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Recent trends in seed treatment to enhance seed quality under abiotic stress conditions in legumes: A review

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Abstract
Legume seeds form the abundant source of protein and other nutrients. Commonly, legumes are grown in marginal agricultural lands which are prone to climatic fluctuations. Value addition to the seed through seed enhancement techniques is necessary. The improvement in quality and vigor of the seed by seed enhancement is abided mainly to balance in the metabolic functions, rapid hydrolysis of reserve food material during germination for efficient energy supply, maintenance of seed coat membrane integrity, triggering of antioxidant mediated defense response to invading pathogens and developing inherent resistance to several biotic and abiotic traits that are hindering crop growth. The present review focused on the up gradation of seed quality through different seed enhancement techniques specifically for legume crops.

Keywords: Legumes, physiological aspects, seed enhancement and its types, seed quality, stress conditions

Introduction
Legumes have prime importance in Indian farming. Besides they are a rich source of protein and other nutrient rich compounds *viz*. isoflavones, triterpenoid, saponins and inositol phosphates (Zhung *et al*., 2019) [112] they also benefit the soil by nitrogen-fixation. Generally, legume production is taken in marginal lands which are susceptible to erratic climate changes which severely reduces productivity (Varshney *et al*., 2009) [104]. Drought, salinity and heat stresses are known to induce the incidence and multiplication of insects, weeds and pathogens (Peter *et al*., 2014) [77]. This necessitates the development of farming strategies to increase the tolerance of crops to combat biotic and abiotic stresses in legumes as germination and seedling establishment are the pivotal stage for crop growth in legumes, it is more crucial to evolve the strategies for improvement using seed based techniques.
The potential of seed enhancement to assuage the effects of stress and improve the plant stand depends upon the extent of stress experienced by it in the stressful environment. Therefore, the technique of enhancement must make sure to impart and help seed germination and achieve good and uniform plant stand by overcoming the potential threat posed by the stressful environment.

Seed Enhancement
Any postharvest practice facilitating the growth of vigorous and healthy seedlings in the field condition can be regarded as seed enhancement. Seed enhancement technologies are gaining more attention for their potential to confer greater disease resistance in seeds, improve seedling vigor and modify seed emergence capabilities. Hydration treatments *viz.* priming, hardening and pre-germination, improve seed physiological characteristics, whereas pelleting and encrusting to facilitate the physical structure of the seed required at the time of planting *viz*. micronutrients, plant growth regulators.

Physical seed enhancements
The chemicals have harmful effects on the ecosystem and human beings; hence alternative techniques were developed and are being used at present for seed enhancement (Elwakil, 2003; Vasilevski, 2003) [31, 105]. Irradiation of seeds with the lower dose of gamma rays enhanced the germination, photosynthesis pigments synthesis and growth of growth (Kovacs and Keresztes, 2002; De Micco *et al*., 2014) [56, 25].

Low dose gamma rays enhanced vigor and seedling development in okra (Dubey *et al*., 2007) [28].

Magneto-priming
Magneto-priming is a noninvasive treatment of dry seeds, which is used for boosting the seed vigor and field emergence under environmental stresses (Baby *et al*., 2011; Shine *et al*., 2011; Bhardwaj *et al*., 2012; Bilalis *et al*., 2013) [13, 17, 18, 94]. Magnetic fields are also known to augment tolerance to biotic stresses (De Souza *et al*., 2006) [26] or abiotic stresses (Anand *et al*., 2012) [12] as a consequence of the antioxidant response activation (Hozayn *et al*., 2018) [42]. Magnetic field alters the properties of the cell membrane and cell division which brings a change in functioning and metabolism of cell and protein biosynthesis, gene expressions and enzyme activities (Atak *et al*., 2003) [12].

