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# Seed Priming-A Traditional Technique to Enhance Crop Establishment and to Improve Livelihood of Farmers

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## Abstract

Seed priming is a seed enhancement technique to improve the seed germination and seed vigor. It is the process of soaking of seeds in a particular solution having particular osmotic potential for particular duration. Through which seeds absorbs water, cell become elongates, repairing of mitochondria, DNA takes place, and helps to activate enzymes and breakdown the storage materials into energy form for the growth of plant. This technique consists of different methods of treatments like, hydro-priming, halo-priming, hormonal priming, osmo-priming, solid-matrix & bio-priming according to different crops. In this review we discuss about the mechanism of seed priming & its tolerance against abiotic stresses, the changes occurring during the treatment, applications and how to maintain sustainability of agriculture by using priming to improve the livelihood of farmers.

**Keywords:** Seed priming; Methods of priming; Physiological and biochemical changes; Sustainable agriculture; Drought and salinity stress

## Introduction

In India, more than 80% of population depends on agriculture for their living. So good quality seed will be most important for a farmer for better crop establishment. Because, seed is the integral factor in crop production. From the time immemorial, seed quality is regarded as an important element in the development of agriculture and evidences can be found in old Vedic literatures. In Manu smriti, it is mentioned that "Subeejam Sukshetre Jayate Sampadyathe" which means good seed in good soil yields abundantly [1] Likewise, germination is also an unavoidable factor. Rapid germination causes fast expansion of leaves and development of roots and it helps to increase the nutrient uptake and the biomass production. In other side, slow germination causes decrease in vigor and crop productivity and thereby causing economic losses to the farmer. Usually, germination having three major stages such as, Imbibition, activation or lag phase, and seed germination phase. The seed quality and germination are interlinked because, if the seed is of good quality the germination rate will increase, if germination increases crop yield will increase and results to improve the livelihood of farmers.

If unfavorable conditions come due to abiotic stresses sometimes the seed will not germinate and it leads to loss of economy, loss of yield and also affects the food supply. And sometimes poor farmers do not have sufficient resources to meet the requirements of the seedbed preparation for sowing and they are at more risk as compared to progressive farmers. Well establishment of crop increases yield, increases tolerance to abiotic stresses etc. So, it is very well accepted fact that the seed priming technique improves seed germination, reduces seedling emergence time, improves stand establishment. A lot of work has been done on seed priming and the results of these studies indicate well the importance of priming to get a good crop stand and final emergence [2].

Seed priming is the process of controlled hydration of seeds to a level that allow pre-germinative metabolic activity to continue, but it breaks the continuity of emergence of radicle. According to it is the controlled hydration of seed that restricts germination, but permits pre-germinative physiological and biochemical changes to occur. This process stimulates metabolism which prevents seed deterioration, breaks dormancy, and induces resistance against biotic and abiotic stresses. And this method consists of several techniques like hydropriming, halo-priming, osmo-priming, hormone-priming, solid-matrix priming, and bio-priming. And some of the advanced techniques also found out like nanoparticles seed priming method, Gamma ray, Magnetic priming UV radiation. It is an ecofriendly safe and effective technology to enhance germination and one of the better solutions against the issues related to germination when the seeds grown under unfavorable conditions [3].

## Seed Priming

Seed priming technique has been practiced in many countries like Pakistan, China, Australia etc., and more than thousand trials have been conducted by them in various crops [4]. And almost all farmers found out that primed seeds grew faster, enhances germination, flowered and matured earlier, and causes to get higher crop yield. Seed priming is a pre-sowing process, it involves the hydration of seeds and enables every metabolic event before germination to takes place. It is an approach in which seeds are treating with several organic or inorganic chemicals at different conditions of temperature. It is an easy, cheap, highly effective and low risk technology, and it provides lot of advantages like germination under any unfavorable conditions, enhancing root to grow deeper, initiate growth of organs for reproduction, early flowering and maturity, better resistance to various soil-borne diseases etc [5].

## History of Seed priming

At the time of beginning of agriculture, farmers realized that most of the seeds do not germinate under several conditions uniformly and effectively. The seed priming technique is an age-old technique

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practiced by Greek farmers. Theophrastus, 372-287 BC, he focused on seed physiology and he recommended the soaking of cucumber seeds in milk or water before sowing to germinate early.

