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Seed Priming with Phytohormones to Improve Germination Under Dormant and Abiotic Stress Conditions

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Abstract

A crop seed which is viable can germinate soon it gets necessary conditions for germination, except when it's in a state of dormancy. Apart from the physiological dormancy, the critical limiting factors for seed germination and better seedling establishment are the abiotic stress. Moisture (water potential) stress is the leading one. Germination and seedling establishment are vital stages in subjected to abiotic stress. Among many of the techniques implemented to minimize germination and related problems are the different priming techniques. A seed can be primed with water, organic extracts, different salt solutions and hormones. Phytohormones act and interact to affect many processes in the plant life cycle among these are the germination process. These hormones can be synthesized artificially. They are used as a treatment for seed priming and other process. GA, auxins and cytokinin are the major ones used in hormonal seed priming techniques used to increase germination of seeds under dormant and abiotic stress conditions.

Keywords: Phytohormones; Stress; Dormancy; Germination

Seed Germination and Dormancy

Seed germination is the growth and development of an embryo (the living part) of a seed in to a new plant which may or may not be similar with the parent plant. The first step of germination is water imbibition [1]. The main criterion to know whether a seed is germinated or not is, the emergence of the radicle from the seed coat. Temperature, water and oxygen are the basic necessities for germination to take place. On the other hand, a seed may not be germinated even if it can get these basic requirements. The inability of a seed to germinate even though environmental conditions for germination are fulfilled is termed as dormancy i.e., the physiological dormancy of the seed, to differentiate from other types of dormancies [2,3]. It is also defined as the failure of a viable seed to complete its germination process under suitable conditions which is a common phase in the life cycle of most spermatophytes [4].

Though there are other dormancies of a seed like morphological dormancy, morphophysiological dormancy, thermo dormancy, conditional dormancy and other exogeneous dormancy, it's the primary dormancy especially the physiological dormancy that is responsible for seeds to germinate or not [5]. Dormancy in seeds is not always an undesirable characteristic, rather it has time and place to be evaluated. When we are going to grow crops in a given area and the seed is not able to germinate, we can say its undesirable. But if we are not using our seed to germinate now but for the future, its required for the seed to be in a state of rest or dormant, this can be desirable characteristic (the details about this point will be given in another article). Germination is a process that consists of a series of many mixed biochemical and physiological changes involving the initiation of growth in seeds and the movement of plant substitute nutrients for embryo growth [6].

Nature has provided the seed to withstand extremes of drought and temperature by adjusting the mature seed to be a in a state of inactive or quiescent [7], thus the seed exists in the threshold of life which helps to exist for many years without harm (the positive side of seed dormancy, this is for orthodox seeds). Enzymes and other structural components of the seed are also in a state of quiescent until they get water to start metabolism. Once the seed starts imbibition, synthesis of new organelles and protein also commences. However, unless there is suitable environment for germination, the seed will not be able to germinate under stress conditions even the endogenous (physiological) dormancy can be broken. he seed thus exhibits a different phenomenon for its germination under unfavorable conditions.

Germination Under Stress Conditions

These days, with the rise of global warming and related problems, crop production and productivity are threatened by increasing environmental constraints [8]. The effect is more severe at earlier stages of development, the seed germination and seedling establishment stages. Because these are the vital stages in crop development which determines the future production and productivity of a crop [9]. Seed germination and emergence are affected by several environmental factors such as moisture stress, salinity and extreme temperatures [10]. The effect of salinity on seed germination is in two ways. Through osmotic effect so that seeds cannot imbibe water easily and through ion toxicity [11,12]. Many researchers also added that field emergence of seeds is affected by temperature stress [13-15].

The conditions necessary for a seed to germinate are water, oxygen, light, suitable temperature, food and growth regulators (substrates). However, the seed should have passed its rest period (internal dormancy, for those seeds which have known period of rest after harvesting) and it should be a viable seed. Poor seed germination and seedling establishment are major agricultural problems especially in

moisture stress areas, and these stages are considered to be important in later plant growth and development which in turn affects yield and related components [16]. Its mentioned by researchers that environmental factors such as temperature, light, pH, and soil moisture are the most important factors for seed germination [17,18]. When the seed is not able to be provide with these suitable conditions for germination it will fall in to stress conditions and may not be initiated to germinate. Yali et al. [19] said that, under unfavorable conditions, the seeds of *S. ferganica* may not germinate or germinate in a small amount. Most of the stress conditions a seed encountered during germination are the abiotic stress [17].

Moisture is the most important abiotic stress limiting the germination of many plant species [20,21]. The effect of water stress varies with crop species, constant and/or high moisture requirement for bromeliad seeds to germinate [22]. The effect of moisture stress is more serious in areas where salinity and sodicity are existing. This is because when there are salts and other soluble sods, the water potential of the solution surrounding the seed is getting lower, resulting in a condition in which seeds can't take water easily [23]. Salinity affects the ability of seeds to imbibe water, necessary for metabolic changes within the seed that leads to germination and growth of seedlings similar to those caused by the water stress.

