Seed Priming on Germination, Growth and Flowering in Flowers and Ornamental Trees

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Abstract

Seed dormancy is an emerging problem related to germination which is common in many species of ornamental trees and flowers. Poor seed germination and subsequently poor field establishment are a common phenomenon at adverse conditions of environment. The most important problems faced are the heterogneity and lack of suitable conditions in soil that causes decrease in germination percent. Priming is a water-based technique that consents metabolic processes necessary for enhancing germination rate and seed quality by managing the temperature and seed moisture content in which the seed is taken through the first biochemical processes within the initial stages of germination but preventing the seed transition towards full germination. This is a successful way through which plants would be able to complete their growth on or before the stresses arrive (Subedi KD, Ma BL. Agron J 97(1):211–218, 2005). Seed priming technique has been practised in many countries including India, Pakistan, China and Australia, and more than thousand trials had been conducted to evaluate the performance of priming in a variety of crops. The principle of seed priming is to minimise the period of emergence and to protect seed from environmental stresses during critical phase of seedling establishment to synchronise emergence which lead to uniform establishment and improved yield. It reduces the effect of salinity on the morphological parameter of the plants. Various priming techniques, like osmopriming, biopriming, halopriming, thermopriming, hydropriming, hormonal priming and solid matrix priming, give favourable result in seeds of ornamental flowers as well as trees. This technique has been successfully carried out in flower crops like balsam, coneflower, cosmos, gladiolus, pansy, marigold,

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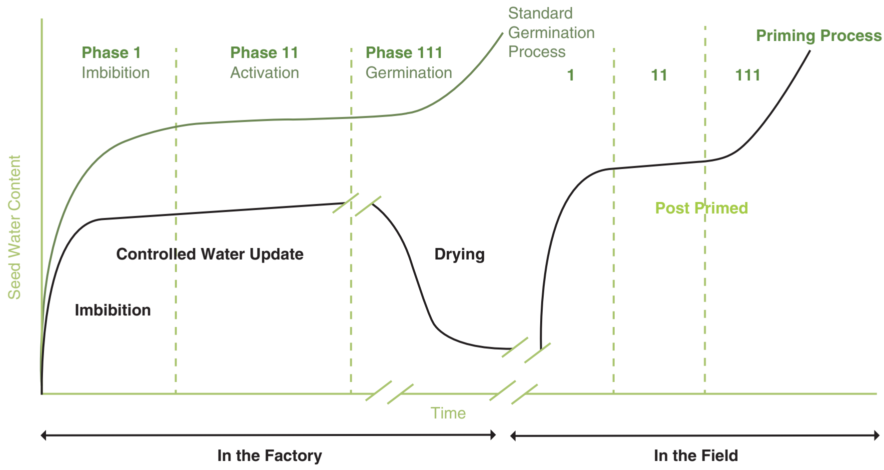
periwinkle, rudbeckia, salvia, snapdragon and zinnia and trees like cassia, cypress, senegal, eucalyptus, fig, teak, pine, almond, tamarind, oak, *karanj*, *khejri*, *siris*, *subabul*, *kapok*, *gulmohar*, *kachnar*, etc.

Keywords
Priming · Gladiolus · Periwinkle · Eucalyptus · *Kachnar*

Establishment of crop is the primary importance for optimising horticultural production. Every year, mankind awaits for the miraculous transmogrification of seeds into plants and again into seeds. Poor seed germination and subsequently poor field establishment are a common phenomenon at adverse conditions of environment. It has been reported that the major difficulty to high yield and production of crop plants is due to the lack of synchronised crop establishment and adverse weather and soil conditions (Mwale et al. 2003).

Seed dormancy is another problem related to germination which is common in many species. It is an adaptation that allows a species to regulate the timing of germination for seeds in a population. Some species use environmental cues (such as drought, rainfall or temperatures) to integrate germination for most seeds at a particular time of the year. Temperature, moisture, air and light conditions are the most important factors for seed germination. Minimum temperature is the lowest temperature at which seeds can germinate effectively (Nleya et al. 2005), and the maximum is the highest temperature at which seeds can germinate. Slight change in this temperature can damage seeds or make them go into the dormancy condition. At optimal temperatures, germination is rapid and uniform. Seeds need correct moisture to initiate internal processes leading up to germination. Osmotic adjustment or priming of seeds prior to sowing is known as a potent way to increase germination and emergence rate in some species with stepwise seed development (Sivritepe 2000).

Seed priming technique has been practised in many countries including India, Pakistan, China and Australia, and more than thousand trials had been conducted to evaluate the performance of priming in a variety of crops. The need for increased seed quality has become a priority necessary to tackle the current demand for high standards of seeds in the agricultural market. Achieving rapid and uniform seedling emergence is a key point for crop performance since slow germination rates frequently expose plantlets to adverse environmental conditions and soilborne diseases (Osburn and Schroth 1989). Priming is a water-based technique that consents metabolic processes necessary for enhancing germination rate and seed quality by managing the temperature and seed moisture content in which the seed is taken through the first biochemical processes within the initial stages of germination but preventing the seed transition towards full germination. This is the way through which plants would be able to complete their growth on or before the stresses arrive (Subedi and Ma 2005).



The above graph shows about the standard germination process and seed priming process in the factory and field condition. The green line corresponds to a standard germination process. During Phase I (imbibition), seeds take up water sufficiently under suitable availability of temperature and moisture. During Phase II (activation), the biochemical processes are activated and will eventually start the germination in Phase III (germination) where roots and hypocotyls emerge from the seeds. During priming, the seed invloves the activation processes followed by drying, before root can emerge from the seeds. Once conditions (temperature and moisture) are appropriate in the field, Phase III can continue, and germination occurs in a much shorter time (Hasegawa 2016).

