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Seed Biopriming– A Review

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Abstract

There are various seed priming methods such as hydro priming, osmo priming, solid matrix priming, hormo-priming, chemo-priming, nutri-priming and biopriming being useful for enhancing the seed germination, seedling vigour and to overcome abiotic stress. Moreover to these advantages, of all priming methods only biopriming method gives an extra advantage of biotic stress management and thus gain special attention. Solubilisation or mobilization of soil macro and micronutrients, siderophore production, induction of plant growth promoting activities, induction of useful biochemicals, phytoalexin and defense-related enzymes and induced systemic resistance are the mechanisms involved in seed biopriming. Range of fungal or bacterial bio agents *viz*., *Azotobacter*, *Rhizobium*, *Arthrobacter*, *Agrobacterium*, *Azospirillum*, *Enterobacter*, *Streptomyces*, *Bacillus*, *Burkholderia*, *Klebsiella*, *PSB*, *Pseudomonas fluorescence, Trichoderma viride, Trichoderma harzianum* and Vesicular Arbuscular Mycorhiza, whether they are biofertilizer or biopesticide, may be useful as biopriming agents. Seed biopriming is useful in almost all the crops over the globe and is an eco-friendly substitute to chemical fungicides.

Keywords: Biopriming, bioagent, PGPR, seed

1. Introduction

Bio-priming is an innovative skill of seed treatment that assimilates biological (inoculation of seed with beneficial organism to protect seed) and physiological facets (seed hydration) of disease control (Reddy, 2012). It is recently used as an alternate method for controlling many seed and soil-borne pathogens. Biopriming of seeds denotes standard tactic for introduction of disease resistance via bio control agents. Priming of seeds with helpful microorganisms and bio control means has been testified more proficiently for the management of diseases and pests as equated to other available methodologies (Prabha et al., 2019). The seed biopriming is a recently adapted method of seed priming. Seed priming is a pre-sowing treatment which leads to a physiological state that allows seed to germinate more proficiently. The preponderance of seed treatments are based on seed imbibition allowing the seeds to go through the first reversible stage of germination but does not allow radical protrusion through the seed coat. Seeds keeping their desiccation tolerance are then dehydrated and can be stored until final sowing (Stanley et al., 2016). Even though there are diverse types of seed priming approaches being adopted in the crops biopriming is having its own importance and thus tried to summarize the review of literature on the seed biopriming here.

2. Different Types of Seed Priming

There are numbers of priming approaches being expedient in numbers of horticultural and forest tree crops. First one is hydro priming which relies on seed soaking in pure water and re-drying to original moisture content prior to sowing. No use of additional chemical substances as a priming agent makes this method a cheap and eco-friendly (Taylor et al., 1998). The second one is osmopriming which involves soaking seeds in salty solution with low water potential instead of pure water. Due to low water potential of salty solutions, water enters seed slowly which allows steady seed imbibition and activation of early phases of germination but restricts radicle protrusion (Di Girolamo and Barbanti, 2012). Third one is solid matrix priming which involves mixing and incubation of seeds with wet solid water carrier for a certain period. Subsequently, seeds are detached from matrix, washed and back-dried. The use of solid medium permits seeds to hydrate gradually and stimulates natural imbibition process arising in the soil (McDonald, 2000). Fourth one is hormopriming in which seeds imbibition arises in the presence of plant growth regulators, which can have direct influence on seed metabolic processes. The growth regulators frequently used in hormopriming are: abscisic acid, auxins, gibberellins, kinetin, ethylene, polyamines and salicylic acid (SA). Gibberellic acid (GA_3) and PEG priming improved photosynthetic properties, antioxidant system, seedling emergence and growth of white clover on heavy metal polluted soil (Galhaut et al., 2014). Fifth one is chemo-priming which denotes to seed treatment with different chemical solutions used as priming agents. This practice includes priming with extensive range of both natural and synthetic compounds such as antioxidants (ascorbic acid, glutathione, tocopherol, melatonin and proline), hydrogen peroxide, sodium nitroprusside, urea, thiourea, mannose, selenium, chitosan, fungicide etc. Positive effects of chemo-priming with various priming agents in a wide range of environmental conditions were directed by various studies (Patade et al., 2012). Sixth one is Nutri-priming in which seeds are soaked with solutions containing the limiting nutrient instead of pure water. The inkling of this technique is to acquire nutritional influence composed with biochemical benefits of priming in order to increase seed quality, germination parameters and seedling establishment (Farooq et al., 2012). Seventh and last one is biopriming which involves seed imbibition together with bio control agent or PGPR inoculation of seed (Callan et al., 1990).

