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Solid Matrix Priming: An Effective Technique Used for Improvement in Seed Emergence, Vigor and Seedling Growth of Vegetable Crops

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ABSTRACT

Poor crop stands are one of the most common abiotic constraints faced by vegetable growers of developing countries due to production of low quality seed. Multiple factors, especially abiotic stresses and seed dormancy restrict seed germination and seedling growth. Up till now, seed priming is still considered as effective and cheapest method to enhance seed germination and to mitigate the drastic effect of abiotic stresses. Manipulation of seed hydration through solid matrix priming technique not only improves germination characteristics but also stimulates biochemical processes like restoration of metabolic activities through protein and nucleic acid synthesis (RNA and DNA), increases enzymatic activities, and improves the storage of organic substances in germinating seeds. It was also found effective in improving seedling establishment under salinity, drought, and temperature stresses by activating defence mechanisms. Therefore, this review highlights the role of solid matrix priming in improving the germination and stand establishment of vegetable crops under suboptimal conditions.

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INTRODUCTION

With an immense increase in human population, a pressure has been developing on an agricultural sector to fulfill human food needs at limited resources with changing climatic conditions. For this purpose, availability of improved quality seed is considered as an important challenge for production of high yielding produce (Kumar *et al.*, 2020). Seed industry faces many problems regarding storage and quality control. Crop growth and product quality are determined by genetic (varieties) and somatic (vigor) factors of seed (Chomontowski *et al.*, 2020a). As the main purpose of seed is to develop into vigorous and healthy plant having maximum physiological and metabolic activities. However, seeds can't retain their vigor and viability for a longer time period because they deteriorate rapidly and die. (Adhikari *et al.*, 2022). Moreover, delayed germination and slower growth of seedlings under different biotic and abiotic stresses not only limit their growth and development but also adversely affect yield and quality (Lamichaney *et al.*, 2018; Kumar *et al.*, 2020). Therefore, development of techniques for uniform and fast growth of germinated seedlings is an important and sustainable approach to enhance agricultural productivity (Kumar *et al.*, 2020). Seed technologists developed seed invigoration technique to hasten germination and synchronize emergence (Mercado and Fernandz, 2002). Among different new technologies for seed enhancement, seed priming still plays an important role in improvement of seed germination and vigor (Chomontowski *et al*., 2020a).

Factors Effecting Germination of Vegetable Crops

Vegetable crops possess higher yield potential, high return value, and sustainability; therefore, these are very important for improvement in livelihood of small land-holding farmers (Thakur *et al*., 2022). Demand for vegetable crops is increasing now a days as these are essential for the human diet and provides carbohydrates, phytochemicals, protein, minerals, and vitamins important for human health (Singh & Khokhar, 2014). However, reliable and high-quality vegetable production is recognized as an important challenge by farmers and scientists (Srivastava *et al*., 2022). There are multiple factors including biotic and abiotic stresses, poor and delayed, germination, loss of seed viability and seed dormancy constraining the production of vegetables (Sohindji *et al*., 2020; Faiz *et al*., 2022; Sehgal and Robotka, 2020). The main issue preventing seed germination in vegetable crops is seed dormancy. Seed dormancy is defined as an inability of a seed to germinate under conditions not favorable for survival of seedlings (Reed *et al*., 2022). There are various types of dormancies that prevent seed germination in favorable conditions ranges from adverse environmental conditions, hormonal regulation and physiological factors (Srivastava *et al*., 2022). As in okra and cucurbits hard seed coat causes impermeability to water (Safdary *et al*., 2020; Rani *et al*., 2021) and in spinach presence of germination inhibitors and mucilage layer prevent oxygen availability to embryo (Kulsumbi *et al*., 2020). While temperature variability and drought at seed maturation stage induced physiological dormancy i.e. lettuce and tomato (Reed *et al*., 2022) whereas suboptimal storage conditions such as fluctuating humidity and temperature causes loss of viability in onion seeds (Rao *et al*., 2006).

Seed priming proves to be an effective technique to improve vegetable production in response to changing climatic and environmental conditions. As rapid seed germination with uniform seedling not only shorten plant life cycle but also leads to cost efficient crop production.