X- rays
X-rays have a 0.01 to 10 nm wavelength of the electromagnetic spectrum (Kotwaliwale *et al*., 2014). X- ray irradiation to the date palm seeds reduces the seed germination but improves the root growth (Al-Enezi *et al*., 2012) [7]. Exposure of plants to X- rays leads to physical and chemical changes that alter the physiological processes in the plant (Ahloowalia and Maluszynski, 2001) [6]. Low doses of X-ray irradiation have a positive effect on productivity (Afify *et al*., 2013; Aly *et al*., 2018) [4, 8] but higher doses (>15 Gy) have a negative impact on seed quality.

Gamma irradiation
The most widely used physical mutagen in mutation breeding is the gamma ray technique (Sagel *et al*., 2009) [86]. Gamma rays irradiation is utilized for developing biotic-abiotic stress tolerance (Jain, 2010) [45]. Bajaj (1970) [15] in bean the gamma rays at low level (0.5 krad) stimulate cell growth, but at an enhanced dose of irradiation cell growth comes to a half. Relatively low doses of ionizing radiation accelerate physiological (Kiong *et al*., 2008) [54] and biochemical traits confined to stress tolerance (Chakravarthy and Sen, 2001). The stimulation of seed germination by gamma rays is attributable to the activation of protein biosynthesis leads to a release of enzymes (Abdel-Hady *et al*., 2008) [2].

Plasma treatment
Cold plasma treatment is an economic and ecofriendly treatment to upgrade seed and plant performance (Tony *et al*., 2014; Dhayal *et al*., 2006) [27]. It has the ability to reduce the bacterial infection of seeds, enhance the permeability of seed coat membrane, stimulate seedling establishment (Zhou *et al*., 2011; Selcuk *et al*., 2008; Sera *et al*., 2008) [113, 89, 90]. Seeds soaked into cold plasma are attacked by oxygen radicals and are bombarded by ions which lead to seed coat erosion (Stoffels *et al*., 2008) [96]. Plasma treatment might increase superoxide dismutase activity, dehydrogenase activity and peroxidase activity, photosynthetic pigments and photosynthetic efficiency. The fluorocarbon plasma treatment has also a negative effect on the seed germination of bean due to the deposition of hydrophobic materials on the seed coat which reduces water uptake (Volin *et al*., 2000) [107].

Physiological seed enhancement
Seed priming
In recent year's effective and facile technique to enhance the better establishment of seedlings and high vigor under unfavorable conditions was seed priming (Rashid *et al*., 2004; Jisha *et al*., 2013; Das *et al*., 2015; Paparella *et al*., 2015) [80, 49, 24, 73]. Seed priming induces higher germination by reducing the lag time of imbibitions (Brocklehurts and Dearman, 2008; Arif *et al*., 2014) [20], enzyme activity (Lee and Kim, 2000; Ling *et al*., 2017) [59], metabolic repair (Farooq *et al*., 2006) [32]. Seed priming with KNO_3 and Ca $(NO_3)_2$ enhance physiological seed quality under heat stress condition (Batista *et al*., 2016) [16]. Seed priming is a functional physiological technique for glycophyte species to adopt a saline environment in soybean (Miladinov *et al*., 2015) [67].

Hydro priming
Hydro-priming enhances the water use efficiency under abiotic stress conditions (McDonald, 2000) [65]. Under drought stress, seed germination rate increased by three to four times than nonprimed seeds by hydro priming (Kaur *et al*., 2002) [51]. There is significant upregulation was recorded for the *SOD* and *APX* genes which are associated with ROS scavenging and DNA repair in response to two hours and four hours of hydro-priming time in *Medicago truncatula* (Chiara *et al*., 2020) [23]. Various proteins that appeared during hydro-priming are identified by the MOLDI-TOF model (Gallardo *et al*., 2004) [35].

Hormonal priming
Salicylic acid (SA) treatment can augment the accessible carbohydrates into cotyledons so that the embryo abortion reduces ultimately lead to more number of seeds per pod (Gunes *et al*., 2005) [37]. Cytokinin priming is known to enhance seed germination (Riefler *et al*., 2006) [82] and yield components in many crops. (Faruk, 2015) [33] Seed priming of $ZnSO_4$, GA_3 and PEG-6000 may be useful techniques due to their positive influence on seed quality and yield components of lentil.