The purpose of seed priming is to minimise the period of emergence and to protect seed from environmental stresses during critical phase of seedling establishment to synchronise emergence which lead to uniform establishment and improved yield. It reduces the effect of salinity on the morphological parameter of the plants. One of the priming techniques called osmopriming is a commercially used technique for improving seed germination and vigour. It controls imbibition of seeds to start the initial germination process followed by seed drying up to its original weight. Apart from germination process, seed priming also helps in growth and flowering of the crops. Various seed priming techniques like hormonal priming and chemopriming for enhancing flowering and growth of plant are commercially practised in- or on-farm basis. Where, on farm seed priming is energy intensive, high technology seed priming, seed hardening or seed conditioning process are available to farmers to help them in high input temperate agriculture and horticulture. (Harris et al. 2001).

The priming treatments which enhance seed germination include hydropriming (Afzal et al. 2004), biopriming, halopriming, solid matrix priming, chemopriming, thermopriming, osmopriming and hormonal priming (Afzal et al. 2006).

14.1 Physiological and Biochemical Aspects of Priming

A successful application of seed management technique depends upon the type of test, method of application, selection of crop, initial performance of the crop, selection of chemical, its concentration, duration of treatment and the purpose of implication. Priming method in seed management techniques is proven very essential factor for enhancing quality issues, germination rate, establishment, etc. Priming can inverse some of the ageing-induced deteriorative events, resulting in improved seed performance (Taylor et al. 1998). It has shown an immense effect to activate different processes related to cell cycle and to induce synthesis of nuclear DNA in radial tip cells in tomato (Liu et al. 1997).

Long duration seed storage caused a decline in the level of protein content which may cause oxidation of the amino acids, due to the increase in the respiratory activity and advance in the degradation process of the stored seeds. Seed deterioration causes loss of membrane integrity, changes in enzymatic activities and declines in protein and nucleic acid synthesis and lesions in DNA (McDonald 1999). Priming with 30% PEG for 24 h resulted in increase in the activity of superoxide dismutase (SOD) and peroxidise (POD) which enhance the intensity of respiration of plant and cause an increase in vigourity in germination (Jie et al. 2002). Priming is also thought to increase the activity of many enzymes involved in metabolism of carbohydrates (α- and β-amylases), proteins (proteases) and lipids mobilisation (isocitrate lyase) that are implicated in the stored reserves mobilisation (Varier et al. 2010; Di Girolamo and Barbanti 2012). These enzymes are vital in the breakdown of macromolecules for the development and growth of the embryo that ultimately result in early and higher seedling emergence (Farooq et al. 2006a, b; Varier et al. 2010). There are reports that priming facilitates the repair of chromosomal damage (Sivritepe and Dourado 1995), permits early DNA replication and repair, increases RNA and de novo protein synthesis and reduces the leakage of metabolites (McDonald 2000; Farooq et al. 2007a, b; Manonmani et al. 2014; Paparella et al. 2015). Thus, total seed protein, POD, PPO, RNA and de novo protein synthesis were increased significantly by seed priming. Among the various processes of priming, osmopriming may enhance rapid seed germination by reducing mechanical hindrance on the germinating embryo (Toorop et al. 1998).

14.2 Seed Priming Techniques

Seed priming includes various techniques which influences growth, establishment and germination of seeds and also influences yield of the crop. Techniques include the following.

14.2.1 Hydropriming (Drum Priming)

A major cause of poor establishment and low crop yield in agricultural areas is the lack of moisture content that reduces the ability of seedling to further emerge and growth. Hydropriming is a technique for enhancing germination without the emergence of the radicle and plumule which involves soaking of seeds in a priming agent solution followed by drying even if seeds are infected with pathogens (McDonald 1999). In hydropriming, distilled water plays a vital role for imbibition up to 10–20% (Pill 1995). It results into uncontrolled water uptake, since the process depends on seed affinity to water and the main critical point is to find and maintain optimal temperature and humidity conditions to avoid radicle protrusion (Taylor et al. 1998). Another limiting factor of hydropriming is the lack of homogeneous seed hydration which can lead to uneven germination (McDonald 2000). The main variant of hydropriming also called drum priming, patented by Rowse (1991) in which a drum that contains seeds is connected with a boiler generating vapour. The vapour condenses into liquid water inside the drum. The machine measures the increase in seed relative mass during the treatment. The time and volume of water required to complete seed rehydration are strictly controlled to reach gradual and even seed imbibition (Warren and Bennett 1997). Hydropriming is the most ancient type of priming, since the benefits of this pre-sowing treatment have been known for a long time; however, it is now applied less frequently in comparison with other methods.

14.2.2 Biopriming

Biopriming is a new technique of seed treatment that assimilates biological (inoculation of seed with beneficial organism to protect seed) and physiological aspects (seed hydration) of disease control. To respond to the negative effects of pathogens, biopriming uses beneficial microorganisms to protect against pathogens and enhance plant growth. Biological seed treatments for control of seed and seedling diseases offer the grower an alternative to chemical fungicides. Storage and application conditions are more critical than with chemical seed protectants and differential reaction to hosts, and environmental conditions may cause biological seed treatments to have a narrower spectrum of use than chemicals. Conversely, some biocontrol agents applied as seed dressers are capable of colonising the rhizosphere, potentially providing benefits to the plant beyond the seedling emergence stage (Nancy et al. 1997). Seed treatment with biocontrol agents along with priming agents may serve as an important means of managing many of the soil- and seed-borne diseases, the process often known as 'biopriming'. It involves coating seed with a bacterial biocontrol agent such as *Pseudomonas aureofaciens* AB254 and hydrating for 20 h under warm (23 °C) conditions in moist vermiculite or on moist germination blotters in a self-sealing plastic bag. The seeds are removed before radical emergence. The bacterial biocontrol agent may multiply substantially on seed during biopriming (Callan et al. 1990). Biopriming seed treatments can provide a high level of protection against root rot diseases of crop plants which was generally equal or superior to the control provided with fungicide seed treatment. So, it could be suggested that biopriming (combined treatments between seed priming and seed coating with biocontrol agents) may be safely used commercially as substitute for traditional fungicide seed treatments for controlling seed- and soilborne plant pathogens.