Priming

Seed priming, also known as pre-germination technique, is a physiological process that manages seed hydration for effective germination with early and uniform seedling growth (Garcia *et al*., 2022; Ling-Yun *et al*., 2022). It initiates germination process by partially hydrating it to maintain pre-germination metabolic activity but at low water potential to prevent radical protrusion (Choudhary *et al*., 2008; Olszewski *et al*., 2012). Moisture content of seed is maintained up to 40-45% of fresh weight basis that corresponds to the moisture content of 90-95% to permit radical protrusion (Corbineau *et al*., 2023). After treatments, seeds were dried back to their initial moisture content and stored for germination (Olszewski *et al*., 2012). Overall, priming activates physiological processes involved in early phase of germination (Abdelkader *et al*., 2023).

History of seed priming was dated back to 372-287 BC, when Greek farmers soak cucumber seeds in water or milk for enhancement of germination. However, the term priming was introduced by Heydecker in 1973 who observe that priming improves germination and seedling growth in any stressful growing conditions (Nair, 2022). It is a relatively affordable method of seed hydration, and it usually involves preparing the seeds either with natural water or with various chemicals (Sarthi and Rawat, 2020). Priming also shorten the mean emergence time between sowing and the emergence of seedlings by increasing carbohydrate biosynthesis, antioxidants, phytohormones production, induced enzymes and protein activity such as heat shock protein and late embryogenesis abundant protein and initiate respiratory associated pathways (Ling-Yun *et al*., 2022; Srivastava *et al*., 2022). It minimizes seed sensitivity towards adverse environmental conditions (Michalska-Klimczak *et al*., 2018) by reducing cellular damage during water imbibition process, ionic homeostatis, regulating metabolic activities, and helps in repairing any damage to DNA (Tania *et al*., 2022; Ling-Yun *et al*., 2022). It prompts plants to immediately open their immune responses and has the potential to become an effective and strategic tool for modern plant protection methods (Srivastava *et al*., 2022).

Priming technology is commonly approved and used by growers and seed manufacturers due to its cost effectiveness, variability for wide range of plants and environmentally friendly (Garcia *et al*., 2022). Furthermore, it also helps in development of sustainable agriculture as it saves time, minimize expense related to re-seeding, application of additional irrigation and fertilizer to weak plants and reduced labor cost (Acharya *et al*., 2020).

Different seed priming techniques (physical and chemical) such as conventional solid matrix priming, osmo-priming, halopriming, hydropriming and advanced i.e., biopriming, cold plasma priming, and nanopriming are employed to break seed dormancy and increase seed yield and vigor in many horticultural crops. These priming techniques are used for improving plant growth, nutrient efficiency and stress tolerance in different crops (Sher *et al*., 2019). But the success of seed priming depends on plant genotype/specie, environmental conditions, seed vigor and priming technique being employed to improve seed germination (Adhikari *et al*., 2022).

Solid Matrix Priming

Among the several priming methods, Solid matrix priming is an important priming method for repairing aging and improving seed quality (Muhie *et al*., 2020a). SMP technique proposed by Eastin (1990) involves combination of seed, solid matrix and water to control temperature, oxygen and moisture that affect germination. In this technique, moistened seeds are mixed with insoluble solid matrix/organic carrier and their moisture level is maintained to a level just below seed sprouting (Nakkeeran *et al*., 2021). During this process, seeds are hydrated enough to begin metabolic process required for germination but prevent radical protrusion (Cumagun, 2014). Insoluble solid matrix materials allow **seeds** to hydrate moderately and work similar to imbibition process take place in soil under normal field conditions (Raj and Raj, 2019). SMP also known as solid matric conditioning is a limited and controlled hydration like osmo or hydorpriming but in this technique good amount of oxygen is provided during the hydration process (Sher *et al*., 2019). In this priming, both matrix and seed compete for water. Treated seeds absorb water and reach an equilibrium which is exactly the right time of priming to be occur (Adnan *et al*., 2020). Due to which, an optimally hydrated, metabolic active state is achieved within a seed (an important criteria for germination). These also include development of immature embryos, destruction of enzymes causing dormancy, alteration of tissue covering embryos and repair mechanisms (membrane, genetic material) (Rhaman *et al*., 2020).

