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Seed Quality Enhancement Through Seed Biopriming to Increase Productivity: A Review

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ABSTRACT

Consistent agricultural production needs a package of methods starting from the improved crop varieties to agronomic practices to fulfil the food demand worldwide. Agricultural productivity is mainly restricted due to poor seed quality coupled with several biotic and abiotic stresses. Therefore, enhancement of agricultural production through improved quality of seed needs additional practice to achieve sustainable growth of farm income. In this context, biopriming could serve as a viable approach to enhance crop productivity as it improves the performance of plants under sub-optimal conditions. In biopriming, the bacterial inoculum is used during the imbibition process that bypasses the need for hazardous agrochemicals linked with crop management practices. The use of microbial solution on the planting material is an economically and environmentally safe method for uniform crop establishment. Alongside biotic stress amelioration, biopriming also serves as a viable solution to enhance the nutrient use efficiency in crop plants. Overall, the introduction of biopriming in agricultural practices allows farmers to achieve better production with a minimum investment of costly inputs.

Key words: Biopriming, Biotic and abiotic stress management, Nutrient use efficiency, Seed quality enhancement.

Germination of non-dormant seeds generally requires hydration under several favorable conditions such as light, suitable temperature and presence of oxygen. Following imbibition of seeds, metabolic activities resume resulting in radicle emergence (Bradford, 2017). Thus, germination of seeds and emergence of seedlings are the crucial stages for obtaining optimum crop stand in fields. The quality seeds of newly released varieties of various field and horticultural crops by plant breeders along with proper agronomic management practices can assure augment crop yield with supplemented nutritional values (Singh *et al.,* 2015; Dutta 2018; Dutta *et al.,* 2020a, b; 2021a, b). But inadequate crop stand because of poor seedling emergence still remains a constraint that farmers have to face (Singh *et al.,* 2015). Unsynchronised seedling emergence due to variable environmental factors *viz.,* low soil moisture content is a major area of concern directly affecting the crop stand and consequently yield of the crop. Under such a scenario, there must be some innovative and cost-effective approaches to overcome these hurdles. Seed priming is one such approach. It allows seeds to proceed through the first reversible stage of germination but does not permit radical protrusion through the seed coat. The primed seeds retain desiccation tolerance and are dried and preserved until final planting (Lutts *et al.,* 2016). The different approaches to priming have found applications in various economically important crops. These methods have not only been instrumental in tackling abiotic stress (osmopriming, hydropriming) but have also been able to handle biotic stress (biopriming). The final result of seed priming is improved seed vigour defined as the entire set of properties influencing a seed lot's performance in diverse environmental conditions (Zhang *et al.,* 2015). So, the current context mainly focuses on seed biopriming, its methods and applications as a way of ensuring better crop stands and enhancing agricultural productivity.

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Seed priming: A comprehensive approach

Seed Priming is primarily considered as a seed quality enhancement method, wherein seeds are hydrated to initialize their metabolic activities followed by dehydration prior to radicle emergence. This results in rapid and uniform germination to improve crop establishment under field conditions (Singh *et al*., 2020). During seed priming, a series of physiological events take place inside the seeds leading to metabolic activation. These reversible changes upon priming treatments include activation of cell cycles, DNA repair mechanism, precise regulation of oxidative status, change in phytohormones levels, synthesis of enzymes and consequently mobilization of storage reserves (Chatterjee *et al.,* 2018, Lutts *et al.,* 2016). The hydrated seeds are then

dehydrated to a safe moisture content causing a temporary stoppage of metabolic activities. It is assumed that rehydration of the seeds will allow uniform emergence and crop stand as the primed seeds retain desiccation tolerance (Lutts *et al.* 2016). Thus, this process can also be described as a method for seed invigoration. Furthermore, seed priming is an approach concerned with the whole plant rather than the seed only. It has been observed that plants that have been exposed to stress early on in their lives undergo a series of transient metabolic adaptations that result in a stress memory, helping them to better adapt to future exposures to stresses (Tanou *et al.,* 2012).