14.2.3 Halopriming

Halopriming is one of the methods of priming practices that includes salts like $CaCl_2$, $CaSO_4$ and NaCl in such a way that the pregermination metabolic activities start preventing radical protrusion followed by drying seeds to the original moisture level (McDonald 2000). In this method, the seeds are immersed in different salt solutions which facilitate the process of seed germination and subsequent seedling emergence even under adverse environmental conditions. Seeds treated with NaCl concentrations should be in a tolerable limit. Early initiation of metabolic activities and reserve breakdown and mobilisation might be the reason for faster germination in such type of primed seeds. Khan et al. (2009) reported salt priming induced salinity tolerance of hot pepper at seedling stage, wherein seed priming improved significantly the germination percentage and index, vigour index, plumule and radical length and dry weight of seedling as compared to the non-primed seeds (control). Improved stress tolerance of primed plants is thought to rise from the activation of cellular defence response due to halopriming (Beckers and Conrath 2007). This has been substantiated by reports on better antioxidant system in primed plants (Afzal et al. 2006) on exposure to stress. Conrath et al. (2006) proposed that halopriming could involve accumulation of signalling proteins or transcription factors. Halopriming is a simple and cheap agrotechnique and found suitable to be recommended to the farmers owing to better synchrony of emergence and crop stand under various conditions of environment (Sedghi et al. 2010).

14.2.4 Solid Matrix Priming

Solid matrix priming (SMP) is similar to osmotic priming that allows the seed to attain a threshold moisture content and pre-germinative metabolic activity but preventing radicle emergence. However, it has the advantages of allowing aeration, incorporation of biological agents to combat soilborne pathogens and improved ease of handling (Taylor et al. 1988; Wang et al. 1998). The matrix comprises of finely divided non-plant pathogenic water holding solid, which may be carbonaceous substance, preferably a lignateous solid which has a large eqilibrium water potential (ψ) and preferably has an osmotic potential component which is atleast about 90% or greater than 95% of the total water potential. Such materials include coal, especially soft coal, lignateous shale such as the leonardite shale, sold as Agro-Lig, and sphagnum moss. The matrix material when containing the water to prime the seeds must be sufficiently friable, non-clumping, etc., so that it can be mechanically separated from the treated seeds after treatment without damage to the seeds when required. The process of SMP includes the admixture of a predetermined amount of solid matrix material and a predetermined amount of water and the mixture allowed to stand preferably in a container which allows entry of air but reduces evaporative losses, resulting in sufficient amount of moisture level in seeds. Matrices can be readily used in tree seed nursery operations.

14.2.5 Thermopriming

Seed treatments carried out at various intervals of time before sowing are known as thermopriming. Information exists to specify that seeds germinate better under alternating temperature conditions compared to a constant daily temperature (Felippe 1980; Shin et al. 2006; Markovskaya et al. 2007). Changing temperature can break the dormancy of seed easily. This technique has been widely adapted to improve germination efficiency under adverse climate reducing thermo-inhibition of seed germination (Huang et al. 2002). Pre-sowing seed treatments with alternating daily temperature regimes have resulted in enhanced plant development, increased cold and/or frost resistance and higher plant productivity in cucumber and melon (Markovskaya et al. 2007). Small changes in ambient temperature can regulate flowering time via a thermosensory pathway (Franklin 2009). It was shown that cold treatment at the seedling stage can modulate the flowering of some ornamental plants (Runkle et al. 1999; Garner and Armitage 2008). Although high temperature condition has been used in some species, resulting pregermination especially for plants adapted to warm climates (Khalil and Rasmussen 1983). Seeds of white spruce (*Picea glauca* L.), lettuce, etc. that were primed with combinations with other treatments resulted in beneficial effects on germination parameters (Liu et al. 2013; Ashraf and Foolad 2005). It has been suggested that priming is responsible to repair the age-related cellular and subcellular damage of low-vigour seeds that may accumulate during seed development (Bray 1995). Wang et al. (2003) reported that both thermo- and hydro-primed seeds showed significant increase in germination performance. The resultant effect of priming depends on the method used and time of treatment.

14.2.6 Osmopriming

Osmopriming, also known as osmotic conditioning, is a widespread pre-sowing priming procedure which involves treatments of seeds with osmotic solutions at low water potential facilitating the control of water uptake into the seeds. The main goal of osmopriming is to limit the reactive oxidative species, i.e. ROS-mediated oxidative injury through insufficient water absorption. Thus, the water potential of the osmotic agent used is a crucial parameter during the priming process (Heydecker and Coolbear 1977; Taylor et al. 1998). Priming with PEG provides beneficial conditions for bacterial growth due to poor aeration (Parera and Cantliffe 1994). It shows some disadvantage when used in bulk, due to high costs and extremely high viscosity which limits oxygen transfer within the solution. Hence, research has to be done for choosing the correct chemical and its optimum dose for a crop. It is difficult to manage huge quantities of wet primed seed especially under hot tropical climate condition, while in temperate areas, maintaining the priming temperature is crucial. Some of the osmotica (osmotic compounds used for osmopriming) that can be used include potassium nitrate, potassium dihydrogen orthophosphate, dipotassium hydrogen orthophosphate, calcium chloride, zinc sulphate, borax, magnesium chloride, manganese sulphate, sodium chloride, sodium sulphate and organic compounds, viz. agrosan, cycocel, citric, furamic, succinic, malic acids, purines, pyrimidines, caffeine, uracil, xanthine and uridine diphosphate (De Chandra 1999).