Type of carrier material used as impact on seed germination due to difference in chemical composition and pH of solid matrix (Ashraf and Foolad, 2005). Solid material used for carrier must have low water solubility, high bulk density and bulk value with high matric to osmotic component capacity and water holding capacity. All these properties minimize problems of aeration in solid matrix (Arunkumar *et al*., 2019). They have large surface area, non-toxic to seed and has high ability to stick to seed surface (Raj and Raj, 2019). Materials include sand, charcoal, peat moss, clay, sodium polypropionate gel, charcoal, volcanic cinder, expanded calcined clay, bitominous soft coal, Agro-lig, sawdust (Mercado and Fernandez, 2002). Vermiculite compounds (Zonolite), Celite, Micro Cel E (Hydrated lime, water, Diatomaceous earth) are also used as carrier (Ashraf and Foolad, 2005). After seeds were primed, they were separated from matrix, rinse and dried-back. To obtain effective results, treatment time and water content of matrix must be determined (Lutts *et al*., 2016).

SMP has several advantages over other priming techniques, it is cheaper and easier to execute (Wu *et al*., 2019). It facilitates incorporation of fungicide, insecticide or any other biological agent and minimizes aeration to prevent seed deterioration (Hosamani *et al*., 2020). SMP is used in place of osmopriming due to high cost of osmotic agents and aeration problems faced during osmopriming (Sarthi and Rawat, 2020). Furthermore, it used minute amount of water per unit of seed and solid carrier (Mercado and Fernandez, 2002). It is also useful for increasing germination percentage and germination rates in many crop seeds. Rapid germination after SMP will mostly result in larger seedlings and well-developed transplants in the modules in a shorter period (Ozden *et al*., 2018). Many vegetable crops benefit greatly from solid matrix priming in terms of seed germination, seedling growth and protection from different biotic and abiotic stresses (Table 1 and Figure 1). The review for the first time describes in detail the role of solid matrix priming in improving germination and seedling characteristics of vegetable crops under suboptimal growing conditions.

Effect of Solid Matrix Priming in Improving Seed Germination of Vegetable Crops

Optimum seed germination is considered as an important factor that determined crop stand or establishment in field as seed is the main component in crop production (Rhaman *et al*., 2020). It is the fundamental stage of plant's life that is highly influenced by environmental factors, and it begins with uptake of water by non-dormant, dry seed and finishes with radicle protrusion form the seed coat (Kubala *et al*., 2015).

Table 1. Solid matrix priming improves seed germination characteristics of different vegetables.

Crops	Material	Concentration	Time duration	Best results	Reference
Hot pepper (*Capsicum frustescens*)	Sawdust & GA3	1:2:5	16°C for 6 days	Germination parameters, seed quality, and protein content increased	Ilyas (2006)
Onion (*Allium cepa*)	Micro Cel E	2:1:3	15°C for 5 days	Improved germination of aged seeds.	Kępczyńska *et al.* (2003)
Beet and chard microgreens (Beta vulgaris)	Vermiculite	500 g	27°C for 2 days (beet) 27°C for 3 days (chard)	Increase 0.33 fold shoot growth in beet and 2.79 in chard	Lee *et al*. (2004)
Hot pepper (*Capsicum frustescens*)	Vermiculite	200 g	25°C for 2 days	Reduced leakage of electrolytes	Pandita *et al*. (2007)
Tomato (*Solanum lycopersicum*)	Vermiculite	10 g	25°C for 1 day	Improve soluble protein and phosphorus content in seed	Pandita *et al*. (2010)
Pepper (*Capsicum frustescens*)	Patula herbal tea	2 and 10g/L	25°C for 1 day	All the primed seeds survived under salinity stress conditions	Mavi and Atak, (2016)
Okra (*Abelmoschus esculentus*)	Calcium aluminium silicate	1:0.4:1	1 day	Increased seed germination and fruit yield	Sharma *et al*. (2014)
Carrot (*Daucus carota*)	Vermiculite	200g	25°C for 1 day	Higher speed of germination (14 days) n with maximum seed germination (85%)	Singh *et al*. (2015)
Bitter gourd (*Momordica charantia*)	Perlite	1:2:1	20°C for 3 days	Highest total field emergence, and fruit yield	Kanwar and Mehta, (2017)
Eggplant (*Solanum melongena*)	Vermiculite	1:3:3.2	15°C for 7 days	Increase in seed germination vigor index and seedling emergence,	Ling-yun *et al*. (2017)
Cabbage (*Brassica oleracea*)	Vermiculite	1:2:2.5	25°C for 16hrs	Increased seed germination and emergence	Ermiş *et al*. (2016)
Leek (*Allium porrum*)	Vermiculite	2.5:1.25:3.75	20°C for 1 day	Highest germination and catalase activity	Ozden *et al*. (2018)
Broccoli (*Brassica oleracea*)	Vermiculite	1:1.5:2 (w/w/v)	15°C for 2 days	Increased seed germination vigor, germination index, and vitality index.	Wu *et al*. (2019)
Cauliflower (*Brassica oleracea*)	Vermiculite	1:1.5:1 (w/w/v)	20°C for 2 days	Increase in seed germination, germination index, and vitality index	Wu *et al*. (2019)

