Chapter

# Seed Priming: An Interlinking Technology between Seeds, Seed Germination and Seedling Establishment

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## Abstract

Biologically seed is a small embryonic plant along with either endosperm or cotyledons, enclosed with in an outer protecting covering called seed coat. During the time of seed development large metabolic conversions take place, including proper partitioning of photo-assimilates and the formation of complex polymeric forms of carbohydrate, protein and fats for storing as seed reserves. In developing phase of seeds, every detail information stored in the embryonic plant are genetically and sometimes epigenetically also predetermined and influenced by various environmental/external factors already faced by the mother plant. In the growth cycle of plants, seed germination and seedling establishment are the two critical phases where survivability of the seedlings in natural habitats is a matter of question until the onset of photosynthesis by the established seedling. The various sequence of complex processes known to occur in both the phases i.e., an array of metabolic activities are initiating which eventually leads to the renewal of embryo growth of the dormant seeds and ultimately seedlings are established. Efficient seed germination is an important factor for agricultural sciences and successful establishment of germinated seedling requires a rapid and uniform emergence and root growth. With these aspects of seed physiology kept in mind the present chapter will be designed in such a way where, a gap filling, inter linking, eco- and farmers' friendly technology i.e., 'seed priming' (a pre-sowing partial hydration of seeds) will be considered to improve the rate and uniformity of germination and seedling establishment. Under optimal and adverse environmental conditions, the primed seeds of diversified species lead to an enhanced germination performance with increased vigor index has been reported by various scientists which indicates a good establishment of seedlings in the field and thereafter enhance the performance of crops as a whole.

**Keywords:** seed, seed development, seed germination, seedling establishment, seed priming

*"It's not dead, it's resting."*
*–Monty Python.*

# 1. Introduction

## 1.1 Seed and its botany

The seed is a carrier of genetic informations gathered from the past as memory molecules and pass it on future generation of the plants. The natural packaging of all the genetic wisdom within a embryo of any seed is itself a wonder for long periods of time during germplasm collections. In the language of biology, seed is an embryonic plant surrounded by outer protective covering. Embryo is an immature diploid sporophyte developed from a single cell zygote which is covered by nutritive tissue i.e., endosperm in monocots, cotyledon in dicots and in few exceptional cases perisperm which is enveloped by seed coat (testa and tegmen). If we consider the parts of embryo then it consists of an embryonic root called radicle, embryonic shoot known as plumule, contains immature shoot apical meristem, one or more young seed leaves i.e., cotyledons and epicotyl. In a miniature form it also consists a hypocotyl which is a transition region between stem and root [1, 2].

A 'seed' can be defined as any parts of plant if sown in the field should have the potential to regenerate into a new plant [3]. The first critical step of crop production is successful establishment of seedling, and be a determinant factor of the success or failure of the harvested crop. Due to changing climatic conditions, the uncertainty of crop failure is increasing day by day, in this situation to produce quality seeds and maintain the food security of any nation is an issue. For the production of any crop, seed quality is an essential parameter from resource-poor farming to industrial-scale farming. A detailed study is required in terms of sustainability and profitability of crop production with a widely accepted and critically important agronomic trait i.e., seed quality. Most of the crop seeds are tolerant to desiccate condition for examples, orthodox seed are those seeds, can tolerate desiccation and are storable in a dry state for variable periods of time, according to the species. The world-champion orthodox seed is the 2000-year-old Judaean date palm (*Phoenix dactylifera*) seed that was successfully germinated in 2005 [4, 5]. It is an easy process for transportation of seeds in this 'dry' state with a minimal loss in germination potential. The embryo of a seed is a vital pocket where all the genetic information of any crop is stored and act as a delivery system for agricultural biotechnology and crop improvement. For the protection of their investment in crop improvement, seed companies require high quality of seeds to get the maximum benefit while sown in the field. In addition with the purpose of seed companies, the requirement of the farmers to ensure the reliability and successful seedling establishment in their field and get a good return. The readily measureable characteristics of seed quality includes seed viability, purity of the seed lot, health, and mechanical damage, but another essential component is more enigmatic trait of seed vigor as reported by Perry [6].

