Int.J.Curr.Res.Aca.Rev.2020; 8(6): 6-12

International Journal of Current Research and Academic Review

ISSN: 2347-3215 (Online) Volume 8 Number 6 (June-2020)

Journal homepage: http://www.ijcrar.com

doi: https://doi.org/10.20546/ijcrar.2020.806.002

Review on: Recent Achievement of Seed Priming in Improving Seed Germination and Seedling Growth in Adverse Environmental Conditions

Mekonnen Gebeyaw*

Department of plant science, Mekdela Amba University, South wolo, Ethiopia, Po.box 32

**Corresponding author*

Abstract

Successful crop establishment and high seedling vigor are considered as decisive factors for the success of most field crops, as these parameters contribute to uniform plant growth and maturity, better competition with weeds, and high productivity. Abiotic stresses adversely affect plant growth and productivity. In recent years, seed priming has been developed as an indispensable method to produce tolerant crop plants against various stresses. Seed priming is a method which is potentially able to promote rapid and more uniform seed germination and seedling growth in adverse environmental conditions and enhancing yield of a certain field crops. Seed priming is the cellular state in which the harmful effects of abiotic stress factors in plants are hindered by pre exposure to a stimulus, thus resulting in greater survival. It is becoming increasingly evident that different seed priming techniques in plants can improve the tolerance of crops to adverse environmental conditions. Generally seed priming shows potential strategy for increasing crop production and management in adverse environmental conditions. Seed priming for enhanced resistance to of adverse environmental conditions obviously is operating various pathways involved in different metabolic processes. The seedlings emerging from primed seeds showed early and uniform germination. Moreover, the overall growth of seedling and plant is improved due to the seed-priming treatments, so that farmers or any of crop producers should be practice and apply the science of seed priming for maximizing crop yield in any of adverse environmental conditions

Article Info

Accepted: 04 May 2020
Available Online: 20 June 2020

Keywords

Seed priming, seed germination, seedling growth.

Introduction

Background of the review

Successful crop establishment and high seedling vigor are considered as decisive factors for the success of most field crops, as these parameters contribute to uniform plant growth and maturity, better competition with weeds, and high productivity. Therefore, improving seed vigor is the primary objective of the industry of field crop production to enhance the critical and yield increasing stage of crop establishment. However, low vigor of seeds or adverse environmental conditions after sowing may cause slow seed germination and uneven seedling emergence under field conditions (Christos *et al.*, 2019).

Seed treatment before sowing is the foundation for activation of seed resources that in combination with external ingredients could contribute to the efficient plant growth and high yield. Various physiological and non-physiological techniques are available for enhancing seed performance as well as to combat environmental constraints. The physiological treatments for improving seed germination and stand establishment are composed of seed hydration techniques such as humidification, wetting, and presoaking. The other techniques for promoting germination are comprised of chemical treatments, seed inoculation with beneficial microbes, and seed coating.

Seed quality will determine the possibility of producing healthy seedlings and sufficient plant population for achieving high yield. In practice, seed quality loosely reacts the overall of seed performance. Under field conditions, poor seed quality can delay the onset of germination, adversely affects seedling vigor, and reduce the final crop stand. Establishing rate affects crop entity and competitiveness of the crop stand, tillering or branching, and yield and thus is of great importance. Vigorous plants have high ability to capture resources, can better tolerate pests and plant pathogens, compete with weeds, and are expected to be more tolerant to applied herbicides (Christos *et al.*, 2019). Seed priming is a physiological method of controlled hydration and drying to enhance sufficient pre-germinative metabolic process for rapid germination (Dawood, 2018). It has been reported that primed crop seeds emerged faster and grew more vigorously. They also flowered and matured earlier and gave higher yields, which is very important for adverse environmental condition such as drought-prone area (Mamun *et al.*, 2018).