The word seed priming was coined by Heydecker in 1973, and he successfully found out that seed priming will enhance seed germination and to establish crop at any stressful conditions. To increase the seed germination rate, Roman farmers also conducted an experiment in legume seeds by seed priming technique and the result turns positive **[4,6].** Many other research reports were performed on seed priming on various crops and found out that it is a low cost gemination enhancing technology.

## Mechanism of Priming

Seed germination is an important and complicated process. It is a vital stage in plant development and unavoidable parameter for plant productivity. The process become initiated through water imbibition, mobilization of food reserve, protein synthesis and radicle emergence **[7].** Priming promotes seed germination by undergoing three phases,

Imbibition phase: First phase of germination, in which quick water uptake occurs due to the forces driven by seed and in this phase the DNA and mitochondria are getting repaired. It promotes protein synthesis and respiratory activities through mRNA **[8].**

Activation phase: Second phase of germination and this phase related with the renew of metabolic activities and repairing processes **[9]**. Maturation of mitochondria, protein synthesis, mobilizing the macromolecules into molecules required for radicle growth, enzyme activation etc. occurs in this phase.

Germination phase: The third and most important phase is germination phase. Initiation of growing process and promotes cell elongation leading to radicle protrusion **[9].**

In priming, the first and second phase of germination occurs and it will not allow to go for third and last phase. In this process, second phase that is activation phase will take place for longer time and prepare the seed to germinate by prevent to go directly third phase like as shown in the (Figure 1). Enzymes activated in the in the second phase breakdown the storage materials like fat, proteins, carbohydrates inside the seed into the energy form and transfer it into the growing points for the further growth. Since the seeds are metabolically active during this time, they convert conserved germination reserves in a way that improves on regular imbibition in respect of membrane and genetic repair. After being taken out of the priming solution, seeds are dried and then rinsed with water **[10].** After the process, the seeds can either stored or marketed. Otherwise, after drying, it can be cultivated in fields. All the pre-germinative metabolic events become completed and the seed will be able to germinate easily and early under any stress conditions due to priming. But before sowing, seeds need to be re-imbibed.

## Methods of seed priming

There are few methods of seed priming are present to enhance the germination and crop establishment, as shown in the figure 2.

### Hydro-priming

It is a simple, low-cost environment friendly technique. In this technique, there is no need of any other chemical substances except water. Seeds soaking in pure water and then dry it before going for sowing is hydro-priming. It improves the water uptake efficiency. But sometimes it may result in uncontrollable seed hydration also **[11].**

### Halo-priming

It is the treatment of seeds with chemical solutions like, sodium chloride, potassium nitrate, calcium sulfate to enhance germination and crop establishment **[12].** Treatment of seeds with these chemicals before sowing increases plant growth and plants will attain resistance to abiotic stresses **[11].**

### Osmo-priming

Osmo-priming is the process of soaking of seeds in different osmotic solutions at different various concentrations. According to the different species of plants, there are different osmotic solutions present, like sugar, polyethylene glycol, glycerol, sorbitol, mannitol etc. for soaking of seeds and need to do air drying before sowing the seeds. These solutions having less amount of water so, it causes only partial hydration compared to hydro-priming and pre-germination metabolic process become started **[12].**

Plant growth regulators like, abscisic acid, cytokinin, auxin, gibberellin, ethylene solutions are used for soaking the seeds to enhance germination and it is having direct effect on seed metabolism is known as hormonal priming **[12] (Table 1).**