Nutrient priming
Nutrient priming is a kind of priming, where the seeds are kept in a nutrient rich solution further the seeds are dried to their original moisture level (Shivay *et al*., 2016) [95]. Seeds primed with sodium molybdate showed improved nodulation by the roots, nitrogen fixation into the soil and yield in common bean (Mohandas, 1985) [24] and green gram (Umair *et al*., 2011) [101]. Seed priming of zinc improves the metabolic process of germination and the resultant sugars have a vital role in protein synthesis during germination (Rouhi *et al*., 2011) [84] and enhanced yield in common bean (Kaya *et al*., 2007) [52]. (Pattanayak *et al*., 2000) [75] seed priming with a combination of micronutrients and *Rhizobium* enhanced nodulation, nitrogen fixation, nutrient assimilation into the plant and yield.

Super Absorbent Polymer Coating
The seed coating with Super Absorbent Polymers (SAPs) promotes seedling growth in the early plant growth stages may be attributed to the ability of the hydrophilic polymer to up regulate the water uptake besides reducing the imbibition damage (Vanangamudi *et al*., 2003) [102] and hasten the time of harvest (Yazdani *et al*., 2007; Sathyabhama *et al*., 2016; Tamilarasan *et al*., 2018) [107, 87, 98]. SAPs have the potential to save water, resist drought, preserve fertilizer and increase the yield (Bai *et al*., 2010; Khadem *et al*., 2010: Yazdani *et al*.,

2017) [53, 110]. The ability of bio SAP on seed vigor indices can be attributed to additional nutrients of bio sap like carbohydrates, a trace of Mg, K, Ca, Na and S leading to better growth, establishment and development of crop (Prajapati *et al*., 2014; Njira and Nabwami, 2015).

Biological seed enhancement

The micro organisms used in seed priming ensure the rapid uniform germination, growth of the crop, protect the seed from diseases, colonization of rhizosphere and mitigating the adverse effects of abiotic stresses. The plant growth promoting rhizobacterial strains have positive traits for the physiological growth of plants (Tonelli *et al*., 2011) [99]. (Joshi *et al*., 2018) [50] results revealed that Phosphorus Solubilizing Bacteria (PSB) maximum growth parameters were observed in both peanut and soybean.

Seed priming with plant extracts

Alkaloids, saponins and phenolic substances are concerned with the development of antioxidants and safeguard the plants from pathogens (Satish *et al*., 2007). Botanical extracts are known to possess antifungal activities against seed borne fungi (Suratuzzaman *et al.*, 1994; Ashrafuzzaman and Hossain, 1992; Hossain and Schlosser, 1993) [97, 11, 41]. Seed priming with moringa leaf improves seed germination and vigor under stress conditions (Afzal *et al*., 2012; Imran *et al*., 2013) [5, 44]. Glycine betaine priming prevents the plants from the destructive effects of salinity (Abbas *et al*., 2010) [1]. Priming of seeds with neem leaf extract improves the number of branches per plant in urdbean (Janardhan, 2014) [46].

Seed priming through nanoparticles

The nano-priming improves plant growth by higher diffusion into the seed coat membrane that augments the nutrient absorption and water absorption of the seed (Dutta, 2018) [27]. (Sedghi *et al.*, 2013) [88] confirmed that ZnO nanoparticle can improve seed germination rate in soybean under water stress conditions beyond certain optimum concentration retards the plant growth in mung bean. Silver nanaoparticles (AgNPs) has a supplementary mileage in plant growth and development (Shelar *et al*., 2015) [93] beyond certain concentration causes genotoxic and detrimental deviation at the biochemical and physiological level (Kumari *et al*., 2009; Vannini *et al*., 2013) [58, 103] and induces oxidative stress in plants (Jiang *et al*., 2014; Mahakham *et al*., 2017) [48, 62]. The effect of nanoparticles on seed quality depends on the size, properties and concentration, test plant and the application method (Feregreno *et al*., 2018).