3. Merits of Bio-priming Over Other Seed Priming Methods

As other priming method, bio-priming also intensifies rate and homogeneity of seed germination, but also protects seeds against the soil and seed-borne pathogens. Hydration of seeds infected with pathogens during priming can result in a stronger microbial growth and subsequently weakening of plant vigour. However, applying antagonistic microorganisms during priming is an eco-friendly procedure to overwhelm the disease problem (Reddy, 2013). Moreover, some bacteria used as bio control agents are able to inhabit in rhizosphere and upkeep plant in both direct and indirect way after germination stage (Callan et al., 1997). It was observed that seed biopriming is a highly effective tactic of disease management than other practices such as pelleting and film coating (Muller and Berg, 2008). Now a days, the use of biopriming with plant growth-promoting Rhizobacteria (PGPR) as an integral component of agronomic practice shows great potential (Timmusk et al., 2014). Hydro priming, osmo-priming, hormo-primng, solid matrix priming, chemo-priming and nutri-priming are the priming approaches those were mostly found appropriate to reduce abiotic stress but the biopriming was not only found appropriate to fight abiotic stress but also to fight biotic stress (Stanley et al., 2016). Bio primed seeds have an advantage over nonprimed seeds at the initial germination phase because bio-primed seeds have huge carbohydrate storage reserves which fortify the plant to stay alive from low oxygen stress under waterlogged situations (Ella et al., 2011). Seed biopriming is also a best substitute to chemical fungicides and is eco-friendly too. Thus, biopriming is now days considered as a very good biological weapon which would be useful in Agriculture.

4. Mechanisms Involved in Seed Biopriming

Bio-priming is directly involved in the enrichment of plant development by the excretion of compounds and mineral solubilisation (Sukanya et al., 2018). Phosphorus solubilising microorganism like *Bacillus, Beijerinckia, Enterobacter, Microbacterium*, *Pseudomonas* and *Serratia* release rock crystal dissolving compounds like organic anions, protons, hydroxyl ions, carbon dioxide or liberation of extracellular enzymes namely phosphatase leads to solubilisation of the phosphorus and make it obtainable to plant (Zaidi et al., 2009; Glick, 2012). Some PGPR used in bio-priming have the capacity to mobilize potassium from potassium-bearing minerals (Mica, illite and Orthoclase) by emission of organic acids (citric acid, tartaric acid and oxalic acid) which directly dissolves the rock potassium or chelate the silicon ion (Sheng and He, 2006). Siderophore production by bio control agents in primed seeds has inhibited the disease and improved the plant growth (Keswani et al., 2014; Jain et al., 2012). Bio-priming with PGPR in various crops having the capacity to produce growth hormones such as auxin, cytokinin, gibberellin etc. which recorded high germination rate, higher shoot and root growth and homogenous crop stands (Glick, 2012; Noel et al., 1996; Verma et al., 2001). Bio-priming is the best solution for better growth and expansion of micro-propagated plants which have abridged photosynthetic activity, poorly working stomata and undersized root and shoot system (Kavino et al., 2010). Bio-priming with PGPR reducing the period required for lignification of micro-propagated plants and accelerates production process (Ramamoorthy et al., 2002). Bio-priming leads to biochemical changes viz., enhanced production of proteins, hormones, phenol and flavonoid compounds contribute to enhanced plant growth and improved performance. Growth responses in herbaceous plants are calculated by nitrogen reserve compounds like nitrates, amino acids and proteins (Volenec et al., 1996). Soluble protein fractions in bio-primed seeds and seedlings were found higher as compared to non-primed seeds (Dhanya, 2014). There was increase in total protein content and free amino acid content during the diverse growth stages after seed bio-priming with PGPR (Aishwath et al., 2012; Warwate, 2017, Ahmed et al., 2014). PGPR used in bio-priming enriched the production of particular phenolic substances in plants at diverse growth phases (Singh et al., 2003). Moreover to plant growth preferment, seed bio-priming also encourages the production of defense-related enzymes (peroxidase, superoxide dismutase, catalase, chitinase, ammonia lyases, etc.) which deals with the plant fitness benefit against biotic and abiotic stress. The respiration, energy metabolism and early reserve mobilization events in crops were controlled by bio-priming (Chen et al., 2013; Paparella et al., 2015). Seed biopriming with bio control agents was also found useful in the development of induced systemic resistance in plants. Biocontrol agents, particularly rhizobacteria, have been shown to be effective in defeating disease infection by encouraging a resistance mechanism called “induced systemic resistance” (ISR) in varied crops (Van Loon et al. 1998). Induced resistance is defined as encouragement of plants with enhanced defensive ability of plants against different plant pathogens. Van Peer et al. (1991) found that inoculation of *Pseudomonas fluorescens* in carnation stem lead to low infection of *Fusarium* wilt. This low level of *Fusarium* wilt was endorsed due to induced resistance and deposition of phytoalexins in the carnation stem. Similarly, Wei et al. (1991) confirmed that seed treated with PGPR strains in cucumber resulted in declining of anthracnose disease and further concluded that the application of PGPR strains to seeds activated induced systemic resistance which leads to protect the leaves of cucumber plants against anthracnose disease caused by *Colletotrichum orbiculare*.

