REVIEW ARTICLE

SEED HYDROPRIMING TECHNIQUE IN CEREAL CROPS: A REVIEW

Dipika Bhusal*, Dhirendra Pratap Thakur

Institute of Agriculture and Animal Science, Paklihawa Campus, Tribhuvan University, Nepal.

*Corresponding Author Email: bhusaldipika48@gmail.com

This is an open access article distributed under the Creative Commons Attribution License CC BY 4.0, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

ARTICLE DETAILS

Article History:

Received 25 August 2020

Accepted 28 September 2020

Available online 04 December 2020

ABSTRACT

Cereals contribute to 50% of total caloric intake and 95% of the total food requirement globally. Increasing climate change and population has increased the food demand and endangered the productivity of food crops due to various biotic and abiotic stresses and within these conditions' world is trying to push itself towards increasing the grain yield per unit of land. Several methods of seed priming are practiced to rejuvenate the seeds and remove the environmental stress. Hydro priming, a method of seed priming, has prominent advantage of stresses resistance, better crop stand, and emergence. In order to cope with the future challenges of crop productivity knowledge on the beneficial effects of hydro priming is important. Hydro priming induces DNA repair processes and Antioxidant responses associated as pre-germinative metabolism that leads to early and better seedling growth. Seed Hydro priming may be the best solution to the germination related problems especially in crops grown in unfavorable conditions and enhanced activation of the plant defense mechanism describes this process. Defining the exact treatment duration, water volume, and temperature of water during Hydro priming can revolutionize the farming system with better results.

KEYWORDS

Seed priming, Yield, Germination, Stress, Staple.

1. INTRODUCTION

Cereals are annual grasses having thin, long stalks cultivated worldwide for their edible grain (Sarwar, 2013). Cereals belong to family Poaceae containing mainly seven principle crops grown worldwide namely rice, wheat, maize, sorghum, barley, oats and rye (Deepa et al., 2013). Cereals contribute to almost 50% of total caloric intake with 700 million hectares cropping area (Dunwell, 2014). The major cereals fulfill about 95% of the total food requirement (Zargar et al., 2017; Asgari et al., 2017). Population is increasing worldwide i.e. 10 million by 2050, which has increased the demand of food and commodities, but along with it increasing global warming, heat stress, drought, salinity, and other abiotic stresses have come up the way resulting in the endangered productivity of these crops (Maiti and Satya, 2014). Limited agricultural land and the reproductive capacity of the field crops is all that we have for ensuring food security (Sher et al., 2019). However, within the conditions of increasing climate change world is pushing itself towards increasing the grain yield per unit of land (Singer et al., 2019).

The biotic and abiotic stresses are eradicating by the farmers from old ages by promising seed priming technique that gave trailblazing media that grounds close monitoring (Sivasubramaniam et al., 2011). Seed priming has a prominent advantage of inducing resistance like drought stress, heat stress, salinity, etc. in many field crops including cereals. The results from the works on seed priming have indicated well importance of priming for a better crop stand and emergence (Nawaz et al., 2013). There are many methods of seed priming that rejuvenate the seeds and remove the environmental stress including Hydro priming that includes the pre-hydration of the seeds and activates the early germination events (Lutts et al., 2016). Priming treatments like Hydro priming has been effective in

seed vigor enhancement to achieve rapid and uniform seed germination of different field crops including cereals (Tian et al., 2014; Prasad et al., 2012; Bakfht et al., 2011). A rapid and uniform emergence and root growth leads to the successful establishment of the seedling (Lutts et al., 2016).

It can be successfully used to fulfill the present needs of uniform germination and stand establishment (Nawaz et al., 2013). It reduces the gap between seed sowing and emergence of seedling thus synchronizing emergence (Parera and Cantliffe, 2010). This will enable the crop to escape the stresses by shortening the maturity days, have vigorous growth and higher yield (Subedi and Canada, 2014; Nawaz et al., 2013). Hydro priming can successfully utilize in areas with environmental stresses like high heat and drought because in such conditions hydro priming increases the water uptake efficiency and seed hydration (Waqas et al., 2010; McDonald, 2000). Enhanced activation of the plant defense mechanism describes this process (Hussain et al., 2019). This review covers the effect of seed hydro priming on morphological and biochemical changes on major cereals. It highlights major achievements of hydro priming in the cereals till date. It also explains the stress tolerance mechanism that will help to cope with the increasing climatic change in the world. Furthermore, the future prospects and limitations associated with hydro priming that can be successfully utilized in future are also discussed.