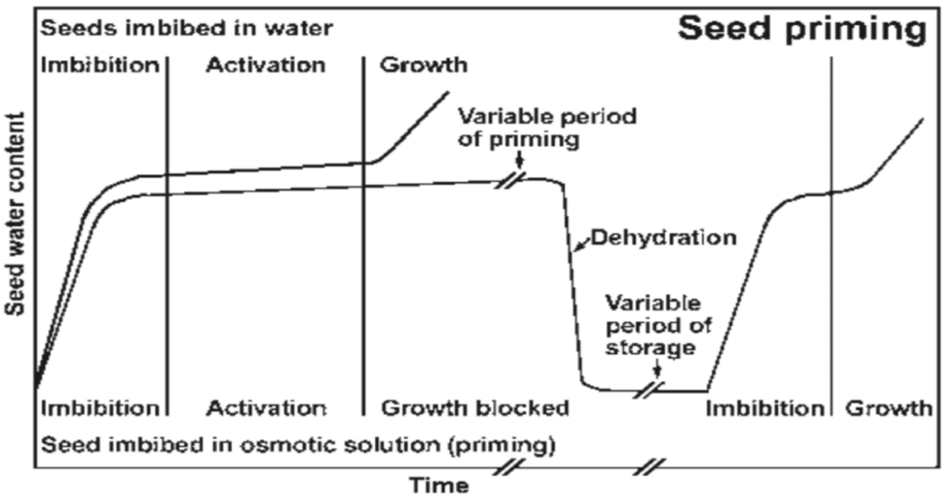


**Figure 1**: Overview of seed priming and the difference between seeds with priming and without priming. [3]

**Table 1:** Applications of seed priming methods in different field crops [12].

| Applications of different seed priming methods in different field crops: | |
|---|---|
| **Seed priming methods** | **Applications of field crops** |
| Hydro-priming | • It plays an important role in germination and seedling emergence in different crops.<br>• It promotes germination rate and seedling emergence under salinity conditions.<br>• It can positively affect the growth at both initial and final stage of development of seed.<br>• It improves crop yield also.<br>• Hydropriming in safflower seed for 12hrs, leads to higher number of plants/$m^2$, capitula per plant, grain yield and oil content.<br>• It helps to grow maize, pearl millet, rice to grow under dry conditions.<br>• Primed maize seeds showed increased plant height and shoot dry weight.<br>• It enhances the salt tolerance in maize, pigeon pea &b acacia seeds. |
| Halo-priming | • It is not only promoting seed germination but also stimulates growth and can increase crop yield.<br>• It improved seed germination, yield and yield contributing characters of okra.<br>• Treating rice seeds in a mixed salt solution germinate more effectively under salt-stress conditions.<br>• it will increase seedling vigor and seedling establishment under salinity conditions.<br>• Different biochemical changes occur due to this type of priming.<br>• The pigeon pea seeds treated with KNO3 & CaCl2 helps to strengthen the content of proteins, soluble sugars in the seed during germination under salinity conditions. |
| Osmo-priming | • In wheat seeds, the seeds will prime by osmo-priming with polyethylene glycol using an aquarium pump provides good germination and improves vigor.<br>• It promotes growth or the seed germination under saline or non-saline conditions.<br>• Improves seed germination of sorghum seeds when it is osmo-primed with 20% PEG-8000 up to the duration of 2 days at 10 degrees Celsius under any water-logged, cold-stress or salinity conditions.<br>• It may be affected embryo expansion, compression of endosperm & tissue deformation.<br>• It causes invigoration of seeds.<br>• Wild rye seeds will be treated with 30% PEG for 24h, showing the result as increasing the super oxide dismutase and peroxidase activity, and increase in respiratory intensity.<br>• Endo-β-mannanase activity increases in primed tomato seeds and results into reducing the mechanical constraint on the embryo during germination.<br>• It promotes the activity of enzymes which regulates growth like amylases, proteases and lipases.<br>• Osmo-primed peanuts should contain grater rate energy as ATP because it promotes the activity of ATPase. |
| Hormonal-priming | • the application of salicylic acid and ascorbic acid enhances the growth wheat crop under salinity stress.<br>• Iqbal and Ashraf found out that wheat seeds hormonal-primed with GA3 can increase grain yield and become tolerant to salinity.<br>• Maize seeds primed with GA3 increase its vigour and germination.<br>• Onion seeds treated with auxin, gibberellin, kinetin assign to germination effectively.<br>• Hormonal-priming with GA3 in chickpea results high number of seeds per pod & increase the yield.<br>• It provides tolerance in rice against drought condition by polyamines priming or spermidine pretreatment. |
| Solid-matrix priming | • crops like soyabean, maize, okra, and onion having positive effect on this type of priming.<br>• Improves germination percentage of invigorative okra and soyabean.<br>• Onion seeds treated by solid matrix priming will promote germination percentage, growth under optimal and low temperature conditions.<br>• Waxy maize seedlings treated by solid matrix priming increases the antioxidant enzymes like catalases, peroxidase, activity and soluble sugar content results in high rate of germination and seedling growth under stress conditions.<br>• It also improved stand establishment and productivity of some vegetable crops growing in tropical conditions.<br>• When okra seeds treated with a mixture of solid matrix priming and *Trichoderma viride* then there will be an increase in okra yield and improved seedling emergence |
| Bio-priming | • Use of Rhizosphere bacteria in carrot, tomato, sweet corn etc. for bio-priming enhances germination.<br>• Use of Pseudomonas fluorescence in pearl millet provides resistance against downy mildew disease.<br>• Bio-priming with rhizobacteria improves germination in radish seeds under saline conditions.<br>• In bread wheat, Zn seed priming with endophytic bacteria helps to improve productivity and bio-fortification.<br>• It resists damping off in cucumber, soyabean, pea like vegetables.<br>• Bio-priming of pumpkin seeds with a combination of A*zospirillum*, phosphobacteria, and *pseudomonas fluorescens* helps to improve yield and quality.<br>• Seed priming with plant growth promoting bacteria enhances germination and crop establishment. |