5. Fungal Bioagents Used in Seed Bio-priming

Extensive kind of fungal bio control agents through its innovative interactions with plant has made them helpful for combating biotic and abiotic stresses. *Trichoderma harzianum* is most commonly used bio-priming fungi for its infinite range of antagonism against plant pathogens, mainly fungi and nematodes (Singh et al. 2004); enlarged plant growth especially roots particularly under stress (Shoresh et al. 2010); systemic resistance to abiotic plant stresses including drought, salt and temperature (Mansouri et al. 2010 ; Shoresh et al. 2010); decomposition of organic matter thereby increasing humic acid in soil; solubilisation and mobilisation of phosphorus and enhanced nitrogen use efficiency and nutrient availability (Singh et al. 2004). Symbiotic fungi, Vesicular Arbuscular Mycorrhiza (VAM), *viz*. *Acaulospora* sp., *Ambispora* sp., *Gigaspora* sp., *Glomus* sp., *Pacispora* sp. and *Paraglomus* sp., have revealed significant influence on plant nutrient uptake, growth and colossal capacity to resist abiotic stresses, especially in drought situations; however, the success of establishing symbiotic interaction was limited through bio-priming, but recent reports suggest that inclusion of some biostimulants has made it successful by increasing the occurrence of viable colonies and percent infection at early seedling growth stages. Seeds of tomato treated with *T. harzianum* Rifai strain T-22 alleviated abiotic stress factors like osmosis, salinity, chilling and high temperature (Mansouri et al. 2010).

6. Bacterial Bioagents Used in Seed Bio-priming

Bacteria are the most ample soil microbes and having vital part in nutrient cycling for preserving the soil fertility. Helpful bacteria in rhizosphere are of two types: (a) bacteria forming symbiotic association through particular assemblies and (b) free-living bacteria present in the neighbourhood of plant province which are mainly known as plant growth-promoting rhizobacteria (PGPR). PGPR include a extensive variety of bacteria belonging to genera *Azotobacter*, *Arthrobacter*, *Agrobacterium*, *Azospirillum*, *Enterobacter*, *Streptomyces*, *Bacillus*, *Burkholderia*, *Klebsiella*, *Pseudomonas* and *Serratia* (Gray and Smith, 2005; Vessey, 2003). Application of PGPR to seed through seed bio-priming enhances plant performance under stress environments and consequently enhances plant yield both directly and indirectly (Dimkpa et al., 2009). Some PGPR may induce direct stimulation of plant growth and its improvement by providing them with some common nutrients and phytohormones that have been impounded by bacterial siderophores (Hayat et al., 2010; Rodriguez and Fraga, 1999). Strains of *Rhizobium leguminosarum* pv. *Viciae* deliberate tolerance to abiotic stress factors like drought and salinity by preserving its capability to nodulate and fix nitrogen in faba bean (Belal et al., 2013). Inoculation of PGPR via seed biopriming shows synergistic effects, where one acts as a helper for enhanced performance of other inoculant. In the rhizosphere, the synergism between various bacterial genera such as *Bacillus*, *Pseudomonas* and *Rhizobium* are well demonstrated to promote plant growth and development. Compared to single inoculation, co-inoculation improved the absorption of nitrogen, phosphorus and other mineral nutrients by seed crop (Figueiredo et al., 2011; Yadegari et al., 2010).