2. REVIEW METHODOLOGY

Rigorous desk study was conducted for the literature collection on seed priming and its effects on the cereals. Various research papers, review articles, and reports studied thoroughly for the compilation of this review information. The database referred were Research gate, Science Direct, Taylor and Francis, Google Scholar, Academia and Semantic Scholar.

Quick Response Code

Access this article online

Website:

www.rfna.com.my

DOI:

[10.26480/rfna.02.2020.85.88](https://doi.org/10.26480/rfna.02.2020.85.88)

3. REVIEW DISCUSSION

3.1 Effect of Hydro priming in Different Cereals

Hydro priming affects the germination and growth stages leading to high yield in cereals. The pre-metabolic activity that occurs during priming induces the biochemical reactions to occur that enhances the germination process and tolerance. However, effect of Hydro- Priming depends on different factors including the length of exposure to the water.

3.1.1 Rice

Rice is the staple food of developing countries and included as the diet of more than half of the world's population (Kalhori et al., 2018; Prasad, 2011; Nascente, 2013). Need of technologies and strategies to increase rice grain yield is must to meet the increasing population (Qin et al., 2013; Mondo et al., 2016). Researches have been carried out to improve yield parameter and stresses in rice through Hydro priming (Kalhori et al., 2018; Mondo et al., 2016; Mahajan et al., 2011). Hydro priming had a positive impact in the physiological potential including germination and vigor enhancement of rice (Basra et al., 2006; Farooq et al., 2006). It resulted high germination and seedling vigor as the indication of maximum vigor enhancement in fine and coarse rice seeds hydro-primed for 48 hours duration (Farooq et al., 2006). Hydro priming for 24 hours resulted 100% germination, maximum shoot fresh weight, maximum root length, highest α -amylase activity and highest content of total and reducing sugar in coarse rice (Basra et al., 2006). Results in hydro-primed Malaysian Indica rice seeds indicated higher germination percentage, germination index and lower mean germination time than the non-primed seeds under drought treatments (Kalhori et al., 2018). A group researcher observed influenced duration of 40-48 hours Hydro priming in rice seeds for better seedling invigoration while above this duration indicated over-priming that decayed the rice seeds showing poor germination and emergence (Prasad et al., 2012; Lee and Kim, 2000).

3.1.2 Maize

Among the major cereals Corn occupies third position in terms of importance but commercially it holds second position (Soare et al., 2018). It provides 30% of the food calories to more than 4.5 billion people in 94 developing countries (Shiferaw et al., 2020). Seasonal drought in the sowing season often in spring and autumn is frequent in semi-arid areas hence to withstand this conditions improvement of water use efficiency is essential (Tian et al., 2014). Hydro priming is found to increase the water use efficiency and improve the grain yields under water stressed conditions (Ali et al., 2013). Maize seeds soaked for 18 hours followed by 2 hours surface drying indicated the most important physiological activities performed to result the best emergence performances like germination percentages of 85% and 95% at 30 and 60% moisture levels respectively, higher germination index as well the mean germination time (Ahammad et al., 2014). A maximum seed invigoration of maize inbred lines was found for 36 hours Hydro priming with higher germination rate, radical length and vigor index (Dezfuli et al., 2008). Improved germination parameters like maximum emergence and vigor index, growth parameters like maximum leaf area, shoot and root dry weight as well as yield parameters like higher number of cobs per plant, grains per cob, seed index and 35% increase in seed yield were found in maize seeds hydro-primed for 18 hours 55-65% soil moisture level (Sudozai et al., 2013). Soleimanzadeh found 18 hours maize seeds hydro- priming as an effective method for increased seed germination, seed yield, and yield components (Soleimanzadeh, 2013). Change in the protein profile of maize embryos followed by accelerated germination of maize seeds was found in 12 hours Hydro priming of maize seeds (Gong et al., 2013).

