve stress tolerance, nutrient uptake and seed germination (Fig. 3). In general, those living organisms shows different multi-functional activities like production of plant growth regulators, such as auxins, cytokinins, abscisic acid, and gibberellins, as well as secretion of effector molecules and secondary metabolites through modulation of various pathways/cascades, are the most suitable for the biopriming method and provides resistance to plant against biotic stress (Singh et al., 2020; Audenaert et al., 2002). Raj et al. (2004) studied that bio-priming of *Pennisetum glaucum* seeds with *Pseudomonas* spp. strains helped to enhance the plant growth and resistance to the disease. Bio-primed seeds can lead to better plant establishment and increased plant yield by increasing germination rate, increasing root length and volume, increasing the number of lateral roots (Ait Barka et al., 2006; Cakmakci et al., 2007; Chitra and Jijeesh, 2021). Deshmukh et al. (2020) reviewed that bio-priming with PGPR enhances crop seedling growth and also found that these PGPR can significantly improve plant growth and health. Hence, bio-priming with PGPR could therefore be beneficial to plant growth.

### 4. Recent advancements and limiting factors of seed bio-priming

In various field crops, modern and advanced priming techniques like nanoparticles, gamma-ray, magnetic ray, and UV irradiation are being established and used. Seed priming with UV irradiation and nanoparticles can improve seed germination and seedling development (Siddiqui et al., 2011; Ghafari et al., 2013). Seed priming with gamma