The present chapter has been prepared on the basis of seed germination and seedling establishment where, an alternative interlinking, gap filling, cost effective, environment- and farmers' friendly technology i.e., 'seed priming' (a pre-sowing partial hydration of seeds) will be considered which has an immense role to improve the speed and uniformity of seed germination and seedling establishment with a good vigor of crop plants.

# 2. Development of seeds

Development of seeds is an unique attribute for plants reproductive phase, gives them privilege to perpetuate the genetic as well as acquired epigenetic information, generation after generation. Acquiring the knowledge from their mother plant the miniature embryonic plant behaves accordingly and protect themselves against various environmental atrocities, in their whole life span. Physiologically, the development process of a seed is a combined effect of two complex processes i.e., the development of embryo and endosperm is known as embryogenesis. According to Taiz *et al*. [5] the term embryogenesis narrates a process in which a single cell is transformed into a multicellular entity with a characteristic, but typically rudimentary, organization. Within this framework, groups of cells become functionally specialized for the formation of epidermal, cortical, and vascular tissues. Embryogenesis is a linking point between the two phases i.e., gametophytic phase and the differentiation of the sporophytic phase by forming shoot and root meristems. At the initial phase of embryo development, the unicellular zygote elongates and makes a polar structure before dividing and establish a body plan of an embryonic plant along with all acquired information to survive in normal and adverse climatic condition in future and remain as a conserved, arrested phase within the seed for many years. In dicot seed development, majority of the seed volume is occupied by embryo as cotyledons at the time of maturity where the endosperm part is consumed by the embryo during this period of seed development. While studying the monocot seed's structure, it was observed that monocot seeds containing different structural form in comparison to a dicot seed, having a starchy endosperm, occupied most of the spaces inside the seed coat along with an embryo which is positioned at the ventral side of a seed. Moreover, the seed is fully covered with an envelope or seed coat. In addition, seed is an important storage unit and serves nutrition during the time of germination and up to seedling establishment phase as well as supply nutrition to animals and humans in the form of healthy diet [5, 7]. Seed maturation is a key period in a plant's lifecycle allowing for distribution of offspring in space and time. Events occurring during maturation include storage reserve deposition, desiccation, dormancy induction, seed coat formation, and protective compound synthesis. The spatial and temporal regulation of these processes involves the concerted action of a signaling network consisting of hormonal, transcriptional, and metabolic components, which will help in germination process and to concur a good vigorous growth [8].

The seed development process can be divided into four phases where it begins with the fertilization of ovule and ends up with physiological maturity of seeds. In first two phases of seed development viz. Phases I, only cell division and expansion occur (Morphogenesis phase). Accumulation of reserves takes place in Phase II as the dry mass of seeds increases (Maturation phase). In addition, the end phase of seed development is the desiccation phase where seed moisture loss is intensified (Phase III i.e., desiccation phase) [5]. In the reproductive phase of plants, after the fertilization process is over, there is a period to form the structure of seed and as a result cell division, cell expansion and differentiation (histo-differentiation) is observed in which primordia are formed and parts of the embryo can be visualized in future. During this phase, the embryonic cells receive assimilates from the parent plant and as a result there is a significant increase in seed size along with this the moisture content of seed remains constant and high in this phase. At the end of the maturation phase, there is a significant decrease in seed moisture content was observed when cell membrane structure organization is changed and increases in enzyme synthesis was taking place and the seed become metabolically inactive by the changes of plant growth regulator takes places within the cell and they enter dormancy, for successful germination in the next season [2]. Between the embryogenesis and seed germination there is typically a period of seed maturation which is followed by quiescence, where seed dissemination occurs. Germination is delayed until the favorable conditions i.e., water, oxygen, and temperature will arise properly, required for seedling growth. Some special seeds are there where an additional treatment, like light or physical abrasion is a requirement, before their germination.

Whereas, germination comprises all the events which take place between the start of imbibition of the dry seed and the emergence of the embryo, basically the radicle by rupturing the seed coat [5].