3.1.3 Wheat

Wheat is considered as the second most important stable food crop after rice grown by about 40% of the world population providing 20% of daily protein and food calories (Giraldo et al., 2019). Sowing time of wheat is one of the most important factors affecting its total yield. Hydro priming of seeds before sowing found to improve the stand establishment, growth and yield of late sown wheat in Rice-Wheat system (Kant et al., 2006). Hydro priming helps to advance the wheat sowing by 10 days that positively affect the yield. It was found that Hydro priming of wheat seeds promoted early emergence, total germination count, increased number of tillers, grain weight, biological as well as economical yield of late sown wheat under different moisture conditions (Ali et al., 2013). The water productivity of wheat is 1500 liters of water per kg of wheat (FAO, 2012). Hydro priming of wheat helped in increasing the water use efficiency under water stressed conditions with higher germination percentage and homogeneity of seedling emergence helping to reduce the water

consumption at huge quantity for same quantity of wheat thus decreasing the cost of irrigation (Meena et al., 2014). Sowing of wheat on 22nd of November with 16 hours hydro-primed seeds resulted highest germination, growth, yield parameters as well as highest economic return (Patra et al., 2016; Sitanshu et al., 2017). Hydro priming of wheat seeds also helped to improve the aged wheat seeds quality, induced increment in enzyme activity, improved germination and seedling characteristics (Ghasemi et al., 2015).

3.1.4 Barley

Barley occupies fourth position in terms of production and cultivation among the cereals particularly used as whole grains for animal feed and in production of alcoholic beverages (Fox, 2009; Nikkhah, 2012). Barley being important role in animal and human feed its production must be increased under the increasing climate change and increasing population demand and improvement in the soil and crop management strategies can be a way to address the problem (Giraldo et al., 2019; Roberts and Mattoo, 2018). Seed priming is one of the crop management techniques to make improvements in crop production (Junhaeng, 2016). Hydro priming of barley seeds had showed enhancement in germination, seedling growth, better stand establishment leading to better yield and reduced seed infection by *F. culmorum* (Djebali, 2012). Hydro priming had also improved the root length, root dry weight, plant height and SPDA of barley seedlings (Jalilian et al., 2014). Seeds Hydro priming enhanced barley seeds malting quality, speed of germination and shorten malting process by 64.81% (Junhaeng, 2016). nature.com/hortres

3.2 Physiological, Biochemical and Molecular aspects of Seed Priming

Seed Priming is a pre-sowing treatment that allows the imbibition of seeds under controlled conditions preventing the radicle emergence and loss of desiccation tolerance in order to induce antioxidant responses as well as DNA repair process associated with pre-germinated metabolism (Ventura et al., 2012). During the initial phases of seed germination, seeds face various stresses leading to oxidative damage of nucleic acids, lipids and proteins (Kranter et al., 2010). Within these conditions seed repair is a need for conservation of seed vigor and efficient germination. Rehydration in seed priming induces major cellular processes in seeds like DE novo synthesis of proteins and nucleic acids, activation of antioxidants, adenosine triphosphate (ATP) production, accumulation of phospholipids and sterols and regulation of DNA repair mechanism which is an important constituent of pre-germinative metabolism induced at start of imbibition (Paparella et al., 2015). Higher activities of different enzyme like proteases, α and β -amylase and iso-citrate lyase involved in the mobilization of stored reserves in seed playing a vital role in breakdown of macromolecules for embryo growth are seen in primed seeds exerting a positive influence on better and early growth of seedlings (Sisodia et al., 2018).

Under normal and stressful conditions, seedlings emerged from primed seeds have been reported with enhanced activities of CAT (Catalase), SOD (Superoxide dismutase) and POD (Peroxidase) that imparts stress tolerance leading to strengthen the defense line of the crop (Zheng et al., 2016). The antioxidant machinery system plays a vital role during seed storage, germination and development by scavenging the excessive ROS (Reactive Oxygen Species) to non-injurious level persuaded by various stresses (Mansour et al., 2019). ROS are the source of oxidative damage of membrane lipids, proteins, nucleic acids as well as enzymes inactivation that eventually leads to the death of cell which is counteracted by the seed defense system and DNA repair (Forti et al., 2020). The biochemical events triggered by water uptake during seed imbibition are associated with ROS accumulation and transformation (Bailly et al., 2008).