14.2.7 Hormonal Priming

Hormone pretreatment is a commonly used priming approach to improve seed germination in stressful conditions (Atici et al. 2003; Gratao et al. 2005; Jisha et al. 2013; Masood et al. 2012; Hu et al. 2013). Hormonal priming in general consists of treatment of seeds with chemicals like growth regulators, sodium hypochlorite (NaOCl) or hydrochloric acid (HCl), natural substances and agrichemicals (e.g. fungicides, pesticides). It has reduced the severity of the effect of salinity, but the amelioration was found maximum due to the application of 50 ppm salicylic acid and 50 ppm ascorbic acid treatments and gives satisfied results on seedling growth, fresh and dry weights under non-saline and saline conditions, whereas hormonal priming with ABA was not effective in some of grass family crops (Afzal et al. 2006). In pepper (*Capscum annum* L.), Khan et al. (2009) showed that pretreatment with acetylsalicylic acid and salicylic acid resulted in greater uniformity of germination and establishment of seedlings under high salinity. In addition to these chemicals, ethylene was used to minimise the effect of high temperatures on seed germination of lettuce (Nascimento 2004, Nascimento et al. 2005).

14.3 Seed Priming in Ornamental Flower Crops

14.3.1 Balsam

Response of hormonal priming on flower quality, growth and germination rate of balsam was observed according to the basis of germination rate dry weight and shoot and root length. GA_3 at 10 ppm strikingly enhanced the germination percentage and speed of germination of balsam. The germination was higher in large seeds (grade A) which might be due to more supply of food material to the growing embryo. However, GA_3 at 30 ppm increased the length of shoot and root, dry weight and fresh weight of seedlings reported by Singh and Karki (2003).

14.3.2 Coneflower

Osmotic priming in polyethylene glycol (PEG) or matrix priming in expanded vermiculite had greater rate, synchrony and germination percentage at 20 °C than non-primed seeds of coneflower (*Echinacea purpurea*). Osmotic or matrix priming for 10 days at −0.4 MPa and 15 °C resulted in higher germination rate and germination percentage than short duration of exposure (5 days) or lower (−1.5 MPa) water potential. Seedling emergence rate, synchrony and percentage from osmotically or matrically primed seeds were similar in both cool (23–27 °C day) and warm (35–40 °C) glasshouse regimes. Emergence was faster in primed than from non-primed seeds in both regimes. Emergence percentage was higher (80%) from primed seeds than from non-primed seeds (50%) in the cool regime, but emergence synchrony was unaffected. Moistened vermiculite substituted for PEG solution as a priming medium for purple coneflower seeds benefits to seed germination or seedling emergence followed by priming (−0.4 MPa, 15 °C, 10 days of darkness) in these media (Pill et al. 1994).

14.3.3 Cosmos

In cosmos (*Cosmos bipinnatus*), hormonal priming plays a main role in enhancing flowering and quality of flowers. The triazoles, which include paclobutrazol (PB) and uniconazole, are more potent and persistent than most other growth retardants. PB is used most commonly in commercial practice, but non-uniform plant size can result from non-uniform spray application. Soaking of cosmos seeds to 1000 ppm PB reduced seedling shoot height but also reduced seedling emergence percentage (Pill and Gunter 2001). Seed treatment with PB also eliminates conventional fungicide seed coating treatment since the triazoles themselves are potent fungicides (Fletcher and Gilley 2000).

14.3.4 Fir

Seeds of true firs, including pacific silver fir (*Abies amabilis*), subalpine fir (*A. lasiocarpa*) and noble fir (*A. procera*), exhibit deep dormancy at maturity. To break the dormancy termination, seeds generally require prolonged moist-chilling condition (i.e. 3–4 months or longer) (Edwards 1981, 1986; Leadem 1986; Tanaka and Edwards 1986; Edwards 1996). In some cases, germination can be impaired by seed-borne pathogens where some of the seedlots have a high proportion of empty seed (Kolotelo 1998). This seed dormancy can be broken down with solid matrix priming when seeds are existed in most chilling temperature. Agro-Lig Greens Grade (humic acids with particle sizes between 0.212 and 1.29 mm), sand (particle size 1.29 mm), peat moss and sphagnum moss are used in matrix priming that help in breaking dormancy in seeds of Abies spp. and early germination in seeds with high seedling establishment (Ma et al. 2003).

14.3.5 Gladiolus

Gladiolus alatus is a prominent bulbous cut flower that sometimes gives less productivity due to low-quality seed, inadequate seedbed preparation, late sowing, poor sowing technique, inadequate soil moisture, adverse soil properties and high temperatures. Seed priming has been successfully demonstrated in this crop to improve germination and emergence in seeds. It is the enhancement of physiological and biochemical events in seeds during interruption of germination by low osmotic potential and negligible matric potential of the imbibing medium. Hydro-primed seeds compared to KNO_3-treated seeds (osmo-primed) were allowed to imbibe water for a longer time. Seeds treated with 0.25% KNO_3 attained the maximum (66.67%) level of germination followed by 60% in 0.75% KNO_3 (60%) and distilled water. After 30 days, the germination percentage was recorded maximum with treatment of 0.25% KNO_3, 0.75% KNO_3 and distilled water (83.33%) followed by non-priming (63%) and 0.5% KNO_3 (60%)-treated seeds (Mushtaq et al. 2012).

14.3.6 Meadow Fescue

Priming is highly useful for seeds under stress condition. NaCl priming (halopriming) and hydropriming on germination and early growth of *Festuca arundinacea* and *Festuca ovina* seeds were studied under salinity condition. It was observed that NaCl priming with concentrations of 15 and 45 dS/m in *Festuca arundinacea* seeds and NaCl priming with concentration 45 dS/m in *Festuca ovina* seeds had the highest performance of improved seed in both species at germination and early growth stages under salinity stress (Shakarami et al. 2011).