### Solid matrix priming

In this technique, seeds are mixed in a proportion with solid material like vermiculite, peat moss, charcoal, compost, sand, clay, press-mud etc. and water. The seed and matrix used in solid matrix priming compete for available water. Seeds absorbing water and it will reach at an equilibrium point and at that time priming occurs. Afterwards, seeds are separated from the matrix through washing and drying. The solid medium used in the mixture helps to hydrate seeds slowly and it stimulates the natural imbibition process in the soil. Materials utilized in matrix in this process having some physical and chemical features like, low matrix potential, high water holding capacity and surface area, minimal water solubility, no toxicity to seeds.

### Bio-priming

In this process, seeds are inoculated with beneficial organism to protect the seeds from diseases and to enhance germination. The procedure of bio-priming was first introduced by **[12,13].** Bio-priming is the soaking of seeds and mixing of formulated products of bio-agent with pre-soaked seeds. And after this, seeds should be covered with a moist jute bag followed by incubation of incubation of seeds to maintain high humidity. In this technique, seed imbibition with destruction of seeds borne and soil borne pathogens are possible. A protective layer formed as bio-agent adheres on the surface of seeds. It also improves seed quality, seedling vigour, and provides resistance against biotic and abiotic stresses etc **[12].**

## Priming induced physiological and biochemical changes

### Metabolic changes

The starch metabolism is important in case of every plants & it

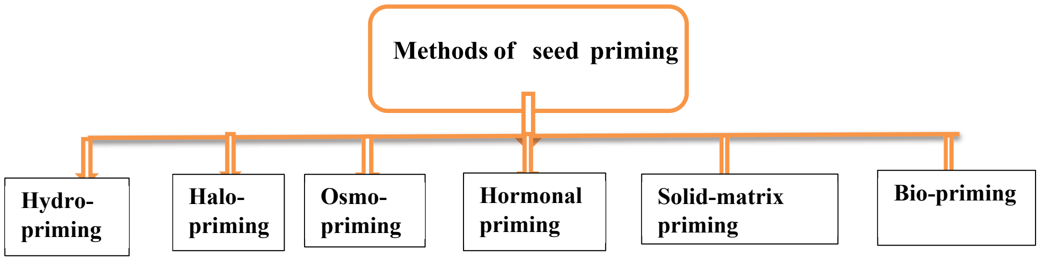


**Figure 2:** Methods of seed priming.

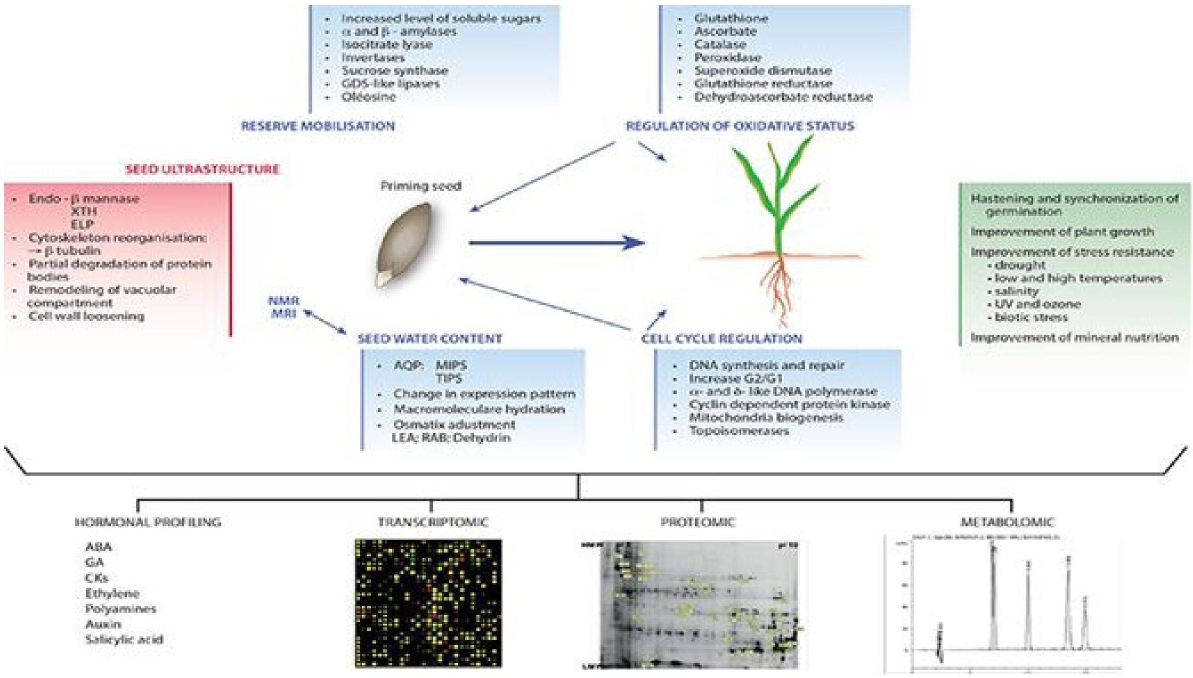


**Figure 3:** Physiological and Biochemical effect on seed due to seed priming [7].

is held by the help of an enzyme α-amylases which hydrolyses starch into sugars to provide energy for the developing embryo. Seed priming boosts the activity of α-amylases and results to hydrolyses the starch macromolecules into smaller sugar particles with ATP production and respiration. Seed priming not only increases the activity of α-amylases but increases the activity of other enzymes also like, phytase, amylase and protease **[14].**