3.3 Future Prospects and Limitations

Poor soil and high soil temperature will be posed within the alarming climate change in future and seed quality will be a need to be influenced by seed priming (Sivasubramaniam et al., 2011). Hydro priming relies on only soaking of seeds in pure water followed by re-drying to original moisture content prior to sowing making it a low cost and environmentally friendly technique (Rhaman et al., 2020). Uncontrolled water uptake by the seeds during hydro priming is the main limiting factor of hydro priming which results unequal degree of hydration leading to asynchronous metabolic activation within the seeds (Mc Donald, 2000). Drum priming as a variant of Hydro priming can be successfully used as an alternative to conventional Hydro priming which allows the seeds imbibition in controlled manner and results simultaneous hydration (Warren and Bennett, 1997). Drum priming includes gentle rotation of seeds in a drum and gradual hydration by addition of water in vapor form

(Yu et al., 2012). On-farm priming may also be used especially for resource poor farmer in marginal environment (Harris et al., 2005). Conventional hydro priming has shown better germination, growth and yield performances in different crop researches. Seed Hydro priming may be the best solution to the germination related problems especially in crops grown in unfavorable conditions (Nawaz et al., 2013). However, it is very important to define the accurate treatment duration, temperature and water volume used in hydro priming in order to ensure desired level of seed priming hydration and better results (Lutts et al., 2016). The packing techniques for primed seeds storage is need to be made that will revolutionize farming in moisture starved areas where farmers are technologically and traditionally poor (Sivasubramaniam et al., 2011).

4. CONCLUSION

Hydro priming is a best approach towards seed enhancement for the increasing the overall germination and yield of cereal crops at normal as well as stressful conditions. Being a simple and zero cost technology, it can be recommended at the farmers' level practice through different extension activities around the globe. Furthermore, researches can also be conducted in large scale with Hydro priming to ensure its positive effects and determine the treatment durations. Within this changing climate, Hydro priming can be a priority for future seed man.

ACKNOWLEDGEMENTS

We would like to express our deepest gratitude to Professor Laxmeshwar Yadav for his guidance and continuous support and our dear parents for making us believe in our work.

REFERENCES

Ahammad, K., Rahman, M., Ali, M., 2014. Effect of hydropriming method on maize (*Zea mays*) seedling emergence. *Bangladesh Journal of Agricultural Research*, 39 (1), Pp. 143–150. <https://doi.org/10.3329/bjar.v39i1.20164>

Ali, H., Iqbal, N., Shahzad, A.N., Sarwar, N., Ahmad, S., Mehmood, A., 2013. Seed priming improves irrigation water use efficiency, yield, and yield components of late-sown wheat under limited water conditions. *Turkish Journal of Agriculture and Forestry*, 37 (5), Pp. 534–544. <https://doi.org/10.3906/tar-1207-70>

Asgari, M.J., Gharineh, M.H., Zaiyan, A.H. Asoudar, M.A., 2017. Effects of water stress on wheat nitrogen use under minimum and conventional tillage systems. *Crop Respiration*, 52, Pp. 209–17.

Bailly, C., El-Maarouf-Bouteau, H., Corbineau, F., 2008. From intracellular signaling networks to cell death: the dual role of reactive oxygen species in seed physiology. *Comptes rendus biologies*, 331 (10), Pp. 806–814. <https://doi.org/10.1016/j.crv.2008.07.022>

Bakht, J., Shafi, M., Jamal, Y., Sher, H., 2011. Response of maize (*Zea mays* L.) to seed priming with NaCl and salinity stress. *Spanish Journal of Agricultural Research*, 9 (1), Pp. 252–261. [10.5424/sjar/20110901-113-10](https://doi.org/10.5424/sjar/20110901-113-10).

Basra, S.M.A., Farooq, M., Tabassum, R., Ahmed, N., 2006. Evaluation of seed vigour enhancement techniques on physiological and biochemical basis in coarse rice (*Oryza sativa* L.). *Seed Science and Technology*, 34 (3), Pp. 719–728. <https://doi.org/10.15258/sst.2006.34.3.18>

Deepa, D.S.B., 2013. Status of Transgenic Cereal Crops: A Review. *Cloning Transgenesis*, 03 (01). <https://doi.org/10.4172/2168-9849.1000119>

Dezfuli, P.M., Sharif-zadeh, F., Janmohammadi, M., 2008. Influence of priming techniques on seed germination behavior of maize inbred lines (*Zea mays* L.). *Journal of Agricultural and Biological Science*, 3 (3), Pp. 22–25.