## 3. Seed germination and seedling establishment

Seed germination is a critical phase of plant life cycle as this process initiate a new life [9–11]. This phase of plant's life of any species is a determining factor that germinating new seedling will survive or not in natural habitat. After completion of maturity phase of seed development, seed undergoes in dormancy phase, consists of an embryonic plant and a nutritive storage tissue which can be utilized during the time of germination and seedling establishment till the onset of photosynthesis by the seedling. 'Germination' is a complex process and it is a combination of both physical and biological processes which starts with the imbibition and ends up with the protrusion of radicle where an array of metabolic activities are initiated that leads to the reactivation of the growth of dormant embryo and finally establishes the seedling. During the onset of germination, several sequential events are going on continuously that are triggered by some endogenous factors like the information acquired from mother plant during the time of seed-development process as well as depends on some external environmental factors like water, air, temperature, soil condition etc. For example, *Stellaria* species growing in dry grasslands and in shady deciduous forests are able to germinate some seeds, while those growing in open forest show complete dormancy during maturity in early summer [12]. Similarly, in *Nothofagus* species increasing the altitudinal gradient the seeds that produce may vary considerably in their germination [13]. Study demonstrates no significant result in terms of phylogenetic signal for the germination of *Caragana* species. Seeds of species from arid and semiarid habitats lacked dormancy, seeds of species from semi-humid habitats had physiological dormancy or physical (seed coat) and physiological dormancy, while seeds of species from humid habitats had physical and physiological dormancy. Climate change will definitely affect the germination of seeds, and subsequently recruitment of plants and population dynamics [14].

Germination of seed is an important process for successful seedling establishment, as it is a junction point from where reverse back is not possible. Once the germination has commenced, consumption of accumulated storage reserves was begins which is essential for the seedlings to produce energy and ensure the heterotrophic growth [15–17]. The reserve mobilization phase takes place prior to greening of the cotyledons and as a results depletion of storage reserves, which shift the newly germinating seedling from heterotrophic to autotrophic metabolism, required for successful establishment of seedling [18–19]. Instead of high impact of seedlings performance on crop establishment and seed yield, relatively very little information is available about the molecular processes necessary for the transition phase from seed to seedling, and/or shifting from heterotrophic to (photo) autotrophic growth of seedling. This is a decision-making transition phase for any plants to enter into a natural or agricultural ecosystem which is important for crop production. To reach the phototrophic state, the seed-to-seedling transition stage is regulated by various temporally and spatially employed regulatory factors. These regulatory factors are the controlling unit able to modulate the genes and proteins, may be responsible for seedling establishment. The two distinctive developmental states of germination physiology, i.e., germination and seedling development's gene expression network depicted the global transcriptional interactions. Moreover, this transition stage is characterized with an agronomic trait of seedling establishment and vigor, one of the major aspects in agriculture as revealed by Silva *et al*. [20].

1. In seed germination, uptake of water by seeds is a triphasic process: phase I is characterized with a rapid initial uptake of water i.e., the physical process imbibition. Moreover, Fait *et al*. [15] revealed that in Phase I there is no visible morphological changes was observed, and it is specified as preparation phase for the protrusion of radicle so various kinds of metabolic activities are going on within the seed. Phase I is followed by plateau phase (phase II) where water content is remaining constant but the metabolic activity increases. Protrusion of radicle by rupturing the seed coat, is an embryo-protecting structure acts as a morphological marker to define the end of phase II, and further a sharp increase in water uptake (phase III) was observed as the embryonic axis elongates and the embryo established itself as a young seedling [21].