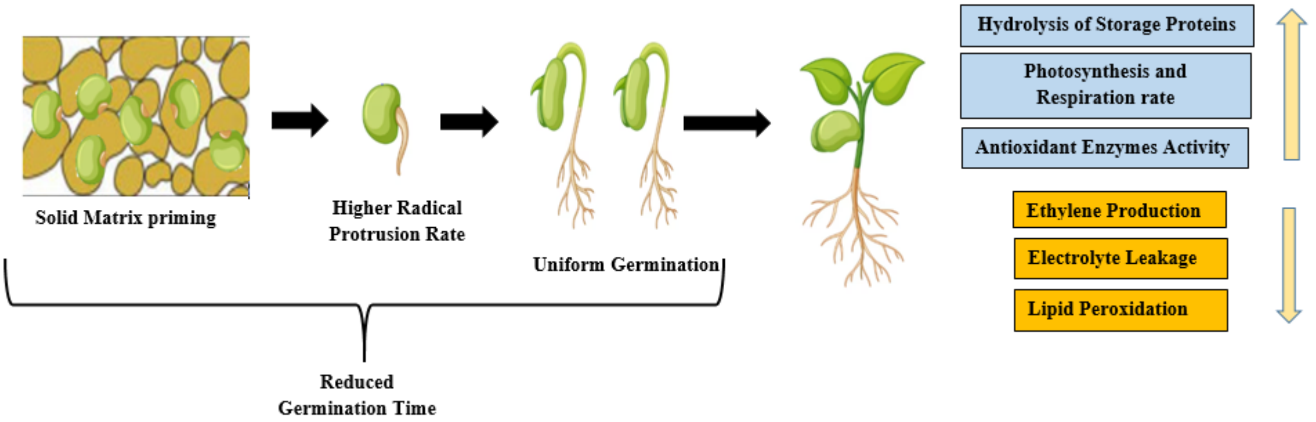

Figure 1. Role of Solid Matrix Priming in improving seed germination parameters: Solid matrix priming of vegetable seed significantly reduced germination time with emergence of uniform seedlings under suboptimal conditions. Moreover, SMP protect seedlings from unfavorable environmental conditions by initiating defence mechanisms and increase metabolic activities.

During this period seeds repair all the damage and prepare themselves to produce normal and healthy seedlings (Lamichaney *et al*., 2018). Abiotic factors like low water potential, nutrient imbalance, fluctuating soil temperature or hard soil pan usually delays seed emergence leads to poor crop establishment (Zulfiqar, 2021). An enhancement in seed germination can be considered as important tool to improve crop yield. Solid matrix priming is one of the important techniques utilized for improving seed germination, reduction in time from sowing to germination with uniform germination (Wu *et al*., 2017).