Seed Priming

Seed priming can be defined in such a way that it is a pre-sowing seed treatment process that provides a moisture sufficient enough to start pre-germination metabolic processes without radical protrusion [24,25]. It's a technique used to minimize problems encountered during germination and emergence either due to adverse environmental conditions or due to seed quality and structure related problems, thus providing uniform emergence and growth of strong seedlings. It is a simple, cost effective and low risk technique used to minimize the problem of soil moisture and salinity in crop lands. It is also important for uniform seedling emergence [26] and better crop stand establishment, especially in adverse environmental conditions such as moisture [27] and salinity stress and temperature stress [28-30]. Priming is also used to improve seed germination under both optimal conditions. It improves water use efficiency and helps to improve yield and related components [31]. Seed germination and seedling growth are the two most critical stages for better crop stand establishment [32]. As compared to unprimed seeds, primed seeds can germinate at a broader temperature range and they are also less sensitive to deficiency of oxygen. In a study to evaluate germination and emergence of primed grass seeds under different temperature ranges, seed priming enhanced both germination and emergence rate with the greatest effect occurring during the earlier, cooler sowing dates [33]. The effect of temperature, and the relationship between decreasing germination rate and percentage germination with increasing water stress, are generally well established in previous studies for many crop species [34-36].

Seeds can be primed with different solutions including salt solution to manage problems of salt stress during germination. For example, tomato germination characteristics and seedling growth are affected by high potential value of primed with $CaCl_2$ and KNO_3 solutions [37,38]. Seeds can also be primed with phytohormones.

Plant Hormones and Seed Germination

Plant hormones are chemical molecules that control growth and development in the plant life cycle. They are also known as phytohormones, to differentiate from animal hormones [39]. They occur in low concentrations in plants. In some areas like UK they are also known as plant growth substances or regulators. The presence of these signal molecules that control growth and development in plants was first discovered by Julius Von Sachs in 1980. Plant growth and development is the integrated result of many environmental and endogenous chemicals (hormones). The action of hormones is very interesting. A single hormone can regulate many processes and at same time many hormones interact to influence a single process [3] and this is one of the differences between animal and plant hormones.

One of the developmental processes or phase changes in which plant hormones interact is seed germination [40]. Hormones like abscisic acid (ABA) is an inhibitor to germination [41] and it can reversibly arrest embryo development at the start of radicle growth initiation by inhibiting uptake of water [42]; but the effect can be removed by using GA and auxin [43]. GA is responsible for the release of an enzyme required for digestion of endospermic starch needed for nourishment of the developing embryo during germination. GA works together with auxins, cytokinin and with some other hormone, through a system of synergism [44].

Seed treatment with hormones is an important remedy to minimize problem of seed germination in stress conditions, due to their consistent effects on germination and growth [45,46]. Phytohormones play a vital role in regulating plant resistance to stress [47]. Now a day where global warming is a critical problem for crop production, wide areas of agricultural land are subjected to moisture stress, and in some case, it makes the arable land liable to salinity stress. In mediating salt tolerance in wheat crops GA treatment was found to be effective [48]. In a study by Yang et al. [49], polyamines affect seed germination and seedling growth under drought stress. In another study, 6-BA or PEG as a seed soak treatment showed synergistic effect on seed germination and seedling growth under drought stress conditions [50]. Hydrogen peroxide treatment of barely seeds also resulted in removal of any delay during germination and minimize the effect of high temperature stress during germination [51]. Hormonal priming of tomato seeds on germination and seedling growth was also investigated by researchers and showed an interesting result with cytokinin [52], auxins [53].

Conclusion

Germination of seed is dependent upon two important factors; the state of the seed whether it's in a state of dormancy or not and the environmental conditions necessary for germination. If a seed is dormant, its necessary to treat it and break dormancy so as to initiate germination. Optimum conditions of moisture, oxygen, temperature and light are necessary for a seed to germinate. Moisture and salinity are the most important limiting factors which hinder seed germination and crop stand establishment.

One important seed treatment practice which can help seeds to break dormancy and to minimize problems of abiotic stress such as moisture, salinity, extreme temperatures is priming. It's a pre-sowing seed treatment practice which provides moisture sufficient enough to start pre-germination metabolic process used to minimize problems encountered during germination and emergence. Hence, it is useful for uniform emergence and growth. Priming can be done with water, different solutions and phytohormones.

Phytohormones are chemical molecules that control growth and development of plant life cycle. One of the developmental process or phase changes in which plant hormones are interacted is seed germination. Due to their consistent effect on germination and growth, phytohormones are important remedies to minimize problems of seed germination under stress conditions. But not all phytohormones promote germination. For example, ABA inhibits but GA promotes seed germination.

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