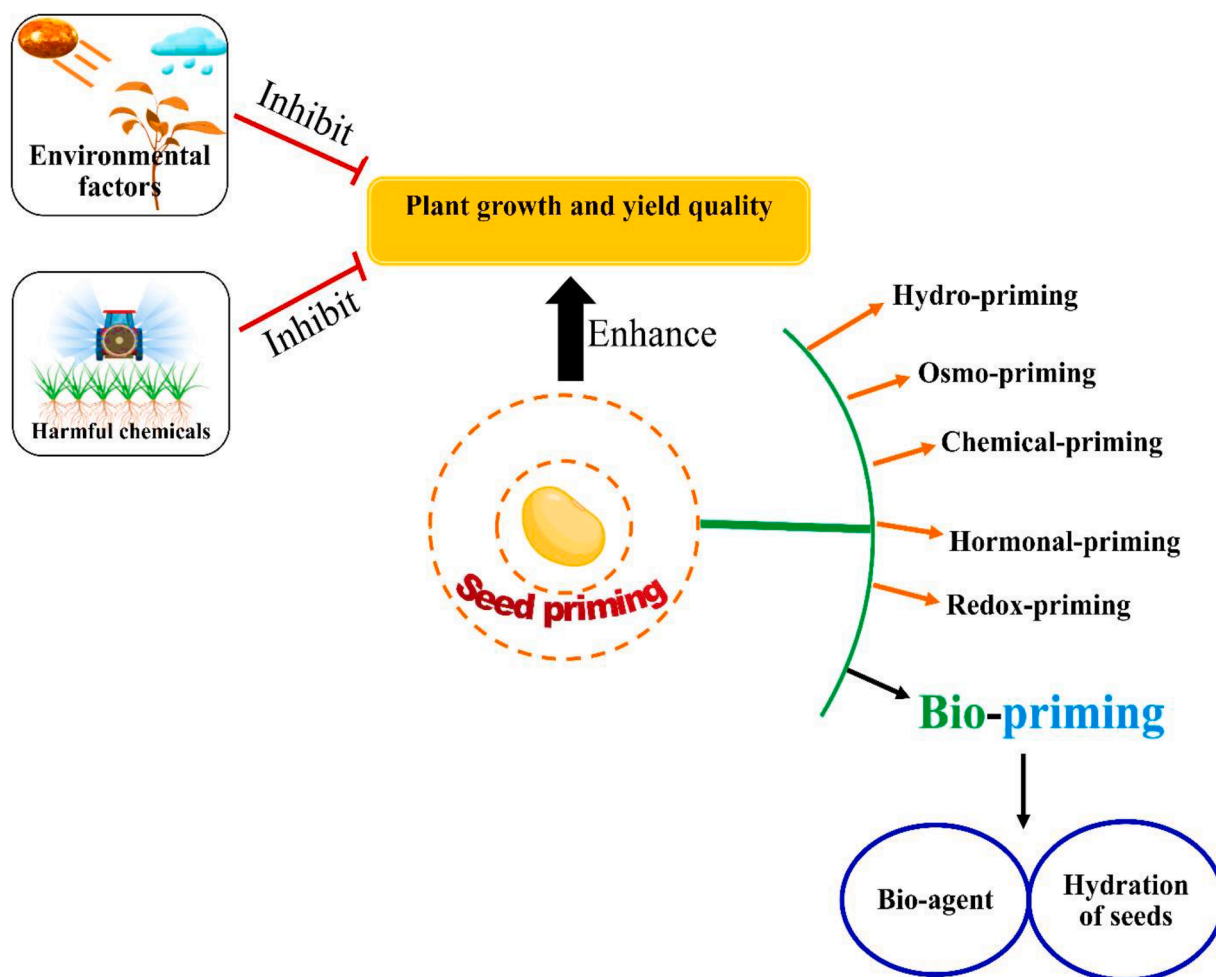


Fig. 1. Seed priming methods for better enhancement of seed germination and plant development.

and magnetic rays improves rice plant yield and wheat antioxidant activity, respectively (Maity et al., 2005; Balakhnina et al., 2015). Various priming approaches are available such as hydropriming, osmopriming, Solid matrix priming, chemopriming, thermopriming, and biopriming, etc. Seeds are immersed in water under ideal temperature conditions (typically 5 to 20 °C) during hydropriming. Osmopriming (also known as "osmotic priming" or "osmotic conditioning") is a widely used pre-sowing process that involves treating seeds with osmotic liquids at low water potential to assist in water uptake regulation. Solid matrix priming ('matricconditioning') has been designed as a cost-effective approach to osmopriming, which requires enormous volumes of osmotic fluid and expensive aeration and temperature control devices (Mercado and Fernandez, 2002; Ermiş et al., 2016). The seeds are combined with solid (organic or inorganic) materials ('solid priming') to properly modify the moisture levels and regulate water absorption during solid matrix priming (Paparella et al., 2015). DNA replication, RNA, DNA, and protein synthesis are all examples of molecular actions that can occur as a result of seed priming (Varier et al., 2010). The DNA repair (Base- and Nucleotide-Excision Repair) system has also been triggered during the early stages of seed imbibition to protect genomic integrity (Paparella et al., 2015; Kimmelshue et al., 2019). Seed dry coating, film coating, seed dressing, pelleting, and entrustment coating seeds via foliar application or direct soil application are all advanced methods for beneficial bacteria enhancement, with inoculation being the most prominent (I. Afzal et al., 2020).

##### 5. Contribution of PGPR for plant systemic resistance through seed bio-priming

Another positive feature of PGPR bio-priming on seed has indeed triggered the host plant to develop systemic resistance, which is a physiological state of improved defense ability that is created by specific environmental catalysts or stimuli and indications to strengthening and stimulating the plant's innate immune defense system against different environmental factors and pathogenic infections and attacks. Bioprimed seeds with high levels of antioxidative enzymes such as catalase, superoxide dismutase, peroxidase, glutathione reductase, ascorbic acid, and others showed better antioxidative defense mechanisms after