Sand priming at 80% WHC for 3 h improved germination rate and uniformity of eggplant (*Solanum melongena*) and chilli (*Capsicum annum*) (Venkatasubramanian and Umarani, 2007). While sand priming at 60% WHC for 3 h increase radical protusion rate and days for 50% germination in okra (*Abelmoschus esculentus*) (Nirmala and Umarani, 2008). Moreover, matricpriming of onion (*Allium cepa*) seeds using sand (80% WHC) enhanced 58% germination speed and 7% germination percentage over control (Selvarani and Umarani, 2011). Priming with vermiculite for 48 hr improve carrot (*Daucus carota*) seed field emergence overgrowth by reducing time to germination and increasing seed vigor index (Singh *et al*., 2015). Vermiculite priming also improves soluble sugar and protein content in pakchoi (*Brassica rapa*) seeds by decreasing malondiadehyde (MDA) content (Chang *et al*., 2013). Whereas priming with sieved compost+ hydrogel+ disillled water reduced days to 10% final germination percentage (10% FGP) and 50% final germination percentage (50% FGP) of carrot seeds as compared to control (Olszewski *et al*., 2012). Priming with sand hasten germination, root length, shoot length and dry matter production in onion seedlings (Saranya *et al*., 2017). While priming using insoluble solid matrix particles results in higher germination (94.9%) with faster and uniform germination of sugar beet (*Beta vulgaris*) (Michalska-Klimczak *et al*., 2018). By completing the metabolic activities required for germination process, perlite treated bittergourd (*Momordica charantia*) seeds emerge 8 days earlier as compared to control (Kanwar and Mehta, 2017).

Coating of eggplant and okra seeds with vermiculite + *Trichoderma harzianum* decreased mean germination time, increased germination index, seedling emergence, vigor and seedling quality (Wu *et al.*, 2017; Hosamani *et al*., 2020). Furthermore, SMP with calcium aluminium silicate for 24 h increase okra seed germination and seedling vigor due to high porosity and water holding capacity thus ensuring maximum oxygen availability (Sharma *et al*., 2014).

Effect of Solid Matrix Priming on Biochemical Process in Germinating Seeds

Priming along with enhancing germination %, improves embryo's physiological and biochemical nature (Waqas *et al*., 2019). Solid matrix priming improves the germination rate by stimulating the hydrolysis of storage protein bodies in the embryo, increasing dehydrogenase activity, inhibit ACC synthase activity, reduced ethylene production and prevent electrolyte leakage (Kępczyńska *et al*., 2003). Seeds of various species showed remarkable ultrastructural changes when treated with solid matrix priming (Ashraf & Foolad., 2005). SMP with O_2 increase seed germination of aged leek seeds by initiating cell repair mechanisms (reduced solute leakage, increase antioxidant enzyme activity) as it improves seed respiration important for many metabolic activities (ATP) by transferring oxygen across seed coat to respiratory substrates (Ozden *et al*., 2018). In broccoli (*Brassica oleracea*) and cauliflower seedlings, SMP treatment increased peroxidase and catalase activity, as well as soluble sugar, proline, and soluble protein content (Wu *et al*., 2019). SMP priming in combination *Tricoderma viride* improve membrane integrity of okra (*Abelmoschus esculentus*) seeds due to low electric conductivity and reduced production of water soluble sugars and total free amino acids (Pandita *et al*., 2010). While matricpriming with sand reduced electric conductivity with an increase in protein content % in okra seeds (Kuppusamy and Ranganathan, 2014). Also, solid *T. harzianum* improves stomatal conductance rate, transpiration rate and net photosynthetic rate in eggplant seedlings (Lingyun *et al*., 2017). Sand using matrix in solid priming matrix accelerates degradation of embryo protein after 1 day of germination in sweet corn as it is essential for to degrade embryo protein in order to supply food/energy to germinating seed (Zhao *et al*., 2009).

Effect of Solid Matrix Priming on Enzymatic Activities in the Germinating Seed

Presence of food stores including nutrients, starch, lipids, and protein, in the seed before germination is the prerequisite for the seed to germinate. Specific pathways and activity of various enzymes provide these food stores to the seed embryo (Miransari & Smith, 2014). Seeds with a low germination rate had lower enzyme activity and higher electrolyte leakage, which is associated with cell damage and necrosis, pathogenic fungus growth, and necrotization of the entire seed (Ozden *et al*., 2018). Priming affects the substances that are released during the second stage of germination, which stimulates the synthesis of hydrolytic enzymes. These substances make high-energy compounds and essential chemicals available to germinating seedlings. (Waqas *et al*., 2019).