Benefit of priming is to increase the rate of germination at any particular temperature. On a practical level, primed seeds emerge from the soil faster and often more uniformly than non-primed seeds because of limited adverse environmental exposure. Priming accomplishes this important development by shortening the lag or metabolic phase in the germination process. The metabolic phase occurs just after seeds are fully imbibed and just prior to radical emergence. Since seeds have already gone through this phase during priming, germination times in the field can be reduced by approximately 50% upon subsequent rehydration. Moreover priming has been commercially used to eliminate or greatly reduce the amount of seed borne fungi and bacteria. In this framework, we have mentioned the following priming techniques on farm priming, Hardening, Hydro priming, Osmo hardening, Vitamin C (Ascorbate) priming and Control (Mamun *et al.*, 2018). Moreover, seed priming has been shown to improve seed performance under cold environmental conditions (Lin and Sung, 2001).

On the other hand, globally, soil salinization is one of the most important ecological issues of dry land agriculture and has become a major hindrance for the yield of field crops. Moreover, salinization is spreading in irrigated lands because of inappropriate management of irrigation and farming (Abraha and Yohannes, 2013). Salinity causes a series of biochemical, physiological and metabolic changes in plants, so that different seed priming techniques has to develop for facing the challenges behind soil salinization on seed germination seedling vigor as well as crop productivity (Ibrahim, 2016). Therefore reviewing and gathering information based on the previous research finding, as well as identifying the knowledge and research gaps o the recent achievement of seed priming in improving seed germination and seedling growth in adverse environmental conditions is very important.

Objective of the review

To review the recent achievement of seed priming in improving seed germination and seedling growth in adverse environmental conditions

Defination of terms

Seed priming

Seed priming could be defined as controlling the hydration level within seeds so that the metabolic activity necessary for germination can occur but radical emergence is prevented. Different physiological activities within the seed occur at different moisture levels (Taylor *et al.*, 1998).

Seed germination

Seed germination commonly implies three distinct phases; consisting in Phase I: seed hydration process related to passive imbibitions of dry tissues associated with water movement first occurring in the apoplastic spaces; Phase II: activation phase associated with the reestablishment of metabolic activities and repairing processes at the cell level; and Phase III: initiation of growing processes associated to cell elongation and leading to radical protrusion. Phases I and III both involve an increase in the water content while hydration remains stable during Phase II. It is commonly considered that before the end of Phase II, germination remains a reversible process (Lutts *et al.*, 2016).

Recent achievement of seed priming in improving seed germination and seedling growth in adverse environmental conditions

Adverse environmental conditions importantly reduce plant growth, yield, and the marketable produce quality, with annually considerable economic losses as a consequence. Most of the adverse environmental conditions, including drought, salinity, extreme high and low temperature, high light, and pollutants, such as heavy metals or pesticides, result in oxidative stress, i.e., an increase in the cellular levels of reactive oxygen species. Adverse environmental condition stresses not only retard plant growth and diminish yield in cases of crop plants, but also severe stress can trigger programmed cell death (Petrov *et al.*, 2015). According to Yan Dai *et al.*, (2017) Seed priming treatments, including hydro priming and comprehensive seed priming, can mitigate the effects of soda saline-alkali stress in soybean seedlings. Moreover, seed priming with ZnSO4, CaCl, betaine hydrochloride and GA32 was found to be more effective than hydro priming to flourish under soda saline alkali stress. The better growth performance of soybean seedlings from comprehensive seed priming was associated with a stronger osmotic adjustment, higher activities of the antioxidant defense system, more photosynthetic pigment contents, better membrane integrity and more added starch accumulation under soda saline alkali stress.

Sorghum seeds responded well to priming treatments consisting of N, Zn solutions or water. Priming sorghum seeds with Zn solution for 10hour duration dramatically improved the germination percent, germination index, and reduced mean germination time compared to the unprimed seeds. Priming seeds with Zn for 10 h had also a profound effect on vigor and seedling growth parameters and increased the seedling height, seedling dry weight, and seedling vigor index-1 and 2 as compared to unprimed seeds. Among sorghum varieties studied, varieties Melkam followed by Dekeba and Teshale with 10 h priming duration performed better than the other varieties with respect to the majority of the traits studied. Priming of sorghum seeds for 10h is an optimum priming duration for most of the varieties. Moreover, the use of limiting nutrients such as Zn as seed priming agent would be an excellent option to improve germination, seedling growth, and its vigor. However, in the absence of Zn or urea, farmers have the option to use water to prime their seeds to enhance seedling germination and stand establishment (Wondemu *et al.*, 2018).