## 4. Seed priming as connecting link between seed germination and seedling establishment

Seed priming is an innovative, delicate and complex alternative option for the overall improvement of germination physiology as well as many traits during the period of plants life cycle [22, 23]. Seed priming, pre-activate the physiological metabolic processes of a seed that triggers the germination process by imbibing the seed up to a certain level. In priming, the imbibition should be halted precisely at a right time; this time depends on the species, genotype, and the types of seed and has to be dried carefully under the fan/forced air retaining the original weight. Different kinds of seed priming techniques are applied now a days in various crop plants where various priming agents like osmoregulators, salts, plant growth regulators, biopriming agents, magnetic waves, nanoparticle, macro and micronutrients including water are extensively used according to the specific problem associated with the crop's genetic makeover as well as to survive in the multifarious environmental conditions. With special reference to seed germination, if a graph is plotted between seed water content (imbibition/osmosis) and time among the non-primed and primed seeds in three subsequent phases in a stepwise manner it was observed that the first phase of germination represented by the entry of water in the seed via imbibition; is same for both the cases. Second phase (phase II) represents the hydration process in case of nonprimed seeds. Whereas in case of primed seed, this hydration treatment permits restricted imbibition and induce the pre-germinative metabolism ("activation"), but emergence of radicle is prevented. The last phase (phase III) represents the germination and post-germination processes which resembles each other i.e., in both primed and non-primed seeds [24]. In context to this, Ruttanaruangboworn et al. [25] reported that the pattern of rice seed imbibition was affected by $KNO_3$ concentration. Higher the concentrations of $KNO_3$, delayed the time of imbibition of rice seed which took a longer time to reach the end of phases I and II as compared to lower concentration. While using distilled water to see the imbibition pattern, it was quite similar in both rice cultivars. Seeds, primed with 1% $KNO_3$ during imbibition time of early phase II, improve the seed germination and increased both the speed and uniformity of seed germination.

Seed priming is of different type based on the priming agents used for this purpose, namely hydropriming, osmopriming, halopriming, hormonal priming, nutri-priming, bio-priming, matrix priming, nano-priming, magneto-priming and many other. It can be depicted like hydro-priming (continuous or successive addition of a limited amount of water to the seeds), osmo-conditioning or osmo-priming (exposing seeds to relatively low external water potential), halopriming (pre-sowing soaking of seeds in salt solution), hormonal priming (priming solutions containing limited amount of plant growth regulators or hormones), nutri-priming (seeds are soaked in solutions containing the plant growth-limiting nutrients instead of being soaked just in water), bio-priming (coating of seeds with biocontrol agents), redox priming (it represents the redox state of cell and regulates the key processes in growth and development as well as stress tolerance in response to any external stimuli; plants modify their redox state, and the extent of change is dependent on the nature of the stimulus itself, the dose and the time to which the tissue is exposed), solid matrix priming (mixing seeds with a solid or semisolid material and measured amount of water), and pre-sowing soaking (soaking of seeds either in water or in any solution of low water potential before sowing) [26]. For instance, Bose and Tandon [27] depicted that priming can induce the seed germination by improving the speed and synchronization of germination; it can also increase the seed vigor which requires a very short span or no activation time during germination. A wide range of temperature for germination was experienced by Anaytullah and Bose [28] in wheat, which can help to break the dormancy, or may shorten the emergence time with improved seedling vigor in rice [29] and this leads to a better crop establishment with higher yields in rice [30]. The phase I of priming represented the activation of priming memory molecules, repairing of DNA and mitochondria, increase the respiration, and energy metabolism process, ROS signaling and antioxidant mechanism, transcription and translation of different genes, initiate the cell cycle, and induction of stress response gene like LEA, DHY, AQP, and hormone signaling [31]. In seed priming case, Phase II of germination involved in second rehydration and protein synthesis by using newly synthesized mRNA in phase I. Phase III is denoted as postgermination phase; the events taking place in this phase are stored reserve mobilization, elongation of radicle cells, and ultimately at the end of this phase, radicle is emerging out by rupturing the seed coat [31]. However, Dahal *et al*. [32] observed that if the seeds were pre-treated with different priming agents, it facilitates the absorption process of ionic molecules actively with greater availability of ATP and repairing of deteriorated seed parts was also noted by reducing the leakage of metabolites which leads to faster growth of embryo. Greater cellular membrane integrity along with counteraction of free radical and lipid peroxidation reactions [33], was also reported as a positive effect of seed priming; in addition to this, reactive oxygen species (ROS) chain reaction are mostly found to be directly correlated for the maintenance of viability and reduce the moisture uptake by hydrated-dehydrated seed [34], antipathogenic effects [35], repair of biochemical lesions by the cellular enzymatic repair system [36] and metabolic removal of toxic substances [37], biochemical changes such as activation of enzymes [38], and rate of germination of old seeds was increased [39, 40]. Several scientists depicted that seed priming promotes early replications of DNA, increased the synthesis of RNA and protein and enhanced the growth of embryo [31, 41]. Seed priming is an important viable technology for enhancing uniform and rapid emergence of seedlings and high seedling vigor with a better seed yield in some of the field crops like rice, wheat, maize, chickpea etc. was also reported [42–45].