## Cell cycle regulation

Seed priming activates cell-cycle processes, peroxidase and SOD activity & respiratory activity so it results to improve seed germination and seed vigor. For example, in maize crop, it stimulates nuclear DNA synthesis, peroxidase concentration and seed protein content. In G1 phase of cell division, after a cell divides, its daughter cells enter this phase and begin to synthesize the enzymes and nutrients necessary for the DNA replication and cellular division. So, priming increases the replication of DNA and empower the improvement of growth phase of cell cycle from G1 phase to G2 phase. It is important to activate the DNA repair mechanism for the activation of cell cycle and it has been observed during the seed imbibition of germination steps. It also increases the activity of DNA polymerase occurs during the pre-activation of cell cycle. It promotes mitochondrial biogenesis process by which cells increases its mitochondrial numbers. The pre-activation of cell cycle is one of the reasons for the better performance of primed seeds compared to the unprimed seeds **[15].**

## Management in oxidative stress and seed longevity

Priming avoids the lipid peroxidation and oxidative damage, which affect seed longevity by improving the function of malate synthase and isocitrate lyase, it is the enzyme which helps to convert lipids into carbohydrates and anti-oxidant enzymes like POD, SOD etc. & those enzymes have the ability to trap ROS or reactive oxygen species. By tracking the expression patterns of genes encoding enzyme antioxidants like SOD, which is crucial in scavenging superoxide radicals, it is possible to measure the antioxidative response of seed. Additionally, the transcript and enzyme activity levels of various other antioxidants, including CAT, APX, and GR, were increased, signifying the activation of the antioxidant defense system. Management of oxidative status helps from aging, and provide protection against oxidation stress **[15].**