Djebali, N., 2012. Seed Hydropriming Effect on *Triticum durum* and *Hordeum vulgare* Germination, Seedling Growth and Resistance to *Fusarium culmorum*. *Plant Pathology Journal*, 11 (3), Pp. 77–86. <https://doi.org/10.3923/ppj.2012.77.86>

Dunwell, J.M., 2014. Transgenic cereals: Current status and future prospects. *Journal of Cereal Science*, 59 (3), Pp. 419–434. <https://doi.org/10.1016/j.jcs.2013.08.008>

Farooq, M., Basra, S. M. A., Afzal, I., Khaliq, A., 2006. Optimization of hydropriming techniques for rice seed invigoration. *Seed Science and Technology*, 34 (2), Pp. 507–512. <https://doi.org/10.15258/sst.2006.34.2.25>

Food and Agriculture Organization, 2012.

Forti, C., Ottobriano, V., Bassolino, L., Toppino, L., Rotino, G. L., Pagano, A., 2020. Molecular dynamics of pre-germinative metabolism in primed eggplant (*Solanum melongena* L.) seeds. *Horticulture Research*, June. <https://doi.org/10.1038/s41438-020-0310-8>

Fox, G.P., 2009. The effect of barley structure and composition on malt quality. Pp. 37–50. <https://doi.org/10.1007/978-3-642-01279-2>

Ghasemi, E., Ghahfarokhi, M.G., Darvishi, B., Kazafi, Z.H., 2015. The Effect of Hydro priming on Germination Characteristics, Seedling Growth and Antioxidant Activity of Accelerated Aging Wheat Seeds. *Cercetari Agronomice in Moldova*, 47 (4), Pp. 41–48. <https://doi.org/10.1515/cerce-2015-0003>

Giraldo, P., Benavente, E., Manzano-agugliaro, F., 2019. Worldwide Research Trends on Wheat and Barley: A Bibliometric Comparative Analysis.

Gong, F., Wu, X., Wang, W., 2013. Comparative proteomic identification of embryo proteins associated with hydropriming induced rapid-germination of maize seeds. *Plant OMICS*, 6 (5), Pp. 333–339.

Harris, D., Breese, W.A., Rao, J.V.D.K.K., 2005. The improvement of crop yield in marginal environments using “on-farm” seed priming: Nodulation, nitrogen fixation and disease resistance. *Australian Journal of Agricultural Research*, 56 (11), Pp. 1211–1218. <https://doi.org/10.1071/AR05079>

Hussain, S., Hussain, S., Khaliq, A., Ali, S., Khan, I., 2019. Physiological, Biochemical Molecular Aspects of Seed Priming. In M. Hasanuzzaman V. Fotopoulos (Eds), *Priming and Pretreatment of Seeds and Seedlings*, Pp. 43–63.

Imtiaz, S.M., Tunio, S., Rajpar, I., 2013. Seedling Establishment and Yield of Maize Under Different Seed Priming Periods and Available Soil Moisture, 29 (4).

Jabe, E.W., Bennett, M.A., 1997. Seed Hydration Using the Drum Priming System.

Jalilian, J., Khalilzadeh, R., Khanpaye, E., 2014. Improving of Barley Seedling Growth by Seed Priming Under Water Deficit Stress. *Journal of Stress Physiology Biochemistry*, 10 (2), Pp. 125–134.

Junhaeng, P., 2016. The Use of Seed Priming Treatments to Improve the Quality of Barley (*Hordeum vulgare* L.) for Malting. *Journal of Developments in Sustainable Agriculture*, 10 (2), Pp. 115–120. <https://doi.org/10.11178/jdsa.10.115>

Kalhari, N., Nulit, R., Azizi, P., Abiri, R., Atabki, N., 2018. Hydro Priming Stimulates Seedling Growth and Establishment of Malaysian Indica rice (MR219) Under Drought Stress. *Acta Scientific Agriculture*, 2 (11), Pp. 9–16.

Kant, S., Pahuja, S.S., Pannu, R.K., 2006. Effect of seed priming on growth and phenology of wheat under latesown conditions. *Tropical Science*, 44 (1), Pp. 9–150.

Kranner, I., Roach, T., Beckett, R.P., Whitaker, C., Minibayeva, F.V., 2010. Extracellular production of reactive oxygen species during seed germination and early seedling growth in *Pisum sativum*. *Journal of plant physiology*, 167 (10), Pp. 805–811. <https://doi.org/10.1016/j.jplph.2010.01.019>

Lee, S.S., Kim, J.H., 2000. Total sugar, amylase activity, and germination after priming of normal and aged rice seeds. *Korean Journal Crop Science*, 45, Pp. 108–111.