Reduction and delay in the germination of spring maize (*Zea mays* L.) may be a problem due to low soil temperatures and low water potentials. However, seed priming is used to improve rate and speed of germination, and expand temperature limits for germination under normal and stressful conditions. Maize seeds were subjected to hydro priming, hormonal priming with 100 mg L or IAA solutions and halo priming with 50 mM $CaCl_2$ or 50 mg L ascorbate (ASA) for 24h. All pre sowing seed treatments resulted in a higher germination percentage and germination index, lower mean germination time and mean emergence time. All seed treatments resulted in higher seedling fresh and dry weight compared with that of control with maximum dry weight recorded for seeds subjected to ASA, CaCl2 and GA. Performance was better in seeds subjected to CaCl be ascribed to the effect of lower ASA followed by GA 503 3-1 GA for 24 h than for the other priming agents. This could, higher reduce and total sugars as well as higher a-amylase activity (Afzal *et al.*, 2008).

Singh *et al.*, (2014) declared that primed corn seeds under adverse environmental condition had a better chance for producing a good crop with higher economic yield. Moreover seed priming has practical implications in improving performance of vegetable crops under stressed environmental conditions such as salinity, drought, low and higher temperature (Piri, 2009). Further more, the chitosan priming increased the chilling tolerance of maize seedlings demonstrated by improving germination speed and shoots and root growth and maintaining membrane integrity and higher activities of ant oxidative enzymes. The 0.50% chitosan seems to be a suitable concentration for seed priming (Guan *et al.*, 2009). According to Afzal *et al.*, (2012), Seed priming was effective in inducing chilling tolerance in maize through modulation of vigor associated attributes such as hydrolytic enzyme activities, chlorophyll and carbohydrate metabolism. Among priming agents, priming with Moraga leaf extract seems more practical being less expensive, non-toxic and the most effective in increasing the ability of maize plants to withstand low temperature. Hence, seed priming with Moraga leaf extract can be recommended after extensive field appraisal across a wide range of environments and genotypes to improve the performance of early spring planted maize.

Seed priming treatments such as selenium and salicylic acid priming were tested in field and growth chamber experiments and the results revealed that under chilling stress, seed priming increased the rice seed germination by 20.96 up to 26.31 %. The length and weight of shoots and roots were also significantly increased. The improved germination and seedling growth of primed seeds under chilling stress were strongly linked with higher a-amylase activity and total soluble sugar content (Wang *et al.,* 2016). Similarly, twenty-four diverse maize inbred lines were primed using a synthetic solid matrix and then exposed to 10°C soil conditions. Chilling substantially reduced total emergence for two of 24 genotypes evaluated. For these genotypes, priming provided protection allowing nearly full emergence. Priming significantly reduced mean emergence time and increased the emergence uniformity of chilling sensitive genotypes. The results suggest that the cold sensitive genotypes may benefit from priming pretreatment (Hacisalihoglu *et al.,* 2018).

Jafar *et al.,* (2012) concluded that, among the different priming agents used, osmo-priming with CaCl and ascorbate priming was the most effective in alleviating salt stress effects on grain yield irrespective of wheat varieties. Physiologically, the beneficial effect of this priming treatment can be attributed to increased accumulation of soluble proteins, phenolics, soluble sugars and K 2+ with simultaneous decrease in Na+ uptake. These treatments can therefore be employed to improve the performance of wheat under saline conditions. Seed priming with Se or SA, was found to be more effective under chilling stress. The better germination and vigorous growth of primed rice seedlings was associated with; higher starch metabolism, enhanced respiration rate, better membrane integrity, higher metabolite synthesis, and increased activities of antioxidants in these seedlings (Hussain *et al.,* 2016).