## Modification of seed ultrastructure

The capability of seeds to germinate depends on the embryo's capacity for growth and the endosperm tissue that surrounds it. In many crop species, the endosperm tissue that surrounds the embryo acts as a physical barrier, stopping the germination process and preventing the formation of radicles. Hemicellulose found in the cell membrane is known as xyloglucans. XTH (Xyloglucan Endo-trans Hydrolase) is an enzyme that can cleave xyloglucans and is involved in loosening cell walls. Another enzyme, endo beta mannase, participates in the hydrolysis of the mannan-rich endosperm cell walls during germination and post-germination seedling growth. During priming, the activity of XTH is increased, endo beta mannase synthesis is increased, and the cytoskeleton is reorganized, all of which are important for loosening the cell wall **[15].**

In summary, due to physiological and metabolic changes during the pre-germinative phase of the seed, seed priming activates different defensive activities that allow for rapid germination and vigorous seedling establishment.

## Factors affecting seed priming

### Types of priming

Each and every priming method having several benefits and limitations on several conditions. For example, in okra, seed germination and seedling vigor can improve by hydro-priming and solid matrix priming with calcium aluminum silicate at the ratio of 1:1:0.4 of seed: water: solid matrix compared to the other methods especially halo-priming ( Figure 3) **[15].**

### Temperature

Each crops needs optimum temperature to complete the process of priming. More or sub-optimal temperature during priming causes longer duration for activation phase. So, moisture will decrease and causes permanent damage during dehydration because of the less moisture. Even, low temperature also causes issues in seeds like delaying in the physiological and biochemical process which need to be done during the process and take a longer time to achieve results if it contains required amount of water also **[15].**

### Aeration

Aeration of soaking solution having great effect on seed during priming. It provides faster germination of seeds. It improves the water uptake and decreases time taken for seed priming. But, sometimes, soaking of seeds in aerated solutions results in increase of rate of metabolism and salt penetration into the seeds. So, to avoid this issue, we can use PEG solution and the primed seeds in an aerated PEG solution results to improve the seed germination percentage by supporting the seed respiration process **[15].**

### Osmotic potential

Water will flow from the solution, where it has a higher water potential, into the seed, where it has a lower water potential, until the equilibrium is reached while seed is soaked in priming solution. The seed size, coat permeability, and quantity of hydratable substrate are all directly tied with the amount of moisture is absorbed during soaking. The efficiency of seed priming is greatly influenced by the concentration and water potential of the priming solution. Seed germination is negatively affected by high ion concentrations in priming fluid. Due to nutritional imbalance and cytotoxic effects, they can be readily absorbed and stored in seeds, which inhibits germination**.**

When the concentration falls below the minimal threshold, the predicted physiological and biochemical germination processes are not activated by priming treatment. In contrast, as a result of toxicity, however, seed germination will either be slowed down or prevented entirely if the priming solution's concentration is too high or the procedure is run for too long.

### Duration

As similar to the concentration, the priming duration is a very important factor which determines the germination success and seedling establishment. The duration of seed priming differs according to the priming agent, osmotic potential of the priming solution, crop species, and the temperature during priming. Priming duration along with the optimum concentration of priming media determines the germination success because water imbibition of seeds during priming, is directed up to the saturation level of the seeds.

### Seed quality

It is the key factor of seed priming, because the use of vigorous and disease or pathogen free seeds is used for the cultivation otherwise it affects the rate of germination as well as the seed priming process. Good seeds are essential for the priming treatment then it results high germination **[15].**

### Light

It affects the priming process depending on the different species which require light for germination. Some seeds like, lettuce and celery which needs light for germination can be exposed to the sunlight during priming treatment to avoid dormancy **[15].**

## Role of seed priming in sustainable agriculture and improvement of livelihood of farmers:

Seed priming is an efficient technique was adopted to improve the plant behavior and several researches found out that it has favorable influence on seed germination, plant growth, nutrient use efficiency and stress tolerance etc. when, all these mentioned parameters improve, then agriculture sustainability also retains or balanced.