Usually, free radicals and peroxides are produced during seed germination due to environmental or abiotic stresses that leads to production of free radicals and peroxides and metabolic dysfunction in germinating seeds. These radicals adversely damage germinating seeds by causing peroxidation of lipid membranes, and inactivation of enzymes (Wang *et al*., 2003). Solid matrix priming of okra (*Abelmoschus esculentus*) seeds resulted in improved germination and seedling characteristics along with better enzymatic activities that reduce oxidative stress (Sharma *et al*., 2014). Priming of bittergourd (*Momordica charantia*) seed with moistened vermiculite at 25°C for 36 h not only promote germination but also increase anti-oxidant enzymes activities antioxidant levels, and the activity of several peroxide-scavenging enzymes and free radicals while decreasing MDA and total peroxide levels in cotyledons and embryonic axes. (Wang *et al*., 2003). Catalase, ascorbate peroxidase and superoxide dismutase activities were found to be significantly higher in vermicompost-treated onion (*Allium cepa*), broccoli and cauliflower seeds. (Wu *et al*., 2019; Muhie *et al*., 2020a). SMP alters the activity of enzymes that are involved in the hydrolysis of storage compounds, as well as other enzymes found in the seed (Dabrwska *et al*., 2002). Therefore, it improved cucumber (*Cucumis sativus*), onion (*Allium cepa*) and hot pepper (*Capsicum annum*) germination rate by stimulating the hydrolysis of embryo storage protein bodies, increasing dehydrogenase activity, endo-β-mannanase activity, ethylene production, and decreasing electrolyte leakage (Dabrwska *et al*., 2002; Kępczyńska *et al*., 2003; Ashraf & Foolad., 2005). It also increases α and β amylase, acid phosphate and alkaline phosphate activity in okra (*Abelmoschus esculentus*) seeds. Phosphatases are important enzymes that hydrolyzed phosphate compounds stored in dry seeds into inorganic phosphatase which is further for energy metabolism by growing seedlings (Sharma *et al*., 2014).

Mitigation of Abiotic Stress by Solid Matrix Priming

Successful plant establishment depends not only on uniform and rapid seed germination but also on the ability of the seed to germinate quickly under varying environmental conditions. (Dhal *et al*., 2022). Plants during their growth cycle are subjected to various abiotic stress includes salinity, drought and temperature. These abiotic stresses mainly affect the critical stage of plant establishment i.e. seed germination (Muhie *et al*., 2020b). Since environmental factors can't be controlled, seed modification by priming is done to improve seed emergence and vigor under various abiotic stresses (Conway *et al*., 2001).

Temperature: Temperature, air, humidity and light conditions are important requirements for successful seed germination. At optimum temperature, rapid and uniform seed germination occurs, however with a slightest change in this temperature leads to seeds damage or undergo dormancy conditions (Arun *et al*., 2022). SMP priming increased seed emergence of broccoli and cauliflower in suboptimal conditions (10-15^{o}C) by enhancing activities of ROS scavenging enzymes peroxidase and ascorbate peroxidase under low temperature stress (Ling-Yun *et al*., 2022). Priming of low vigor sugar beet (*Beta vulgaris*) seed using zeolite as water carrier enhances germination speed, time, early plant growth and increases leaf development under low temperature and non-optimal humidity (Chomontowski *et al*., 2020b). The presence of different hydrolytic enzymes and growth promoting hormones in vermicompost improved seed germination and seedling growth in onion (*Allium cepa*) primed seeds under temperature stress (Muhie *et al*., 2020a). Solid matrix primed okra (*Abelmoschus esculentus*) seedlings growth improved due to activities of enzymes malate dehydrogenase, isocitrate lyase and glyoxylate cycle which convert lipids to sugar during germination. Increase in dehydrogenase activity minimizes the chance of loss of viability of seeds by depleting toxic compounds generated during low temperature stress (Pandita *et al*., 2010).