14.3.7 Pansy

Temperature stress is one of the most important factors that affect the growth and development of seeds of pansy (*Viola tricolor*). Thermo-inhibited seeds fail to germinate in high temperature but can germinate when temperature is reduced which may result in thermo-death of the plant which is mostly seen in pansy. So in such condition, there is a need for priming of seeds that may induce the germination rate by improving seed quality. Dorna et al. (2014) reported that hydropriming, halopriming and osmopriming gave significant effect on germination of pansy seeds. Osmopriming seeds in polyethylene glycol (PEG) solutions of −1.25 and −1.5 MPa osmotic potential at 15 °C and in PEG solution of −1.0 MPa osmotic potential at 20 °C increased the percentage of germinating seeds significantly at 30 °C. Osmopriming seeds, in all combinations used, improved the percentage of germinating seeds significantly at 35 °C. The best result was observed when seeds were primed in PEG solution of −1.0 MPa osmotic potential at 20 °C. At higher temperature hydropriming seeds in volume of water 600 μl H_2O g/seed for 3 days at 15 °C and osmopriming at 20 °C positively affected the germination rate. After osmopriming of seeds at 15 °C and after osmopriming in PEG solution of −1.0 MPa osmotic potential at 20 °C, the percentage of ungerminated seeds was lower than treatment control. Both halopriming at 20 °C and osmopriming, regardless of temperature and osmotic potential of PEG, improved significantly the uniformity of germination at 30 °C compared with untreated seeds. It was also observed that osmopriming followed by halopriming improved the speed of germination in pansy at 20 °C to the largest extent. Moisture content was also increased due to priming, but drying of seeds after priming affects the moisture content (Suleman et al. 2011).

14.3.8 Periwinkle

Seed priming (biopriming) increases antioxidant activity and seedling vigour in seeds of periwinkle (*Catharanthus roseus*). Seeds were treated with diazotrophs, i.e. *Azospirillum* and *Azotobacter* as separate treatments for 30 min. The germination percentage was calculated from 8 days after sowing (DAS) to 12 DAS. There was a significant increase in germination rate and non-significant in dry matter content. There was a significant increase in SOD, POX and CAT activities under *Azotobacter* and *Azospirillum* treatments and also an increase in the germination percentage, root length, shoot length and vigour index of the *C. roseus* (Karthikey et al. 2007).

14.3.9 Pot Marigold

Calendula officinalis, commonly known as pot marigold, was positively affected by seed priming method that influences the germination percentage and quality of seeds. Hydro- and hormonal priming give paramount results in seeds of pot marigold. Water or distilled water is used as hydrating agent in hydropriming in which seeds are needed to be soaked for few hours. As a result, sufficient water gets imbibed into the cell wall of marigold seeds that enhances the germination and further growth. In hormonal priming, GA_3 results better among all the growth regulators in relation to germination rate, flowering and total sugars (Karimi and Varyani 2016), but increase in concentration adversely affects the germination rate. However, GA_3 in addition to KNO_3 results profuse seedling establishment, shooting, rooting, maximum root length and vigour index in seeds of pot marigold. It was also noticed that the catalase activity increased significantly with GA_3 application, while enzyme activity was higher in the distilled water and KNO_3 treatments compared with the untreated seeds.

14.3.10 Rudbeckia

Rudbeckia fulgida, also known as black-eyed Susan, gloriosa daisy and orange coneflower, is a herbaceous perennial plant. Seed germination in this plant is variable with variable species. Osmopriming is a process of controlled imbibition by the seeds using different concentrations of osmotic solution containing polyethylene glycol (PEG). Accumulation of solutes and enzymatic activation during controlled seed imbibition (Bewley and Black 1978) contributed to the increased radicle emergence rate in primed seeds (Fay et al. 1994).

14.3.11 Safflower

In safflower (*Carthamus tinctorius*), hydropriming has an immense impact in increasing number of plants/m^2, capitula/plant, grains/capitulum, etc. In a field experiment, hydropriming of safflower (*Carthamus tinctorius*) seed for 12 h resulted in higher number of plants/m^2, capitula/plant, grains/capitulum, 1000 seed weight, grain yield and oil content compared to untreated seed (Bastia et al. 1999).

14.3.12 Salvia

The germination of *Salvia officinalis* L. (sage) seeds is a problem of great concern that may be overcome by employing the seed priming techniques. An effect of hydropriming positively affects the germination and seedling growth in sage (*Salvia officinalis*). Priming helps in increasing final germination percentage, improving germination rate, accelerating the synchronised seed germination, vigorous seedling establishment and stimulating vegetative growth and crop yield of many crops. Significantly, higher germination percentage and rate of germination observed in hydro-primed seeds as compared to non-primed seeds indicated a positive effect of seed priming in synchronising the seed germination process (Dastanpoor et al. 2013).

14.3.13 Snapdragon

Seed priming affects the germination growth and flowering of many flowers among which snapdragon (*Antirrhinum majus*) is one of them. There is an imperative need to work on priming techniques of these flower seeds because of the higher price and, moreover, the seeds of F_1 hybrids are difficult to germinate. The effect of biopriming influenced the germination character, shooting, rooting and flowering of snapdragon using *T. harzianum* and *B. subtilis* as bioprimers (Bhargava et al. 2015). Hormonal priming also has positive effect on biochemical changes in seeds that improves membrane integrity and metabolism of seed cell wall as well as synthesis of proteins (globulins and cruciferin) in comparison to non-primed seeds (Varier et al. 2010; Rao et al. 2009).

14.3.14 Sunflower

Biopriming in sunflower gave the utmost result for controlling fungal disease called Alternaria blight, the most important disease, and estimates yield loss up to 80%. Integration of chemicals, plant extracts and biotic agents along with priming agents for managing plant diseases has been considered as a novel approach, as it requires low amounts of chemicals, reducing the cost of control and pollution hazards while causing minimum interference with biological equilibrium (Papavizas 1973). Biopriming of sunflower seeds with *P. fluorescens* in the form of jelly can be used as an alternative method to seed treatment with chemicals (hexaconazole as foliar spray) which is eco-friendly and avoids possible residue problems.