Types of priming

Different methods of priming are used for different economically important crop plants such as rice (Reddy *et al.,* 2013), maize (Reddy *et al*., 2013), pearl millet (Raj *et al*., 2004) and chickpea (Singh *et al*., 2012). In this context, hydropriming is the most simple and cost-effective approach for enhancing of planting value of the seeds. It involves soaking of seeds in pure water followed by drying to original moisture content without the use of any other chemicals. On the other side, nutri-priming is an improvement over hydropriming, wherein solution containing nutrients instead of pure water is used for treatment of seeds. This method allows for better seedling establishment due to improved seed quality (Farooq *et al*., 2012). The next approach termed as osmo-priming, where seeds are soaked in salt solution with low water potential and thereby permitting the seed to imbibe water slowly followed by initiation of enzymes activity without radicle protrusion (Di Girolamo and Barbanti, 2012). In hormo-priming, plant growth regulators (PGR) are used during the soaking process which has a direct influence on germination and metabolism of the seed (Galhaut *et al*., 2014). The mostly used growth regulators include salicylic acid, gibberellic acid, auxin, ethylene, kinetin, polyamides and polyethylene glycol. Chemo-priming is another variant of the seed priming where an array of natural and synthetic compounds is used as a priming agent. Studies indicated that this method could be used to counter salinity stress (Fercha *et al*., 2014). Solid matrix priming involves exposing seeds to wet solids for a length of time, then separating, rinsing and drying the seeds. This method was adopted to counter high cost involved in procurement of the osmotic agents used in osmo-priming (Paparella *et al*., 2015). In biopriming, bacterial inoculum is used during the initial imbibition process without the involvement of the agrochemicals (Callan *et al*., 1990). This is the only approach that provides protection against several seed-borne and soil-borne pathogens without sacrificing ecological harmony. Studies also suggest that biopriming is more effective for management of disease as compared to seed pelleting or seed coating methods (Müller and Berg, 2008). Even though the other seed priming methods help to enhance the abiotic stress and uniform crop establishment, biopriming plays an important role in crop establishment as well as amelioration of biotic stress.

Biopriming as an approach to enhance nutrient use efficiency

Biopriming is a potential approach involving plant growth-promoting bacteria (PGPB). It is not only effective in dealing with pathogens but also substantially improves the nutrient uptake efficiency after treatment (Table 1). The process improves plant growth and establishment by releasing compounds involved in mineral solubilization (Sukanya *et al*., 2018). Most of the fertilizers added to the soil are not available to the plant as there are either run-off or leaching losses. This results in poor nutrient uptake and low nutrient use efficiency. In this context, various techniques have been followed to improve nutrient use efficiency. To achieve this, microorganisms have a very important role to enhance nutrient mobilization and their uptake. For instance, phosphate solubilizing microorganisms such as *Enterobacter, Bacillus* and *Pseudomonas* release crystal dissolving compounds and phosphate-solubilizing enzymes that make phosphorus available to the plants (Glick, 2012). Use of plant growth promoting rhizobacteria (PGPR) during biopriming also revealed higher production of plant growth hormones *viz.,* auxins and gibberellins to enhance crop establishment and uniformity (Kavino *et al*., 2010). PGPR has also been reported to mobilize potassium ions from potassium-bearing minerals by breakdown of rock potassium or chelating silicon ions (Sheng and He, 2006). In addition, bioprimed seeds recorded higher amount of soluble protein as compared to untreated seeds (Dhanya, 2014). Moreover, bio-primed seeds supplemented with PGPR have shown

Table 1: Use of biopriming in the enhancement of nutrient use efficiency in crops.