Lutts, S., Benincasa, P., Wojtyla, L., Kubala, S., Pace, R., Lechowska, K., Quinet, M., Garnczarska, M., 2016. Seed Priming: New Comprehensive Approaches for an Old Empirical Technique. *New Challenges in Seed*

- Biology - Basic and Translational Research Driving Seed Technology, Pp. 1–46. <https://doi.org/10.5772/64420>
- Mahajan, G., Sarlach, R.S., Japinder, S., Gill, M.S., 2011. Seed priming effects on germination, growth and yield of dry direct-seeded rice. *Journal of Crop Improvement*, 25 (4), Pp. 409–417. <https://doi.org/10.1080/15427528.2011.576381>
- Maiti, R.K., Satya, P., 2014. Research advances in major cereal crops for adaptation to abiotic stresses, *GM Crops Food*, 5 (4), Pp. 259–279, DOI: 10.4161/21645698.2014.947861
- Mansour, M.M.F., Ali, E.F., Karima, H.A.S., 2019. Does Seed Priming Play a Role in Regulating Reactive Oxygen Species Under Saline Conditions?. 10.1002/9781119468677.ch18.
- McDonald, M.B., 2019. Seed priming. In: M. Black J.D. Bewley (Eds), *Seed Technology and its Basis*. Sheffield: Biological Sheffield Academic Press, Pp. 287–325.
- Meena, R.P., Sendhil, R., Tripathi, S., Chander, S., Chhokar, R., Sharma, R., 2014. Hydro priming of Seed Improves the Water Use Efficiency, Grain Yield and Net Economic Return of Wheat under Different Moisture Regimes. *SAARC Journal of Agriculture*, 11 (2), Pp. 149–159. <https://doi.org/10.3329/sja.v11i2.18410>
- Mondo, V.H.V., Nascente, A.S., Neves, P. de C.F., Taillebois, J.E., Oliveira, F.H.S., 2016. Seed hydropriming in upland rice improves germination and seed vigor and has no effects on crop cycle and grain yield. *Australian Journal of Crop Science*, 10 (11), Pp. 1534–1542. <https://doi.org/10.21475/ajcs.2016.10.11.PNE70>
- Nascente, A.S., Crusciol, C.A.C., Cobucci, T., 2013. The no-tillage system and cover crops—Alternatives to increase upland rice yields. *European Journal of Agronomy*, 45, Pp. 124–131. 10.1016/j.eja.2012.09.004.
- Nawaz, J., Hussain, M., Jabbar, A., Nadeem, G.A., Sajid, M., Subtain, M., Shabbir, I., 2013. Seed Priming A Technique. *International Journal of Agriculture and Crop Sciences*, 6 (20), Pp. 1373–1381. <https://doi.org/10.1016/j.fcr.2004.04.006>
- Nikkhah, A., 2012. Barley grain for ruminants: A global treasure or tragedy. *Journal of Animal Science and Biotechnology*, 3 (1), Pp. 1–9. <https://doi.org/10.1186/2049-1891-3-22>
- Paparella, S., Araújo, S.S., Rossi, G., Wijayasinghe, M., Carbonera, D., Balestrazzi, A., 2015. Seed priming: state of the art and new perspectives. *Plant cell reports*, 34 (8), Pp. 1281–1293. <https://doi.org/10.1007/s00299-015-1784-y>
- Parera, C.A., Cantliffe, D.J., 2010. Presowing Seed Priming. *Horticultural Reviews*, Pp. 109–141. <https://doi.org/10.1002/9780470650561.ch4>
- Patra, S.S., Mehera, B., Rout, S., Tomar, S.S., Singh, M., Kumar, R., 2016. Effect of hydropriming and different sowing dates on growth and yield attributes of Wheat (*Triticum aestivum* L.). *Journal of Applied and Natural Science*, 8 (2), Pp. 971–980. <https://doi.org/10.31018/jans.v8i2.907>
- Patra, Sekhar, S., Mehera, B., Rout, S., Dharavath, N., 2017. Effect of Hydropriming And Different Sowing Dates on Economics of Wheat (*T. aestivum* L.) in Allahabad.
- Prasad, R., 2011. Aerobic rice systems. *Advances in Agronomy*, 111, Pp. 207–236. <https://doi.org/10.1016/B978-0-12-387689-8.00003-5>