14.3.15 Zinnia

It was found that *Alternaria zinniae* seems the most important fungal seed-borne pathogen of zinnia plants (*Zinnia elegans*), causing spotting of the petals, foliage and stems and rotting of the roots (Dimock and Osborn 1943; Richardson 1990; Łacicowa et al. 1991; Palacios et al. 1991; Wu and Yang, 1992). Łacicowa et al. (1991) reported that zinnia seeds produced in Poland were commonly infested with *A. alternata*, *A. zinniae*, *Botrytis cinerea*, *Fusarium* spp. and *Penicillium* spp. The influence of osmopriming on germination, vigour and location of pathogenic and saprotrophic fungi in zinnia seeds was studied in different varieties of zinnia (Szopinska and Tylkowska 2003) at 20 °C at 45% for 24 h that were sterilised with 1% NaOCl for 10 min at 20 °C at darkness. Disinfection of primed seeds lowered the germination capacity and increased the number of deformed seedlings in variety Jowita, Red man and Talia seeds. Seed priming considerably affected the speed of germination, regardless of sodium hypochlorite (NaOCl) treatment.

14.4 Seed Priming in Trees

Most of the tree species face the problem of extinction due to over-exploitation (Onochie 1990). Seeds of forest trees have problematic seed germination due to adverse soil and environment condition. Various salt contents in soil impaired germination of these seeds when available in excess amount, i.e. when the salt concentration increased up to 0.1%. Various salts like sodium, calcium and magnesium are the most common that contribute to salinity. High levels of fertilisation also contribute to salt accumulation and can be significant in agricultural situations (Treshow 1970). Sometimes, the lack of availability of moisture in seeds affects germination process adversely. Seed priming is an alternative way to avoid this type of problem. Some examples of seed priming of forest trees are mentioned below.

14.4.1 Baobab Tree or Senegal Tree

Baobab tree or senegal tree is scientifically known as *Adansonia digitata*, a deciduous tree. Most of the seeds of *Adansonia* fail to germinate as their propagation is adversely affected by seed coat dormancy which leads to poor growth potential. Sometimes the seeds are unable to germinate in natural condition. Osmopriming and thermopriming help in overcoming the dormancy problem in seeds of *Adansonia*. Hot water, cold water and H_2SO_4 are used for osmopriming and useful in enhancing germination percentage (70%) (Falemara et al. 2013). Different concentration of H_2SO_4 is used with variable time periods. Seeds' emergence is very fast (10 days) when treated with cold water.

14.4.2 Cassia

Cassias are ornamental plants of great beauty including more than 1000 species. Seed production is irregular with low germination percentage in natural conditions due to the integument impermeability. The vigour of stored seeds can be increased with priming, with a decrease in costs and reduction in number of collections (Vertucci 1989). Osmopriming by taking PEG with different water potentials is a helpful method for increasing germination tendency in seeds of cassia. Lowering in osmotic potential results in delaying in radicle emergence (Tarquis and Bradford 1992). Osmo-primed seeds are immediately used without drying or dehydrating as it enhances the germination ability of seeds (Heydecker and Wainwright 1976).

14.4.3 Cedar

Cedrus libani, called as Taurus cedar, is now an extinct species and difficult to grow in a large population. The temperature had the strong effect on the germination of *C. libani* seeds (Bewley and Black 1994; Schmidt 2000). The seeds of this tree exhibit seed dormancy that may be corrected by different pretreatment methods or priming methods. The seeds exhibit better germination performance at lower constant temperatures. Rise in germination temperature may develop secondary dormancy in seeds (Khan and Samimy 1982).

14.4.4 Cypress

Arizona cypress (*Cupressus arizonica*) and medite cypress (*Cupressus sempervirens*) are very important forest tree species for multiple purposes in forestry because of their ability to grow in adverse environments such as calcareous, clayish, dry and poor soils (Gallis et al. 2007). Seeds can germinate even in drought condition by using PEG-8000 as osmopriming agent. The germination percentage decreased in seeds of Arizona cypress with decreased water potential.

14.4.5 Eucalyptus

Eucalyptus has about 700 species and is commercially used for timber and pulpwood for paper and other purposes. Poor germination and seedling establishment are regarded as common problem in eucalyptus which can be corrected by pregermination treatments. Seed size is the most important factor that affects germination in eucalyptus seeds. Spring-germinated seedlings have long growing period and attain maximum size with advanced establishment. Thus, larger seeds are more likely to survive in winter frosts as their susceptible growing tips are better adapted to cold-induced photoinhibition due to more advanced foliar pigment development (Close et al. 2000).

14.4.6 Fig

Seeds are the important planting material for propagation in *Ficus* spp. through which genetically different plants can be developed. It is also easily propagated through rooting and cuttings. Osmopriming, hydropriming and hormonal priming are useful treatment in early establishment of seedlings in *Ficus*. KNO_3, GA_3 and water are used for priming purpose. Early germination due to the priming effect of GA_3 results into longest radicle, which helps in early establishment of new seedling to produce maximum food material with the help of photosynthesis that resulted into the maximum survival of seedlings (Rawat et al. 2010)

14.4.7 Gamhar or White Teak

Gmelina arborea (gamhar) is a fast-growing deciduous tree used for furniture, carriages, sports and musical instruments as its steady timber is moderately resistant to termites. Seeds of *Gmelina arborea* (white teak or gamhar) don't have any dormancy and can easily germinate. Hydropriming in seeds may influence the germination tendency and increase the seedling emergence. Also $KMnO_4$ (0.2 M) treatment increases the germination percentage when seeds are treated with different interval of time duration.