## 5. Seed priming and seedling establishment

Successful establishment of seedling is a paramount contributing facet for many developing countries due to low crop yield/production [46]. In most of the developing countries the irrigation facility are not available properly and the crop production is mostly based on rain fed cultivation; as a result water scarcity is there during the time of seed germination and seedling establishment. According to Fischer and Turner [47] high speed and uniform germination of seed under water deficiency is a determinant factor which affect the crop establishment. However, if the effect of stress can be omitted during the time of germination phase, there will be high chances to attain a good crop establishment [48]. Seed priming is an alternative, eco- and farmers' friendly pre-sowing technology promotes the seedling development by modulating and regulating the pre-germination metabolic activity prior to emergence of the radicle and ultimately increases the germination rate and seedlings performance [29].

In continuation with this, *Arabidopsis* is taken as a model plant to study the functional genes involved in seed germination extensively. In this study, *Arabidopsis* mutant was taken into consideration [49–52]. Some of the mutations slow down the germination of seed but do not significantly arrest it. These phenomena may take place due to the mobilization of storage reserves of seeds accumulated during the time of seed maturation and as a result of, a significant reduction in oil reserve content [50, 53, 54]. Whereas, another experiment with a *Arabidopsis* mutant depicted that it was deficient in plastidic pyruvate kinase (pkp1) activity as a result the germination of seeds was delayed and, consequently, it can be said that seedling establishment is not only affected by mobilization of reserves accumulated during seed development, but reduced pyruvate kinase activity was also a determinant factor during germination [55]. In addition, an integration of metabolite and transcript status is required during the time of phase transitions i.e., from seed to seedling. Moreover, Borisjuk *et al*. [56, 57] stated that elevated levels of glucose or sucrose are associated with seedling establishment. For instance, the other metabolic processes of a cell are also working in a high carbohydrate contents state, which may play an important role in seedling establishment [58]. In addition, sugar pathways are also linked with nitrogen pathway via cross-talking mechanism and playing a vital role in seedling establishment [59].

The major transportable form of nitrogen in plants is amino acids [60, 61] and the plant's growth is also dependent on the supply of nitrogen, assimilation and its utilization [62]. According to Zheng, [63] the gene responsible for the synthesis of carbohydrate and proteins are modulated by the balance between C/N and it is a decision-making factor. Likewise, during heterotrophic to autotrophic transition the metabolic regulations extend beyond the primary metabolism. Moreover, the identification of primary metabolites involved in gene expression is possible, by studying their expression pattern of specific genes [64].

For the priming of seeds, mainly in case of halo- and osmo-priming different low water potential chemical solutions are used where PEG, NaCl and various salts can be taken as priming agents. From these solution seeds can uptake various nutrients along with the water during the time of imbibition. These nutrients are required for metabolic activities at the time of germination and seedling establishment in the field and thereafter enhance the performance of crops as a whole [65–67]. These nutrients while going inside the seed may act as a secondary signaling element and enhance the metabolic activity during germination and make it faster as compared to non-primed seeds. Various scientists when compared the non-primed seeds and primed seeds of rice, wheat and mustard, then they observed that seed priming have the capacity to enhance the seedling establishment and seedling vigor, i.e., density of plants, fertile tillers number, test weight, number of grains per panicle, etc. in the field condition [65, 68].