Nutrient	Microbe	Crop	Use efficiency	References
N	*Azospirillum amazonense*	Rice	3.5-18.5%	Rodrigues *et al.* (2008)
	Trichoderma harzianum	Maize	8.8-9.76%	Akladious and Abbas (2012)
	Trichoderma harzianum	Soybean	15.8%	Entesari *et al.* (2013)
	Trichoderma atroviride	Soybean	11%	Entesari *et al.* (2013)
P	*P. fluorescens*	Sugarcane	0.719%	Yadav *et al.* (2013)
	Trichoderma harzianum	Tomato	65.8%	Azarmi *et al.* (2011)
K	*Trichoderma harzianum*	Tomato	324.35%	Azarmi *et al.* (2011)
N+P+K	*Azospirillum brasilense*	Tea	65%, 25%, 14%	Thomas *et al.* (2010)
	Trichoderma harzianum	Tea	44%, 50%, 16.5%	Thomas *et al.* (2010)

Table 2: Use biopriming against pathogens in several monocots and dicots.

Crop	Pathogen	Bioagent	Reference
		Monocots	
Rice	*Rhizoctonia solani*	*Trichoderma virens, Pseudomonas fluorescens*	Reddy *et al* (2013)
Pearl Millet	*Sclerospora graminicola*	*Pseudomonas fluorescens*	Raj *et al.* (2004)
Maize	*Fusarium verticillioides*	*Trichoderma harzianum*	Reddy *et al.* (2013)
Sweet Corn	*Pythium ultimum*	*Pseudomonas aureofaciens*	Reddy *et al.* (2013)
		Dicots	
Chickpea	-	*Trichoderma harzianum, Pseudomonas aeruginosa*	Singh *et al.* (2012)
Pea	*Fusarium solani*	*Bacillus subtilis*	El-Mohamedy and Abd El-Baky, (2008)
Cowpea	*Rhizoctonia solani*	*Trichoderma harzianum*	El-Mohamedy *et al.* (2006)
Sesamum	*Macrophomina phaseolina*	*Chaetomium bostrycoides*	Sankar and Sharma (2001)
Sunflower	*Alternaria helianthi*	*Pseudomonas fluorescens*	Rao *et al.* (2009)

higher free amino acids and protein content pool in the cellular context (Warwate, 2017; Ahmed *et al*., 2014).

Biopriming to counter biotic stress

Biopriming is also used to improve crop stand by incorporating systemic resistance against several disease-causing organisms (Table 2). Jain *et al*. (2012) revealed that a combination of selected microorganisms showed synergistic effect with around 1.4 to 2.3 folds increase in defence parameters of the plants. They also added that interaction between plants and microbial populations results in production of antioxidant enzymes in plant cells to protect them from oxidative stress caused by pathogen infection. Beneficial microbes also help plants in regulation of reactive oxygen species (Singh *et al*., 2016). For instance, inoculation of *Pseudomonas fluorescens* in the carnation stem results deposition of phytoalexins in stem leading to low *Fusarium* wilt infection (Van Peer *et al*., 1991). A similar finding was also evident from cucumber while seeds were treated with PGPR strains resulting in lower anthracnose disease suggesting induced systemic resistance following application of PGPR strains to protect the leaves of the plants against *Colletotrichum orbiculare* (Wei *et al*., 1991). In another scenario, *Trichoderma harzianum* is the most often employed as bio-priming fungi for its wide range of antagonism against plant diseases caused by fungi and nematodes (Singh *et al*., 2004). Bacteria being the most abundant microorganism in soil play an indispensable role in maintaining soil fertility and nutrient upcycling. Seed bio-priming with PGPR improves plant performance in stressful situations, thereby increasing plant yield both directly and indirectly (Dimkpa *et al*., 2009). PGPR mainly exerts its effect by inducing direct stimulation of plant growth and improvement through the supply of common nutrients and phytohormones released from bacterial siderophores (Hayat *et al*., 2010).