14.4.8 Gulmohar

Delonix regia also known as gulmohar exhibits seed dormancy. For breaking the seed dormancy in seeds of *Delonix*, hormonal priming is efficiently useful by using different plant hormones, i.e. ABA, BAP, GA and IBA. Hot water treatment is also useful that tends to give the germination percentage of 95% in seeds of gulmohar. ABA does not have significant effect in breaking the dormancy. Gibberellic acid will promote the endosperm breakdown and the growth of the embryo that results in the elongation of radicle cells and cause a rupture in the micropyle, and the seed dormancy will be terminated by radicle protrusion from the seed coat. The role of temperature in breaking the dormancy to influence germination can be noticed due to the erratic nature of the germination which terms for the standardisation of both the temperature of the water and duration of cooling as suggested by Owonubi and Otegbeye (2004).

14.4.9 Henkel's Yellowwood

This ornamental tree is dioecious in nature and is used for ornamental purpose. Generally, this henkel's yellowwood tree (*Podocarpus henkelii*) is propagated through seeds. Fleshy fruit that surrounds the seed is removed as this inhibits the germination. Removal of epicuticular wax, the epidermis or the entire epimatium leads to rapid water uptake and germination (Dodd et al. 1989). Seeds stored in shade have more moisture content and reserve more starch through biochemical process. Lipids are the major reserve materials in seeds of *Podocarpus henkelii* followed by proteins, and these embryonic reserves are sufficient for early seedling establishment (Nabanyumya et al. 2015). Soaking seeds more than once a day also breaks dormancy in seeds, resulting in maximum germination percentage.

14.4.10 Whistling Pine

The whistling pine (*Casuarina equisetifolia*) is used as a windbreak in agroforestry system and also for many household uses. The wood is resistant to decomposition in soil or saltwater and is often used as roundwood for making piles, poles and fences. This is accentuated as the successful propagation of any *Casuarina spp*. by a vegetative method is very limited even with IBA hormone application (Mahmood and Possuswam 1980; Pinyopusarerk and Bolan 1990). Different concentrations of growth hormones like GA_3 and ABA, acid substances like sulphuric acid and chemical like $NaNO_3$ are helpful in promoting germination and growth in this tree. The waxy and hard seed coat in seeds of *Casuarina* prevents it to germinate which has been broken with the use of concentrated H_2SO_4 by several workers (Mayer and Poljakoff-Mayber 1963; Ballard 1973; Gill and Bamidele 1981; Etejere et al. 1982; Eze and Orole 1987).

14.4.11 Ivory Coast Almond

Terminalia ivorensis, a tropical deciduous tree, thrives in a wide range of soil and is used as multipurpose trees along with having medicinal uses. Seed germination of tropical species is influenced by several biological factors such as seed viability, seed size (Barrera and Nobel 2003) and plant growth regulators through which acts as germination stimulator (Chen et al. 2008). Seeds are very sensitive to temperature stress as it influences the germination process, and high temperature prevents the elongation of radicle and shoot by inhibiting the synthesis of protein and nucleic acid (Sivaramakrishnan et al. 1990). Soaking seeds of *T. Chebula* (Horitaki) enhances germination rate and vigour index (Hossain et al. 2005). Gibberellic acid can overcome the dormancy in seeds of *Terminalia* spp. by inducing rapid and uniform germination due to deficit in endogenous gibberellic acids (Asomaning et al. 2011). The exogenously applied gibberellic acids help in modifying the influence of cytokinins on transport across membranes and are thus able to initiate the biochemical processes necessary for germination process (Chen et al. 2008).

14.4.12 Kachnar

Bauhinia spp. (mountain ebony) are flowering plants and propagated through seeds and cuttings. This tree has been prioritised as one of the trees for conservation to enhance its contribution to health and livelihood of communities. Various methods are there to break the dormancy in the seeds of this tree that promotes its cultivation and successful regeneration. Mainly germination in kachnar depends on the size of the seeds as larger seeds germinate more percentage than smaller one. Soaking in boiled water makes the seed coats permeable to water and water gets imbibed into the cell wall which results in swelling of the seed as water cools. Recommendation of hot water must be applied judiciously without killing the seeds with excessive heating (Phartyal et al. 2005). Chemical stimulators like KNO_3 enhance seed germination by creating a balance between hormonal ratios in the seed and reducing the growth retarding substances like abscisic acid (ABA).

14.4.13 Karanj (Indian Beech)

The use of biologically active products like biomanures and biofertilisers for the production of quality planting material helps in preventing microbial inoculation of bacteria, algae and fungi in karanj (Revathi et al. 2013). Biopriming with liquid *Azospirillum* and *Phosphobacterium* in different concentrations improves germination, seedling vigour and storability of *Pongamia pinnata* seeds by reducing microbial infections. An increase in the seed germination might be due to the increased cytokinin production which actively involved in cell division (Suma et al. 2014) and production of growth-regulating substances like auxin, GA and cytokinin (Kucey 1988) when seeds are encapsulated with biofertilisers.

14.4.14 Khejri

Prosopis cineraria (khejri) is a flowering tree of which seeds sometimes show dormancy effect which can be lessened by priming methods. Fulvic acid that is extracted from compost is beneficial in enhancing germination tendency in seeds of this tree. Fulvic acids are beneficial to increase the permeability of seed coat and plant cell membranes and enhance enzymatic activity of the root system leading to increased root proliferation (Trevisan et al. 2010). Application of $CaCO_3$ can cause buffering capacity in soil that affects nutrient availability to plants, while sulfuric acid treatment has conventionally been used for breaking the dormancy and softens the seed coat through which the radicle can easily protrude.