Priming of maize hybrid seeds with in 50, 100 and 150 ppm (mg l) aerated solutions of SA for 24 h and were dried back. Treated and untreated seeds were sown at 270C (optimal temperature) and at 15 0C (chilling stress) under controlled conditions. Performance of maize seedlings was hampered under chilling stress. But seed priming with SA improved the seedling emergence, root and shoots length, seedling fresh and dry weights, and leaf and root score considerably compared with control both at optimal and chilling temperatures. However, priming in 50 mg l)1 SA solution was more effective, followed by priming in 100 mg l. Seed priming with SA improved the chilling tolerance in hybrid maize mainly by the activation of antioxidants. Moreover, maintenance of high tissue water contents and reduced membrane permeability also contributed towards chilling tolerance (Farooq *et al.,* 2008).

According to Christos *et al.,* (2019) the effects of hydro-priming for 0,8,16,24,36, and 48 hours on final germination percentage, germination speed, germination index, mean germination time, mean daily germination, synchronization index, and seedling vigor index were studied. Averaged over priming duration treatments, hydro priming improved germination speed by 16.2%, germination synchrony by 20.7%, and seedling vigor index by 13.4%, but did not affect significantly final germination percentage and mean daily germination compared with non-primed seeds. In field trials, seed priming for 8 h resulted in higher fresh weight at anthesis by 22.3% and 8.6% in the first and the second year than the non-primed control. Similarly, seed priming for 8 h provided higher seed yield by 12.0% in the first year and by 5.9% in the second year compared with non-primed control. Overall, seed hydro-priming accelerated faba bean germination and seedling emergence in the field, but the magnitude of the response was associated with the environment and was more evident under limited soil moisture after sowing, whereas the beneficial effect of priming was masked when rainfall followed sowing. Similarly, the beneficial effect of priming on seed yield was more pronounced with limited soil moisture after anthesis. As hydro-priming is a simple technique, evaluating the efficiency of this priming method in deferent environmental conditions is essential to optimize our chosen priming technique. Molecular priming is evolving as an efficient technology to counteract the adverse effects of abiotic stresses. It is environmentally friendly and applicable to a wide variety of species. The priming agents can be applied only at critical times, for instance just before an upcoming stress, such as chilling or drought, and at discrete developmental stages susceptible to stress (such as fruit set), to maximize their efficiency. In contrast, this flexibility poses certain challenges. An accurate weather forecast and readiness to apply priming agents as environmental conditions change would be crucial for the exploitation of their full potential (Kerchev *et al.,* 2020).

During the early spring or late autumn cultivation periods, the delaying effect of low temperature on germination of lettuce seeds can be significantly compensated with a short period of priming with aqueous solution of vitamin U. Vitality of the photosynthetic apparatus, which converts incident light energy into chemically stored energy, as well as uptake, and assimilation of carbon dioxide by leaves are less inhibited by cold stress if hydroponically grown lettuce plants are primed with mill molar amounts of vitamin U dissolved in the nutrient medium. Leaves of lettuce plants primed with 0.25-2 mM vitamin U have higher vitamin C content and less reduced carotenoid content upon growth at low temperature, thus they have a higher quality as health promoting food source (Fodorpataki, 2019).

Priming can improve cold tolerance of lettuce in its early developmental stages, resulting in more efficient cultivation and better quality for human consumption. The first reports on the beneficial influence of priming with vitamin U on photochemical efficiency of photosynthesis, on carbon dioxide assimilation, on carotenoid pigment and ascorbic acid content of lettuce leaves exposed to cold stress. The fact that effects of priming are not proportional with concentration suggests that vitamin U may act as a signaling molecule to boost physiological performances through improvements in anti stress pathways that involve sulfur containing compounds. Further investigations are needed to elucidate the mechanism of action vitamin U in plants exposed to different environmental stresses taking into account that scientific information regarding the role of this biologically active natural metabolite is very scarce (Fodorpataki, 2019).