seedling (Hussain et al., 2019). Plant bio-priming by PGPR causes systemic resistance to a maximum range of plant pathogens (Naznin et al., 2013). Many PGPR in the plant rhizosphere contributes to induced systemic resistance (ISR) (Pieterse et al., 2014). The main contribution of PGPR that trigger plant ISRs have the ability to response the root immune system locally by producing signal or molecules that transfers to the plants leaves to actuate the defensive ability systemically. The pattern of amount and type of root secretions changes due to pathogen attack, which in turn leads to the selection of some ISR-inducing bacteria at the rhizosphere (Berendsen et al., 2018). Bio-priming by PGPR leads to ISR signaling and subsequently increases plant growth and development via. changes in the physical and chemical properties under salinity stress (Ji et al., 2020). Bio-priming of *Azospirillum* sp. a salt-resistant strain has been reported to improve grain weight and growth of *Triticum aestivum* L. (wheat) plants under salt stress (Nia et al., 2012). Bio-priming of *Azospirillum* sp. on lettuce seeds improved crop quality, increased growth and stability under different stressful conditions (Fasciglione et al., 2015). It has been reported that *P. fluorescens*, *P. stutzeri*, and *P. aeruginosa* strains isolated from tomato rhizosphere increase the production of phytohormones and ACC-deaminase and improve the tricarboxylic acid cycle and thus increase salt tolerance (De La Torre-González et al., 2018). Bio-priming of rice seeds with *B. amyloliquefaciens* has been shown to increase the tolerance of salinity and improve growth by producing auxin, abscisic acid, and regulating the expression and biosynthesis of several genes under salinity stress conditions (Shahzad et al., 2017). Seed bio-priming is one of the novel approaches to carry beneficial PGPR from lab to land, which increases overall plant growth, resistance against biotic & abiotic stresses and yield in different crops by enhancing physiological, biochemical, and molecular levels, this is one of the valuable assets for sustainable agricultural production in the modern era.

##### 6. PGPR based formulation and recommendations for future research

Biological seed coating is a new seed treatment technology in which microbial inoculants are coated on the seed surface to inhibit seed and soil-borne diseases (Afzal et al., 2020). The successful microbial

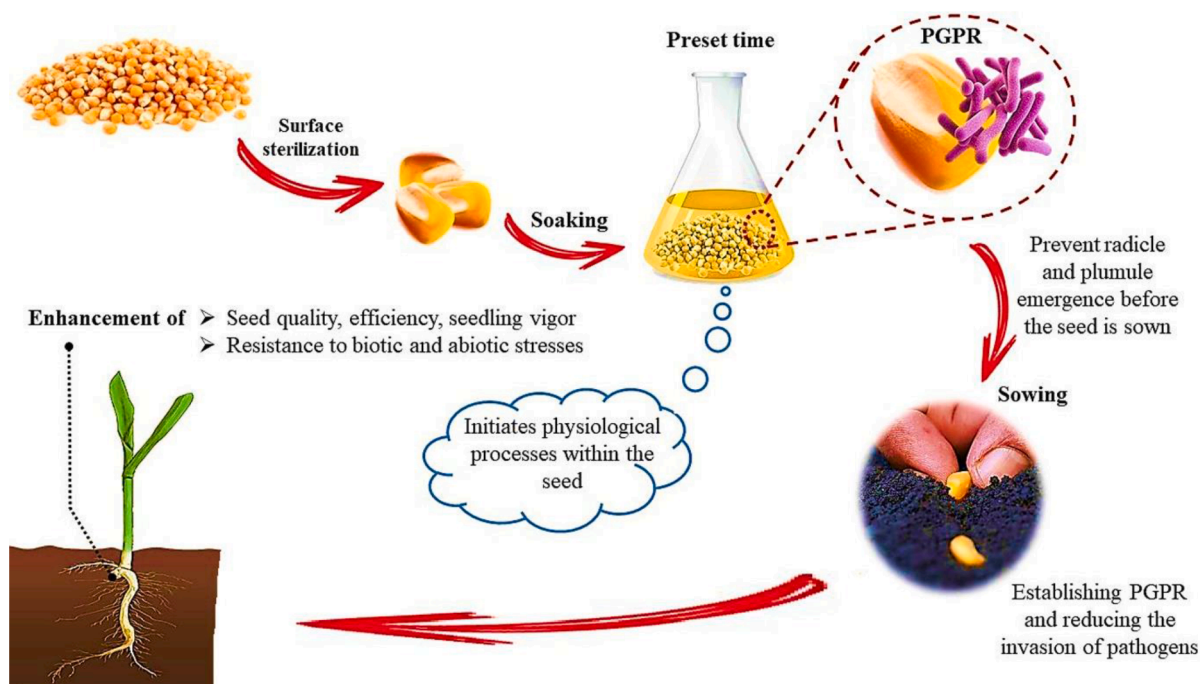


Fig. 2. Method of seed treatment in bio-priming with PGPR.