Salinity: Mostly crops failed to germinate on saline soils due to high concentration of salts in in planting zone (Ibrahim, 2016). Salt stress damage occurs to germinating seeds due to changes in mobilization of stored food reserves, reduction in water availability and alteration in structural organization of proteins (Mavi *et al*., 2013). High concentration of salts interferes with plant ability to uptake water and reduce seed germination due to ionic toxicity of Na^{+} and Cl^{-} (Arun *et al*., 2022). Whereas low salt concentration imparts seeds dormancy (Johnson and Puthur, 2021). Seed priming not only developed seed resistance against salinity stress but also improves their ability to detect secondary signals rapidly (Youssef *et al*., 2021). Under salt stress conditions, SMP treatment enhanced early seedling establishment and seed germination in broccoli (*Brassica oleracea*) and cauliflower. While SMP with organic amendments (Leonardite, waste tea and Patula herbal tea) developed salt stress tolerance in hot peppers (*Capsicum annuum*) by reducing germination time and increasing seedling length (Mavi *et al*., 2013). Sand priming improves tomato (*Lycopersicon esculentum*) seed vigor under NaCl stress by increasing antioxidant enzymes activity with decrease in MDA content (Nawaz *et al*., 2012). Whereas, priming with vermiculite enhances salt tolerance in tomatoes by increasing protein accumulation and α-amylase activity (Huo *et al*., 2018).

Drought: Dehydration stress is one of the most significant environmental factors influencing plant survival and productivity (Abdelraheem *et al*., 2019). It affects plants in all growth stages but seed germination is the most important stage which influences overall plant growth and yield. Drought stress reduced seed germination by inhibiting water entrance into the seed due to hydraulic reduction thus interfering with normal functioning of plant (Marthandan *et al*., 2020). Seed priming has recently emerged as a more efficient and beneficial approach for increasing plant germination in response to drought stress by manipulating defence mechanism, activation of enzymes and mobilization of food reserves (Saha *et al*., 2022). Under drought stress, SMP using chitosan at 5% soil moisture level remarkably increased the drought tolerance in pea (*Pisum sativum*) (Guan *et al*., 2009). Seaweed extract improves onion (*Allium cepa*) seed germination and seedlings performance (height, fresh and dry weight) against drought stress due to presence of growth promoting hormones and mineral nutrients in seaweed (Muhie *et al*., 2020b). Similarly, seaweed in combination with karrikinolide (biostimulant) improved germination characteristics of carrot seed along with catalase activity under PEG induced drought stress (Muhie *et al*., 2021).

Mitigation of Biotic Stress by Solid Matrix Priming

Seed borne pathogens are one the main reason for poor crop establishment and low yield in vegetables. Presence of seed-borne pathogens not only reduced germination but also help in dissemination of disease by transmission of pathogens from seed to the plant (Ilyas, 2006). Pesticide application is the most convenient method for controlling disease, however various hazardous effects on environment and on human beings are associated with it (Mondal and Bose, 2014). To prevent this, alternative approach such as solid matrix priming using biological agents, fungicides or essential oils are employed to induce disease tolerance in primed seeds. Chemo primed seeds of okra (*Abelmoschus esculentus*) (thiram + carboxin) had faster and uniform germination and prevent colonization of seed coat with damping off disease spores (Conway *et al*., 2001). Furthermore, while biomatricpriming with 0.1% clove oil, reduced incidence of seed born pathogen (*Colletotrichum capsici*) in hot pepper seeds (Ilyas *et al*., 2015). Combination of gibberellin synthesis inhibitor trinexapac ethyl (TE) with sawdust significantly minimizes fungal (*Rhizopus* and *Pennicillium*) and non-specific bacterial infection in radish seeds (Klein *et al*., 2017).

CONCLUSION

A good quality seed results in early, fast and uniform germination and determines plant growth and yield. Thus, solid matrix priming, a cost efficient technique proves to be effective in enhancing low quality seed germination, reducing mean germination time, and enhancing the uniformity and seedling characteristics of different vegetable crops under different stress conditions. However, a detailed study on the effect of solid matrix priming on physiological and biochemical processes responsible for improved growth and yield is not known. Therefore, further research is needed to elucidate the initiation of mechanism related to plant growth and mechanism by solid matrix priming.

CONFLICT OF INTEREST

The authors have not declared any conflict of interests.

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