Priming helps to germinate uniformly, increase the rate of germination, by soaking of seeds into a particular solution having particular osmotic potential. It provides the repairing of DNA, mitochondria and activates some enzymes which helps to breakdown the storage materials inside the seed into energy form and transfer it into the active zones or the growing points which required energy for growth and fastens the germination likewise. Primed seeds will grow faster as compared to the non-primed seeds because of the rapid seedling establishment **[15].**

The priming provides the ability to plant to grow under any stressful conditions like biotic and abiotic conditions. For example, priming results in the tolerance in tomato against Fusarium oxysporum viral disease in Brassica rapa, downy mildew in pearl millet etc. In case of abiotic stresses like salinity stress condition with low moisture, priming with GA3 increases the pre-metabolic process thus provides an increase in the rate of germination **[15].**

Likewise, enhancement in nutrient use efficiency due to priming results to induce overexpression of genes encoding for specific transporters. Priming improves nitrogen nutrition in plants by activating the nitrate reductase enzyme. Nutri-priming with phosphorous can improve the availability of phosphorous. Priming with Si increases the silicon content of cultivated plants and it provides the tolerance against biotic and abiotic stresses. Water use efficiency also increases as like as the nutrient use efficiency due to priming which in turn increases the yield of crops. This is because, early emergence produced thriving plants with larger, deeper roots that can still draw water from the deeper levels even with less frequent irrigation **[16].**

By sustaining, it can balance the future life and it helps to improve the livelihood of farmers. Agriculture is the largest source of livelihood in India so by maintaining the agriculture or sustaining through the traditional techniques like seed priming we can increase our livelihood. By using seed priming, we can improve the rate of germination, plants have the ability to sustain under unfavorable conditions, enhances nutrient use efficiency etc. and it helps to increase the income of farmers due to high yield, reducing risk in agriculture due to the several abiotic stresses. Then the livelihood of farmers can improve partially by this method.

## Priming: a cost-effective technique to tolerate abiotic stresses

One of the main benefits of priming-induced abiotic stress tolerance is the method for cost-effective stress tolerance. Cost effectiveness is not an economic concept, although it can be explained in terms of energy use. Simply said, priming starts the plant's stress tolerance mechanisms, particularly the antioxidation process, and allows them to run in alert mode without using any additional energy costs until and unless a stress is introduced. Thus, priming helps plants become more fit in the future while using a lot less energy. In this way, priming reduces the energy required to activate a person's defense mechanisms in the event of future stressful situations. When exposed to a stress stimulus, a primed plant responds more quickly than unprimed plants. It was discovered that the defense mechanism is cost-effectively activated, meaning that the defense process is synchronized with the level of stress. The production of the plant would not be reduced to a greater extent when subjected to stress thanks to this method, which would prevent the plant from allocating more reserves for the stress tolerance process.

Salinity is a comprehensive challenge that has an increased amount of inorganic minerals, produces osmotic and ionic toxicity along with high osmoticum in order to lower the cell's osmotic potential. Understanding the pathways of salt entry through which too many ions build up in the plant is crucial. Various techniques have frequently been used to mitigate the consequences of salt stress on plants. These techniques encompass both traditional breeding practices and more recent ones like gene silencing, mutation, knockout and knock in techniques, among others. However, all of these traditional breeding methods are laborious and have drawbacks, such as high manpower and energy demands. Therefore, creating a solution to salt stress that is both affordable and commercially viable is difficult. Around the world, numerous studies have been conducted to address the stress of salt, and one of the promising approaches is seed priming, which has the potential to mitigate the unfavorable effects of salinity and enhance plant yields and yield quality **[12].** By building up inorganic or synthesizing organic solutes like free proline, glycine betaine, and free amino acids in response to the lowered external water potential, plants are able to overcome the osmotic effects of salinity. This process is known as osmotic adjustment. Thus, one key mechanism of plant salt tolerance is the buildup of organic solutes like sugars that are compatible with plant metabolism. Through this mechanism, the cell's osmotic potential is reduced, enabling an osmotic response to the stress situation. Important markers include the presence of suitable solutes like proline and soluble sugar inside the seeds as well as the activity of antioxidant enzymes including superoxide dismutase, peroxidase, and catalase. These variables may be increased by priming, increasing the crops' salinity tolerance **[16].**