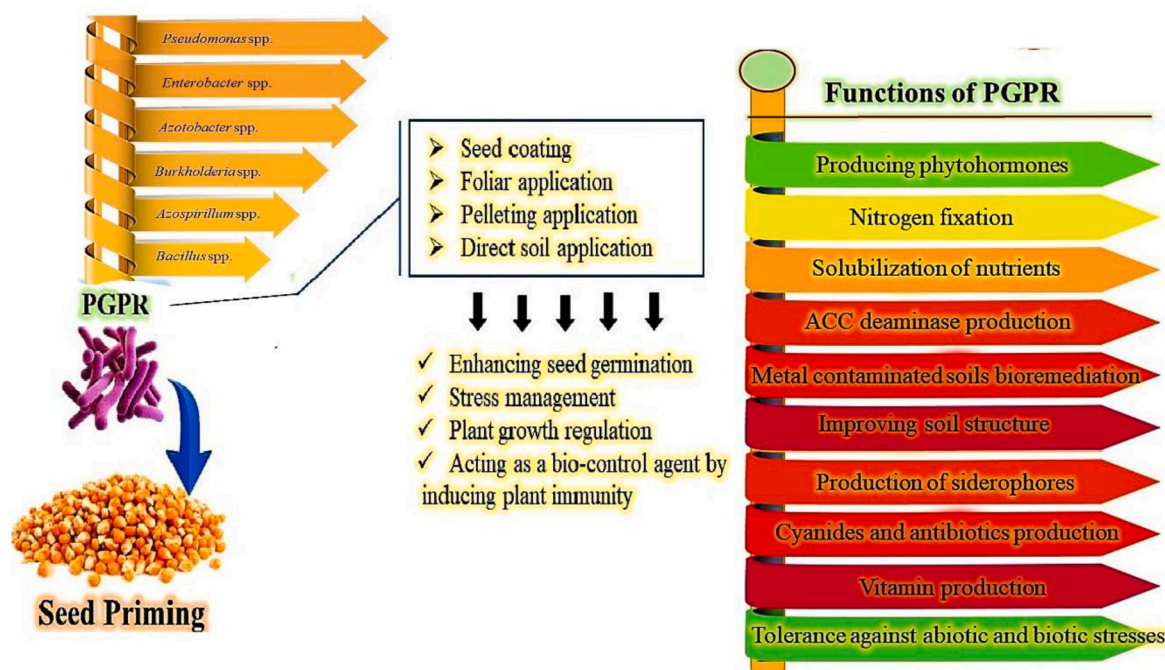


Fig. 3. Bio-priming with PGPR inoculant triggers the plant growth and health.

inoculants are depended on the selection of a right type of microbial strain, better adaptability, longer shelf life, novel carriers (solid or liquid), and other additives etc. The formulation has a significant effect on microbial survival during the product development, storage, and application processes in the field, as well as the efficiency of the product once treated to the plant host and the application's commercial viability (Herrmann and Lesueur, 2013; O'Callaghan, 2016; O'Callaghan, 2016). Though microbial formulation is a significant concern, a very limited number of investigation has been performed regarding this area (Parnell et al., 2016; Rocha et al., 2019). Some recent findings reported that the seeds treated with biopolymer enhance the shelflife of an individual as well as the combination of bacteria (Jagadeesh et al., 2019), this is another area to be focused in the future along with some important micronutrients, enzyme activators and additives etc. For example, a biochar-based seed covering containing *Bradyrhizobium japonicum* inoculum allowed for the long-term maintenance of a high bacterial population, resulting in efficient soybean nodulation (Chen, 2021; Gowthamy et al., 2017). The physical and chemical features of biochar play a significant impact on bacterial viability (Oni et al., 2019) in seeds. Seed coating or priming techniques to be developed and standardized for all type of field, plantation and horticultural crops, which should be cost-effective, time-saving and affordable to all the level of farmers.

#### Declaration of Competing Interest

The authors have declared no conflict of interest.

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