Seed priming with CaCl2, GA3, and H improved I. indigotica Fort. Seed germination and seedling growth under salt stress. The optimal concentrations were 15 g/L for CaCl priming, 0.2 g/L for GA for H2O23 priming, and 40 mM priming. Seed priming treatments greatly promoted SOD, POD, and CAT activities and alleviated the oxidative damage induced by salt stress in I. indigotica. Therefore, it may be concluded that seed priming is a promising approach to accelerating I. indigotica growth under salt conditions (Jiang *et al.*, 2020).

Pretreatment of Arabidopsis plants with A. nodosum extracts activates partial closure of stomata and modifies ABA signaling and antioxidant systems. These preactivation results in enhanced protection when a secondary drought stress stimulus is detected (Santaniello *et al.*, 2017). Arabidopsis, tomato, and pepper plants primed with an extract from A. nodosum are completely protected against paraquat-induced oxidative stress. At the molecular level, the seaweed extract treatment can modulate micro RNAs, which are key regulators of gene expression, and enhance tolerance to salt stress (Shukla *et al.*, 2018). Different structurally unrelated endogenous and synthetic organic molecules have been shown to prime plants against stress. The external application of acetic acid, for example, improved drought tolerance in Arabidopsis, rapeseed, maize, rice and wheat plants. This evolutionarily conserved priming mechanism relies on the promotion of jasmonic acid (JA) synthesis and enrichment of histone H4 acetylation that serves as an epigenetic switch by which plants adapt to drought (Kim *et al.*, 2017).

Priming increased germination characteristics as compared to the unprimed. The highest germination characteristics were obtained from priming by halo and hydro priming in control conditions. Priming improved seed reserve utilization such as: weight of utilized (mobilized) seed reserve, seed reserve utilization efficiency and seedling growth in millet seeds under salinity stress (AghbolaghI and Sedghi *et al.*, 2014). Abiotic stress protection in plants could be mediated by stimulating memory responses at the genetic level (De Palma *et al.*, 2019) but could also be improved by pretreatment with several non pathogenic bacterial strains. Thus the belowground interactions between these beneficial bacterial strains and plants have the capacity to prime and activate defense response (Mhlongo *et al.*, 2018).

Conclusion and recommendation

Conclusion

It can be concluded that:

Seed priming is a method which is potentially able to promote rapid and more uniform seed germination and seedling growth in adverse environmental conditions and enhancing yield of a certain field crops

Seed priming is the cellular state in which the harmful effects of abiotic stress factors in plants are hindered by pre-exposure to a stimulus, thus resulting in greater survival.

It is becoming increasingly evident that different seed priming techniques in plants can enhance the tolerance of crops to adverse environmental conditions. Generally seed priming shows potential strategy for increasing crop production and management in adverse environmental conditions.

Recommendation

It can be recommended that:

Seed priming for enhanced resistance to of adverse environmental conditions obviously is operating various pathways involved in different metabolic processes. The seedlings emerging from primed seeds showed early and uniform germination. Moreover, the overall growth of seedling and plant is improved due to the seed-priming treatments, so that farmers or any of crop producers should be practice and apply the science of seed priming for maximizing crop yield in any of adverse environmental conditions.

Further research is needed in order to create the global image of seed priming phenomena against environmental challenges as well as to characterize specific priming-related protein indicators in crop plants.

References

Abraha, B. and Yohannes, G. 2013. The role of seed priming in improving seedling growth of maize (*Zea mays* L.) under salt stress at field conditions. Agricultural Sciences 4:666-672.

Afzal, I., Hussain, B., Basra, S.M.A. and Rehman, H. (2012), Priming with moringa leaf extract reduces imbibitional chilling injury in spring maize; *Seed Sci. & Technol.*, 40, 271-276.

Afzal, I.,Basra, S.M.A., Shahid, M., Farooq, M. and Saleem M. (2008), Priming enhances germination of spring maize (*Zea mays* L.) under cool conditions *Seed Sci. & Technol.*, 36, 497-503.