Likewise, Normal plant growth may be hampered by drought stress, which can also affect stomatal conductance, photosynthetic efficiency, ion homeostasis, and oxidative damage from an excess of reactive oxygen species (ROS). As a result of the oxidative stress brought on by ROS production, cell integrity is compromised, which eventually causes proteins and nucleic acids to degrade. The production of ROS and their scavenging are in a delicate balance. Effective ROS detoxification is necessary for a cell to operate normally. Superoxide dismutase (SOD), peroxidase (POD), catalase (CAT), and glutathione reductase (GR) are powerful antioxidant enzymes that are used to modify ROS. Non-enzymatic free radical scavengers such ascorbate (AsA), glutathione (GSH), and phenolics are also involved in antioxidative function. This equilibrium, however, is disturbed under circumstances of severe stress. Numerous priming approaches, including hydropriming, osmo-priming, UV-B priming, and chemical priming, have been shown to improve plants' ability to withstand drought stress, according to studies of **[17].**The same priming approaches may also work well in helping the plant recover from drought stress quickly and effectively. Drought priming before anthesis in wheat increased the rate of photosynthesis and ascorbate peroxidase activities and also reduced membrane damage during grain fling; this may significantly contribute to protection from stress that will afterwards occur **[18].**

## Present status of seed priming

A modest and potentially effective method for increasing crop productivity is seed priming. Farmers in Botswana, Malawi, Zimbabwe, India, Nepal and Pakistan frequently use hydro priming as one of their seed priming methods. For the on-farm seed priming of maize, upland rice, wheat, chickpea, and sorghum, the Centre for Arid Zone Studies (CAZS) established "safe limits" (the maximum amount of time for which seeds can be soaked). On-farm seed priming appears to be a trustworthy and commonly used technology. Using on-farm seed priming, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has encouraged the cultivation of chickpea in Bangladesh's arable fallow lands. In 30 on-farm studies, an average yield increase of 50% was noted. Maize yields in Zimbabwe and India were up to 22%, sorghum yields in Zimbabwe and Pakistan were up to 31%, wheat yields in India and Pakistan were up to 37%, and upland rice yields in West Africa were up to 70% as a result of on-farm seed priming. So, the application of seed priming for different seed crops is increasing day by day because it is an effective method to improve the germination and thereby increasing of yield and improve the livelihood of farmers **[15].**

## Future perspectives of seed priming method

Seed priming is a technique that can be applied to different crops to reduce environmental stress. Being a cost-effective technique, it is a practical and suitable approach to reduce the gap between potential and actual yields, even under stressful conditions **[11].** Even though seed priming has evolved into a useful tool for many crops, the conditions and techniques for treating seeds vary from crop to crop. However, there are several drawbacks to the current seed priming techniques. For instance, prolonged seed priming may result in loss of seed tolerance to desiccation and some priming may determine infection with fungus and bacteria. Another obvious issue is that primed seeds have shorter lifespans than unprimed seeds. It is essential to choose appropriate priming protocols and procedures that are advantageous to plants and the environment because seed priming with modern techniques, such as priming with nanoparticles, may have negative impacts on plants, human health, and the environment. New and advanced priming techniques such as nano-particles, gamma-ray, magnetic-ray, and UV irradiation are being developed and applicable in various crops. These advanced technologies may have deleterious effects on plant, human health as well as on the environment. It is crucial to select specific priming protocols and techniques which are beneficial to plants and environment **[19-21].** Its application will be more in future because of an environmentally safe and effective technology which can be easily adopted by not only resource-poor farmers but also different plant researcher to mitigate abiotic stress. Especially when crops are cultivated in unfavorable conditions, seed priming is one of the best techniques to decrease germination-related issues under stress.

## Conclusion

A technology known as seed priming increases germination, promotes early flowering and maturity, increases crop resistance to abiotic challenges, and is both safe and effective for the environment. The discussion above makes it clear that various priming techniques have been researched on a variety of crops and have been found to be effective in terms of crop yield. It is also proposed that seed priming is a better solution against germination issues when seeds are grown in unfavorable conditions. However, there are still a number of restrictions on seed priming techniques. Not every priming technique will result in considerable germination and growth. In this aspect, choosing a certain priming technique is crucial to getting greater germination and eventual yield. It is cost effective technology which can be used to improve the plant behavior. It promotes higher rate germination in each crop and it results in higher yield by early germination and through that way priming technique can improve the economic condition in our society by increasing the yield. It sustains agriculture by increasing the germination, plant growth, nutrient use efficiency, water use efficiency, etc. But, the selection of particular methods having great dependance on the maintenance of sustainability, so proper selection of methods for different crops to ensure better yield is necessary.

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