Applications of biopriming

Experimental evidence from various crop models made biopriming instrumental in support of biotic stress resistance management and augmenting nutrient use efficiency (Sukanya *et al*., 2018; Glick, 2012). The use of biocontrol agents (BCAs) such as *Pseudomonas* and *Trichodema* have been proven to ameliorate plant diseases. As root rhizosphere is the home for many microbial colonies, seed biopriming allows better interaction of plants with the microbial population leading to better plant growth. The capacity of a group of suitable soil microorganisms to collaborate among themselves and with the plant favors the adoption of microbial consortiums rather than inoculation of seeds with a single microbe species. Plant development and abiotic stress tolerance may benefit from the synergistic action of microbial consortia. In addition, microbial consortiums may potentially improve the plants' resistance responses to a wide range of soil and seed-borne diseases (Jain *et al*., 2012; Wei *et al*., 1991). In rice, use of *Trichoderma* and *Pseudomonas* as a biopriming agent improves the antagonistic effects against infection by *Rhizoctonia* (Reddy *et al*., 2013). Other beneficial microorganisms such as *Pseudomonas* and *Bacillus* have been implemented in pulses crops (pea and chickpea) to reduce the pathogenic effect exerted by *Fusarium* spp. (El-Mohamedy and Abd El-Baky, 2008). Improvement of several growth parameters (root length, dry weight and shoot length) and reduced occurrence of root rot were also evident in the field trial of mung beans when seeds were treated with *Trichoderma harzianum* (Sarkar and Bhattacharya, 2008). Similarly, treatment of *Pseudomonas aeruginosa* on soybean was successful to control damping-off disease caused by *Colletotrichum truncatum* (Begum *et al*., 2009). Mung bean seeds treated with *Pseudomonas fluorescens* were shown to enhance growth and better resistance against *Macrophomina phaseolina* causing charcoal rot disease. The number of seeds per pod and the number of pods per plant had increased significantly when the inoculum was added as compared to the control (Saxena, 2010).

CONCLUSION AND FUTURE PROSPECTS

Plant resistance to a wide spectrum of plant diseases is enhanced by a microbial consortium of agriculturally relevant

bacteria that allows the plant to manage defence response in a synergistic manner. The use of microorganisms in the management of plant diseases is not only economical but an eco-friendly approach. Biopriming is a method that is effective to mitigate biotic stress. It is a new priming approach that outperforms all existing priming methods in terms of improving seed germination, seedling vigour and plant health. Various bioagents can be used to manage pathogens in many agriculturally important crops. Alongside, biopriming can also be practiced to achieve sustainability in agriculture by reducing the use of hazardous agrochemicals. Additionally, the bio-primed seed can be subjected to an expression study to understand the underlying molecular mechanism (Forti *et al*. 2020; Dutta *et al*. 2019 a, b and c, 2020 c). Scientists have highlighted that biopriming may be utilized effectively in the application of bacteria because it provides a sufficient quantity of bacteria in the seeds. It might be an alternate method for applying bacteria to tiny seeded crops that can ingest the bacterial solution, allowing bacteria to enter the seed. Biopriming provides equivalent or superior control of various root rot diseases, making it a viable commercial alternative to fungicides. Competition of our intended inoculants with native bacteria is another issue that can be solved by biopriming since our chosen bacteria will already be within the seeds, minimizing the risk of desiccation and the detrimental effects of any pesticides used in the field. Due to cost barriers, there is a need to seek for better medium for application in the application, which may be decreased with additional study. Second, this strategy may be used for other crops that have yet to be tested, providing a more accurate picture of the technology's potential.

Authors' contribution

Writing of the manuscript: Abhik Roy, Swarnadip Ghosh, Bipratip Dutta and Suman Dutta; Conceptualisation of the manuscript: Suman Dutta and Abhik Roy; Curation of the table: Swarnadip Ghosh and Abhik Roy; Outline of the manuscript: Abhik Roy, Swarnadip Ghosh and Suman Dutta.

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