14.4.15 Oak

Himalayan oak trees (*Quercus glauca*) have irregular fructification, and consumption of seeds by animals (Troup 1921) and loss of viability during storage for extended periods (Chalupa 1995) have overrated the problem of regeneration (artificial and natural). Propagation (clonal propagation) through stem cuttings is difficult in most of the oak species and has not been much successful in these species. Even the seeds' weight is also affected by germination percentage. Seed coat acts as a mechanical barrier in germination of oak seeds which prevents radicle emergence and is corrected by several scarification methods and priming treatments (Alderete-Chavez et al. 2011). The KNO_3 plays an osmotic role on water uptake with a nutritional effect on protein synthesis. KNO_3 is used for growth regeneration and also as germination-stimulating substance in many species (Ozturk et al. 1994).

14.4.16 Pine

It is the most widely distributed tree used for timber purposes and for making boxes, paper pulp and temporary electric poles. Seed germination in pine (*Pinus kesiya*) is a common problem which depends on the moisture level and substrate pH level in seeds (Verma and Tondon 2010). Hydropriming increases the imbibition rate and moisture level in seeds which enhances the germination rate. Available soil moisture also influences germination and early seedling survival. Influence in germination in pine is due to leaching of growth inhibitors and increase in endogenous level of growth regulators when seeds scarified or subjected to chilling treatment.

14.4.17 Siris

Albizia lebbeck (siris) has special place among all the forest crops. Despite its importance, the species is becoming scarce due to deep seed dormancy. Seed priming is a method used for producing numerous number of planting material by overcoming its seed coat-imposed dormancy (Baskin and Baskin 1998). Seeds are often used for propagation in Siris which is a cheapest method of propagation in many species of this tree. Its hard seed coat makes the germination process difficult in nursery and/or out in the fields. Sulphuric acid, hot water and gibberellic acid are used for breaking dormancy in this species (Alderete-Chavez et al. 2011; Baskin and Baskin 1974). The disintegration of the seed coat increases the imbibition and subsequent germination in seeds when treated with sulphuric acid (Egley 1989).

14.4.18 Kapok

The silk cotton tree (kapok), *Ceiba pentandra*, is a fast-growing and emergent tropical forest tree species which can grow up to a height of 60 m (Gribel et al. 1999). It is one of the extinct species among forest trees, and seeds of this tree are also limitedly available. It is pollinated by hummingbirds (Gribel et al. 1999; Toledo 1977) and non-flying primate mammals, particularly by *Saimiris ciureus* (squirrel monkey), *Cebus paella* (capuchin) and *Ateles paniscus* (spider monkey) (Janson et al. 1981). Seed soaking in seeds of silk cotton tree significantly influences the germination process. But heavy rainfall may limit the process of germination and fails to break the seed dormancy.

14.4.19 Subabul

This subabul tree (*Leucaena leucocephala*) is also called ‘miracle tree’ due to its multipurpose nature (Ssenku et al. 2017). Germination capacity in seeds of subabul can increase by different priming or pretreatment methods. NaCl concentration in soil shows a marked effect on the germination. With the increase in salinity, the germination initiation in this species is delayed and gets ceased (Rafiq et al. 2006). The reason behind this is that the osmotic pressure of the soil solution increases with increase in salt concentration that results in the prevention of uptake of water. It also reduces the germination energy of seeds.

14.4.20 Tamarind

Tamarind (*Tamarindus indica*) has been recognised for its potential nitrogen-fixing nature (Okoro et al. 1986). Seeds in tamarind do not have self-capacity to germinate due to the lack of the factors required for breaking dormancy. Hot water treatment and sulphuric acid affect the germination rate, and seed germination increased with increasing water temperature and soaking period.

14.4.21 Teak

Teak (*Tectona grandis*) is a tropical tree species, hardy and deciduous in nature, is valued for its durability and water resistance and is used for boat building, exterior construction, veneer, furniture, carving and other small wood decorative uses. Germination of the seeds involves pretreatment to remove dormancy arising from the thick pericarp. Pretreatment involves alternate drying and wetting of the seeds. Saline solution also affect the germination ability of seeds in teak, as increased salinity results in decreased germination ability of seeds and delayed rate of germination. This is due to the complex nature of salts that present in the solution for germination which may be sometimes having toxic effect in germination.

14.4.22 Wigandia

Wigandia caracasana, or *Caracus wigandia*, is a species of evergreen ornamental plant having purple flowers in large clusters. Sometimes, seed burial can improve the chances of establishment of seedlings through breaking the dormancy. Priming consists of a regulated hydration process that permits enhancement of some metabolic processes through the osmotic solutions or water. Burial enhanced germination process and favoured uniform and rapid germination of *W. urens* seeds (Gonzalez-Zertuche et al. 2001). This enhancement in germination is due to the increased protein synthesis in burial seeds as compared to control seeds. Burial with priming treatment in seeds increases the germination percentage, seedling growth and breaking dormancy than the priming treatment alone.

14.4.23 Willow Tree

Willow tree (*Salix babylonica*), also called sallows, is a deciduous tree as well shrub. Seeds are viable for a short period of time. Priming methods are useful in enhancing germination and growth of dormant seeds. Thermopriming gives efficient result in germination up to 100%. Seeds of willow tree results in better germination rate in lower temperature regimes (Young and Clements 2003).

14.5 Conclusion

There is a huge gap between the number of seeds sown and availability of stocky seedlings in any ornamental flower crops and several important tree species. The most important problems faced are the heterogneity and lack of suitable conditions in soil that cause decrease in germination percentage. Heterogeneous emergence, unbalanced seedling growth and competition for environmental resources such as light, nutrients and water subsequently make difference in biomass and performance of plants. Priming is helpful in reducing the risk of poor stand establishment under a wide range of environmental conditions. The purpose of these treatments is to shorten the emergence and to protect seed from biotic and abiotic factors during critical phase of seedling establishment so as to synchronise emergence, which lead to uniform stand and improved yield.

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