Ghassemi-Golezani *et al*. [69] while studying the early emergence and stand establishment of lentil (*Lens culinaris* Medik) noted that these parameters are playing a vital yield-contributing factors in rainfed areas. To mitigate the problem of rainfed cultivation a seed invigoration technique can be used for lentil seeds; i.e., lentil seed are primed with water (hydropriming) and NaCl (osmo-priming) and resulted in higher seedling emergence and field establishment, as compared to non-primed seeds and primed with PEG and $KNO_3$. The rate of seedling emergence was also improved in primed seeds with water, NaCl and $KNO_3$. Therefore, they concluded that hydropriming is a very simple, low cost and environmentally friendly technique for the betterment of seed and seedling vigor of lentil.

Germination and subsequent seedling growth of many springs sown legume varieties, can be inhibited by different genetic and environmental factors depending upon the species and varieties. Under drought condition, priming may be a beneficial technology to reduce the risk of poor stand establishment and it allows more uniform growth under irregular rainfall. Furthermore, pre-hydration of the seeds and enhancing the metabolic activity, hydropriming is a simplistic approach which minimizes the use of chemicals. In this case, the beneficial effects of hydropriming under water stress conditions in lentil were clearly observed [70]. In addition, hydroprimed seeds were germinated and grew more rapidly as compared to non-primed control seeds, and the lentil germinated seeds are benefited by successful seedling establishment and improved seedling growth under water stress condition [70].

Eskandari and Kazemi, [71] did an experiment with cowpea (*Vigna unguiculata*) and considered the parameter early emergence, stand establishment and vigor of seedlings in rainfed areas by priming the seeds with water (hydropriming), 1.5% $KNO_3$ and 0.8% NaCl (halopriming). It was analyzed that hydroprimed seeds showed significantly improvement in germination rate, seed vigor index, and seedling dry weights followed by NaCl priming. Likewise, it was again proved that in pulses like lentil, cowpea and in many other hydropriming is a better option to avoid chemicals for the improvement seed and seedling vigor which is a simple, cost effective and eco-friendly technology.

For instance, Peraza-Villarreal *et al*. [72] evaluated the effects of seed priming and soil retainers on seed germination and performance of early seedling of useful species in a tropical semideciduous forest of Veracruz, Mexico. They tried to determine the mass, water and lipid content in the seeds of *Albizia saman*, *Cedrela odorata*, *Enterolobium cyclocarpum*, and *Swietenia macrophylla*. The seeds were hydroprimed with water and natural primed by seed burial inside the soil and let them germinate at 25°C and 25/35°C. The seedlings produced were grown in a shade house and planted in a plain terrain land and/or in hillside (slope 75%). After assessing the above said parameters, it was observed that *S. macrophylla* and *E. cyclocarpum* seeds had the lowest and highest water content, whereas, *S. macrophylla* and *C. odorata* had oils in seeds. In addition to this, *A. saman* and *E. cyclocarpum* seeds exhibit physical dormancy. Natural priming improved the rate of germination in *A. saman*, *C. odorata*, and *S. macrophylla,* while hydropriming at 25/35°C enhanced the rate of germination in *E. cyclocarpum*. So natural priming can be recommended for *A. saman*, *C. odorata*, and *S. macrophylla*, and for *E. cyclocarpum* seeds hydropriming was a better option for seed germination and seedling establishment in plain terrain and hillside land. From this study it can be concluded that seed pre-treatments were an inexpensive and easy tool and can be potentially applicable in restoration and conservation programs.