Christos A. Damalas, Spyridon D. Koutroubas and Sideris Fotiadis. (2019). Hydro-Priming Effects on Seed Germination and Field Performance of Faba Bean in Spring Sowing; Journal of Agriculture, 9, 201.

Dawood MG (2018) Stimulating plant tolerance against abiotic stress through seed priming. In: Advances in seed priming. Springer, Singapore, pp 147–183.

De Palma, M., Salzano, M., Villano, C., Aversano, R., Lorito, M., Ruocco, M., Docimo, T., Piccinelli, A.L., D'Agostino, N., Tucci, M., 2019. Transcriptome reprogramming, epigenetic modifications and alternative splicing orchestrate the tomato root response to the beneficial fungus *Trichoderma harzianum*. Hortic. Res. 6, 5.

Hacisalihoglu G, Kantanka S, Miller N, Gustin JL, Settles AM. (2018) Modulation of early maize seedling performance via priming under sub optimal temperatures. PLoS ONE 13 (11): e0206861. https://doi.org/10.1371/journal. pone.0206861.

Ibrahim, E.A. 2016. Seed priming to alleviate salinity stress in germinating seeds. Journal of Plant Physiology 192:38-46.

Kim, J.-M., To, T.K., Matsui, A., Tanoi, K., Kobayashi, N.I., Matsuda, F., Habu, Y., Ogawa, D., Sakamoto, T., Matsunaga, S., Bashir, K., Rasheed, S., Ando, M., Takeda, H., Kawaura, K., Kusano, M., Fukushima, A., Takaho, A., Kuromori, T., Ishida, J., Morosawa, T., Tanaka, M., Torii, C., Takebayashi, Y., Sakakibara, H., Ogihara, Y., Saito, K., Shinozaki, K., Devoto, A., Seki, M., 2017. Erratum: Acetate-mediated novel survival strategy against drought in plants. Nat. Plants 3, 17119.

Laszlo Fodorpataki, Katalin Molnar, Bernat Tompa Sebastian R.C. PLUGARU.2019. Priming with Vitamin U Enhances Cold Tolerance Of Lettuce (Lactuca sativa L.), Not Bot Horti Agrobo, 47(3):592-598. DOI:10.15835/nbha47311433.

Lin, J.M., Sung, J.M., 2001. Pre-sowing treatments for improving emergence of bitter gourd seedlings under optima and sub-optimal temperatures. *Seed Science and Technology*, 29 (1):39-50.

Ling Yan Dai, Hong De Zhu, Kui De Yin, Ji Dao Du,Yu Xian Zhang.(2017). Seed priming mitigates the effects of saline-alkali stress in soybean seedlings, Chilean Journal of Agriculture Research 77(2).

M. Farooq, T. Aziz, S. M. A. Basra, M. A. Cheema and H. Rehman. 2016. Chilling Tolerance in Hybrid Maize Induced by Seed Priming with Salicylic Acid; Journal of Agronomy & Crop Science, ISSN 0931-2250.

M. Piri, M. B. Mahdieh, J. A. Olfati, and Gh. Peyvast International Journal of Vegetable Science, 15:285–292, 2009 Copyright © Taylor & Francis Group, LLC ISSN: 1931-5260 print / 1931-5279.

M. Z. Jafar and M. Shahid M. Farooq M. A. Cheema I. Afzal S. M.A. Basra M. A. Wahid, T. Aziz & M. Shahid.(2012). Improving the Performance of Wheat by Seed Priming Under Saline Conditions J. Agronomy & Crop Science, ISSN 0931-2250.

M.A. AGHBOLAGHI and M. SEDGHI. 2014. The effect of halo and hydro priming on germination characteristics of millet seeds under salinity stress; Vol. XLVII , No. 2 (158).