7. Application of Seed Bio-priming in Various Crops

Khan (1992) showed that seed priming comprehended a range of physiological treatments that boosted seed germination and seedling vigour through the addition of moisture. The addition of microbial biocontrol agents during biopriming allowed bioagents for colonization of the seeds prior to planting and added a new dimension to seed priming treatment. Malathi and Doraisamy (2004) found that seed priming with *Trichoderma* protected seeds of groundnut from the infection of *M. phaseolina* with improved seedling vigour, dry matter production and prevented loss of oil content up to six months of storage. Mohamedy et al. (2006) found that biopriming of pea seeds with *T. harzian*um showed significant decrease in pre-emergence damping off caused by *F. solani*, *R. solani* and *M. phaseolina* which was at par with soil treatment of bagasse + *T. harzianum* (10% w/w). It also resulted significantly more fresh pod yield and quality as compared to the chemical seed treatment. Sarkar and Bhattacharya (2008) found that the mung bean seeds soaked in suspension of *P. fluorescens* or *T. harzianum* not only reduced the root rot incidence in pot trial but also increased root length, shoot length, dry weight of seedling (45 DAP) and yield as compared to control in field trial. Mohamedy and Baky (2008) found that biopriming of pea seeds with *B. subtilis* and *T. harzianum* showed the highest survival and lowest root rot disease incidence. It also showed highest plant height, more numbers of leaves and branches/plant, dry weight of shoots/plant, pod length and diameter, numbers of seed/pod, highest percentage of green pod, seed to pod weight, TSS, highest carbohydrate and protein. Nayaka et al. (2008) emphasized that the biopriming with *T.harzianum* was more effective in controlling the *Fusarium verticillioides* incidence of maize. The result further indicated an increase of seed germination, vigour index, field emergence, yield, and test weight in comparison with the control. Biopriming with *P. aeruginosa* was the most effective treatment for controlling pre and post-emergence damping-off of soybean caused by *C. truncatum*. It also enhanced germination of seed and healthy seedling stand (Begum et al., 2009). Sharma et al. (2009) showed that biopriming of cumin seeds with *T. harzianum* increased the germination of seeds while biopriming with *T. viride* showed good shoot-root ratio in pot condition. Someshwar and Sitansu (2010) used bacterial inoculum of *P.fluorescens* for seed biopriming and they found better performance in stimulating the germination of seeds of chilli, tomato and brinjal over some fungal biopriming agents *viz*, *T. viride* AN-10 and *T. harzianum* AN-13 while it was equivalent to *T. harzianum* WB-1 in inducing germination of the crop seeds. The highest germination of seed was obtained when crop seeds wereprimed with mycelial form of inoculum of *T. harzianum* AN-5 and WB-1. Minaxi and Saxena (2010a) recommended bacterization of seeds of moong bean with *P. fluorescens* BAM-4 as a potential method for enhancing plant growth, yield and for providing protection against *M. phaseolina*. It also showed a significant increase in seed germination, shoot length, shoot fresh and dry weight, root length, root fresh and dry weight, leaf area and rhizosphere colonization. Yield parameters such as pods, numbers of seeds, and grain yield per plant also enhanced significantly in comparison to the control. Moreover, the production of siderophore (a source providing iron) and chitinase (a source providing protection against pathogenic fungi) by *P.fluorescens* BAM-4 was also observed *in vitro*. Further, Minaxi and Saxena (2010b) reported bacterization of seeds of moong bean with *P. aeruginosa* RM-3 as a potential method for enhancing plant growth, yield and for providing protection against diseases caused by *M. phaseolina*. It also showed a significant increase in seed germination, shoot length, shoot fresh and dry weight, root length, root fresh and dry weight, leaf area and rhizosphere colonization. Yield parameters such as pods, number of seeds, and grain yield per plant also enhanced significantly in comparison to control both *in vitro* and in field condition.

8. Conclusion

Seed bio-priming is one of the innovative priming method over all the other priming methods as it is being useful not only for enhancing the seed germination, seedling vigour and to overcome abiotic stress but also useful for the management of biotic stress. Range of fungal or bacterial bio agents whether they are biofertilizer or biopesticide may be useful as biopriming agents. Seed bio-priming is useful in almost all types of cereal, pulse, vegetable, horticultural and forest crops.

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