Various works related to seed priming in different crops and in various aspect such as in normal and stressful environmental condition was reported by different scientists. Anaytullah & Bose, [28], Mondal *et al*. [29], Sharma & Bose, [73], Bose *et al*. [74] & Anaytullah *et al*. [75] were working in the field of seed priming with different nitrate salts where the seeds of various fields crops like rice, wheat, mustard were imbibed in nitrate salt for restricted period of time i.e., before the protrusion of radicle & dried back to its original weight under forced air at normal room temperature before sowing. These scientists stated that nitrate seed priming technology have the potentiality to improve the germination physiology, vegetative growth & increase the productivity of these crops as reported by Bose and Mondal, [76]. They named these seed priming process as nitrate seed hardening technology. Bose *et al*. [77] did an experiment in maize (*Zea mays* L.) by soaking the seeds in Ca $(NO_3)_2$ and $GA_3$ and found a sharp increase in fresh and dry weights of shoot and root during the later period of seedling growth; whereas seed primed with $GA_3$ showed better performance during early seedling emergence. Likewise, Krishnotar *et al*., [78] revealed that seed invigoration with $Mg(NO_3)_2$ and distilled water in maize significantly improved the seedling emergence and stand establishment in field condition, vegetative growth, relative water content of shoots and roots, and yield attributes; that means it has an immense crucial role in seedling emergence and stand establishment. In addition, Pant and Bose, [79] reported that seed priming with salts like $NaHCO_3$, $KH_2PO_4$ and $K_2SO_4$ in different concentrations, improved the germination percentage, dry weight and vigor index of rice seeds and seedlings respectively. Priming also increased the α-amylase activity and soluble sugar content in the rice endosperm during the time of germination which signifies the importance of seed priming in seed germination to seedling establishment. Moreover, Kumar *et al*. [80] designed an experiment on late sown sesame crop. The sesame seeds were primed with $KNO_3$ which promotes the germination percentage, shoot and root length, fresh and dry weights of seedling, increase the activity of catalase and peroxidase, proline content as well as different yield attributes. It can be said that seed priming under late sown condition also improves the germination to seedling establishments and as a result yield was increased. For instance, Jangde *et al*. [81] experience low temperature in wheat crop by primed them with $CaCl_2$, $Ca(NO_3)_2$, EGTA during the time of germination and seedling emergence. Among the priming treatments it was noted that $CaCl_2$ was more efficient for the improvement of germination percentage, relative and absolute water content, increased the activity of α-amylase and as a result better shoot and root length of seedlings under low temperature condition. Whereas, Kumar *et al*. [82] depicted the beneficial role of seed priming with water (as hydropriming), $Mg(NO_3)_2$ and $Ca(NO_3)_2$ (as halopriming) for the improvement of seed germination and early seedling establishment of wheat under heavy metal stress (by applying $HgCl_2$) in wheat.

## 6. Conclusion

To understand the transition between seed to seedling establishment, magnificent number of successful and contributory research works are still going on. Introduction of gene expression and related regulatory networking system provides a template for the identification of different transcriptional regulators beside their cross-linking effects and interacting path ways; it further unveils a no. of signaling mechanisms between germination to seedling formation of a seed. This involves the extensive study and understanding of the physiology of germination. However, agriculturally important but a complex trait which comes after the establishment of seedling i.e., seed vigor, very much responsible, contributory and deciding factor for the productivity of any crop in the farmer's field. From the physiological point of view if we engross ourselves to understand germination basically incepts from the beginning of radicle protrusion and ends to seedling establishment, in that seed vigor has a crucial role, can be practically enriched by using an alternative, interlinking, gap-filling eco- and farmers friendly technology i.e., seed priming. Rapidly growing population with erratic changes in climatic conditions, people are standing in endangered situations; in this point of view the significance of seedling stand establishment and vigor of any crop is increasing with time. The present chapter highlights mainly that how seed priming, a technology, can be handled by general crop growers without much effort is being helpful in reducing the risk of poor seedling establishment in field even in erratic ambient or the broad spectrum of climatic conditions via improving seed vigor. In seed priming, various range of priming agents including water are used to pre-fabricate the seeds. The time duration for priming depends on the genotype makeover of any crop and during this period seed absorb different ions based on the external solution which may act as a signaling element within the seed for the pre-activation of metabolic activities during the process of germination. In nutshell, seed priming interlinks the processes as whole like pre-activation of metabolic events which reduce the time gap from seed sowing to seed germination and speed up the different phases in later one; along with this it also helps a continued supply of mobilized reserve nutrients, required for successful establishment of seedlings.

## Conflict of interest

The authors declare no conflict of interest.

## Notes/thanks/other declarations

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