Mhlongo, M.I., Piater, L.A., Madala, N.E., Labuschagne, N., Dubery, I.A., 2018. The chemistry of plant-microbe interactions in the rhizosphere and the potential for metabolomics to reveal signaling related to defense priming and induced systemic resistance. Front. Plant Sci. 9, 112.

Muhammad Qudrat Ullah Farooqi, Ju Kyong Lee. 2016. Cold Stress Evaluation among Maize (*Zea mays* L.) Inbred Lines in Different Temperature Conditions; Plant Breed. Biotech. 4(3):352–361.

Pavel Kerchev, Tomvan der Meer, Neerakkal Sujeeth, Arno Verlee, Christian V. Stevens, Frank Van Breusegem, Tsanko Gechev. 2020. Molecular priming as an approach to induce tolerance against abiotic and oxidative stresses in crop plants; Biotechnology advances, 40 issue 107503.

Petrov,V., Hille, J., Mueller Roeber, B., Gechev, T.S., 2015. ROS mediated abiotic stress induced programmed cell death in plants. Front. Plant Sci. 6, 69.

Rodríguez VM, Romay MC, Ordás A, Revilla P. 2010. Evaluation of European maize (*Zea mays* L.) germplasm under cold conditions. Genet. Resour. Crop Evol. 57: 329-335.

Santaniello, A., Scartazza, A., Gresta, F., Loreti, E., Biasone, A., Di Tommaso, D., Piaggesi, A., Perata, P., 2017. *Ascophyllum nodosum* seaweed extract alleviates drought stress in Arabidopsis by affecting photosynthetic performance and related gene expression. Front. Plant Sci. 8, 1362.

Shukla, P.S., Borza, T., Critchley, A.T., Hiltz, D., Norrie, J., Prithiviraj, B., 2018. *Ascophyllum nodosum* extract mitigates salinity stress in Arabidopsis thaliana by modulating the expression of miRNA involved in stress tolerance and nutrient acquisition. PLoS ONE 13, e0206221.

Stanley Lutts, Paolo Benincasa, Lukasz Wojtyla,, Szymon Kubala S, Roberta Pace Katzarina Lechowska, Muriel Quinet and Malgorzata Garnczarska. (2016). Seed Priming: New Comprehensive Approaches for an Old Empirical Technique; http://dx.doi.org/10.5772/64420.

Taylor A.G., Allen P.S., Bennett M. A., Bradford K. J., Burrisand J. S. and Misra M. K. 1998. Seed enhancements. Seed Sci. Res. 8: 245-256.

Wang W, Peng S, Chen Q, Mei J, Dong H, Nie L. 2016. Effects of pre-sowing seed treatments on establishment of dry direct-seeded early rice under chilling stress. AoB PLANTS 8: plw074; doi:10.1093/aobpla/plw074.

Wondemu Tessome, Tamado Tana, Nigussa Dechessa and T. N. Singh. (2018). Effect of Seed Priming on Germination and Seedling Growth of Grain Sorghum (*Sorghum bicolor* L. Moench) Varieties; East African Journal of Sciences, Volume 12 (1) 51-60;

Xu-Wen Jiang, Cheng-Ran Zhang, Wei-Hua Wang, Guang-Hai Xu, and Hai-Yan Zhang. (2020). Seed Priming Improves Seed Germination and Seedling Growth of *Isatis indigotica* Fort. Under Salt Stress HORTSCIENCE 55(5):647 650. https://doi.org/10.21273/HORTSCI14854-20.

Ya-jing GUAN Jin HU, Xian-ju WANG and Chen-xia SHAO.2009. Seed priming with chitosan improves maize germination and seedling growth in relation to physiological changes under low temperature stress; Journal of Zhejiang University SCIENCE; 10(6):427-433.

How to cite this article:

Mekonnen Gebeyaw. 2020. Review on: Recent Achievement of Seed Priming in Improving Seed Germination and Seedling Growth in Adverse Environmental Conditions. *Int.J.Curr.Res.Aca.Rev*. 8(6), 6-12.
doi: https://doi.org/10.20546/ijcrar.2020.806.002