Seed coating treatments

Seed pelleting

Seed pelleting is the method of adding up inert materials to seeds augment their mass, size and shape (Halmer, 1988) [37] and allowing for accurate spacing and depth of seed in the field. Seed pelleting with pungam leaf powder enhances the seed germination, this is due to calcium presence which acts as an enzyme cofactor in the germination process by increasing protein synthesis (Yadav *et al*., 2014) [108].

Seed pelleting with pungam leaf powder and fly ash improves the seed quality parameters and yield parameters in black gram (Georgin, 2017; Prakash *et al*., 2018) [36, 79]. Seed pelleting with zinc sulphate increases plant growth could be attributed to its association with auxin biosynthesis (Krishnasamy, 2003) [57] and cell development (Masuthi, 2005) [64] in cowpea.

Seed coating

Seed coating is a promising technique for inoculation of a minor quantity of inoculums, colors and tracers; protectants and soil adjuvants; compounds that stimulate seed germination and stress resistance and micronutrients and macronutrients (Ehsanfar and Modarres-Sanavy, 2005; Jetiyanon *et al*., 2008; Oliveira *et al*., 2016; Pedrini *et al*., 2017; Rouphael *et al*., 2017; Accinelli *et al*., 2018) [30, 47, 71, 76]. The often used seed coating techniques are pelleting, film coating (Halmer, 2000) [39] and seed dressing (Hartley *et al*., 2004; Shaharoona *et al*., 2008; Cely *et al*., 2016; Shahzad *et al*., 2017) [40, 91, 21, 92]. Polyvinylidene chloride polymer emulsion efficiently managed the invasion of storage fungi. Seed coating of *Paenibacillus lentimorbus* B-30488 along with ($C_6H_8O_6$) and $CaCl_2$ can augment the germination rate and helps to overcome of water stress in chickpea (Pedrini *et al*., 2017) [76].

Physiological and Biochemical aspects

The chilling stress rigorously affects seed germination, seedling growth and development (Oliver *et al*., 2007) [72]. Phosphate metabolism is negatively affected by stressful conditions (Mihoub *et al*., 2015) [66]. Osmopriming is known to improve the seed quality parameters, responses to antioxidants and membrane stability in *Moroccan alfalfa* under water stress at the early stages of seedling development (Mouradi *et al*., 2015) [69]. Magnetic seed treatment stimulates seed development by various cellular and biochemical processes (Rochalska and Grabowska, 2007) [83] and enhances the ascorbic acid content (Yinan, *et al*., 2005) [111].

Molecular aspects

There is variation in the abscisic acid and gibberellin biosynthesis genes influencing seed germination under an abiotic stress environment (Vishal *et al*., 2018; Huang *et al*., 2019) [106, 43]. The GA signaling pathway enhanced the DELLA protein degradation, ensuing in a beneficial impact on gene *viz RGL2*, concerned with seed germination effect in saline condition (Ravindran *et al*., 2017) [81]. The seed priming effects at the cellular level is known by studying at RNA and protein level (Bray, 1995) [19].

The abiotic stress affects the balance among ROS production and resulting DNA damage leads to poor seed quality (Parkhey *et al*., 2012) [74]. In soybean seed coat under water stress the transcriptional changes were noticed at the pod filling stage and some of the genes have been altered (Leisner *et al*., 2017) [60].

Conclusions

Seed enhancement techniques improve the growth and development of the plants through high vigor with efficient use of resources even under biotic and abiotic stress situations. Seed priming has been effectively utilized for many crops were rapid, uniform and complete seedling emergence is crucial. The use of advanced physical and biological methods of treating seeds alternative to chemical seed treatment is ecofriendly. The use of nanoparticles and the application of nanotechnology in the sustainable development of agriculture are still in the juvenile phase. Hence, in order to exploit the peculiar and inimitable properties of NPs there is necessary to understand the interaction between plants and nanoparticles at cellular as well as molecular level. There is a need to understand the molecular mechanism involved in the improvement of seed quality by seed enhancement.

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