- Prasad, S., Prasad, B., Singh, R.K., 2012. Effect of Hydro priming duration on germination and seedling vigor of rice [*Oryza sativa* L.] cv. Prasad. *Journal of Crop and Weed*, 8 (1), Pp. 65–71.
- Qin, J., Impa, S.M., Tang, Q., Yang, S., Yang, J., Tao, Y., Jagadish, K.S.V., 2013. Integrated nutrient, water and other agronomic options to enhance rice grain yield and N use efficiency in double-season rice crop. *Field Crops Research*, Pp. 148. 10.1016/j.fcr.2013.04.004.
- Rhaman, M.S., Rauf, F., Tania, S.S., Khatun, M., 2020. Seed Priming Methods: Application in Field Crops and Future Perspectives Seed Priming Methods: Application in Field Crops and Future Perspectives.
- Roberts, D.P., Mattoo, A.K., 2018. Sustainable agriculture—Enhancing environmental benefits, food nutritional quality and building crop resilience to abiotic and biotic stresses. *Agriculture (Switzerland)*, 8 (1). <https://doi.org/10.3390/agriculture8010008>
- Sarwar, H., 2013. The importance of cereals (*Poaceae: Gramineae*) nutrition in human health: A review. *Journal of Cereals and Oilseeds*, 4 (3), Pp. 32–35. <https://doi.org/10.5897/jco12.023>
- Sher, A., Sarwar, T., Nawaz, A., Ijaz, M., Sattar, A., Ahmad, S., 2019. Methods of Seed Priming. In M. Hasanuzzaman V. Fotopoulos (Eds), *Priming and Pretreatment of Seeds and Seedlings*, pp. 1–11.
- Shiferaw, B., Prasanna, B.M., Hellin, J., Bänziger, M., 2020. Crops that feed the world 6. Past successes and future challenges to the role played by maize in global food security, Pp. 307–327. <https://doi.org/10.1007/s12571-011-0140-5>
- Singer, S.D., Foroud, N., Laurie, J.D., 2019. Molecular Improvement of Grain: Target Traits for a Changing World. 10.1016/B978-0-08-100596-5.22439-6.
- Sisodia, A., Padhi, M., Pal, A.K., Barman, K., Singh, A., 2018. Seed Priming on Germination, Growth and Flowering in Flowers and Ornamental Trees., 10.1007/978-981-13-0032-5_14.
- Sivasubramaniam, K., Geetha, R., Sujatha, K., Raja, K., Sripunitha, A., Selvarani, R., 2011. Seed Priming: Triumphs and Tribulations. *Physiology*, 98, Pp. 197–209.
- Soare, E., Chiurciu, I., Bălan, A., David, L., 2018. World Market Research on Maize. <https://doi.org/10.2478/alife-2018-0032>
- Soleimanzadeh, H., 2013. Effect of seed priming on germination and yield of corn.
- Subedi, K., Canada, A., 2014. Seed Priming Does Not Improve Corn Yield in a Humid Temperate Environment.
- Tian, Y., Guan, B., Zhou, D., Yu, J., Li, G., Lou, Y., 2014. Responses of seed germination, seedling growth, and seed yield traits to seed pretreatment in maize (*Zea mays* L.). *Scientific World Journal*, <https://doi.org/10.1155/2014/834630>
- Ventura, L., Donà, M., Macovei, A., Carbonera, D., Buttafava, A., Mondoni, A., Rossi, G., Balestrazzi, A., 2012. Understanding the molecular pathways associated with seed vigor. *Plant physiology and biochemistry: PPB*, 60, Pp. 196–206. <https://doi.org/10.1016/j.plaphy.2012.07.031>
- Waqas, M., Emmanuel, K., Khan, M.D., Nizami, A.S., Deeba, F., Ali, I., Hussain H., 2019. Advances in the Concept Methods of Seed Priming. In M. Hasanuzzaman V. Fotopoulos (Eds), *Priming and Pretreatment of Seeds and Seedlings*, Pp. 11–35.
- Yu, C., Chen, R., Li, J.J., Li, J.J., Drahansky, M., Paridah, M., Moradbak, A., Mohamed, A., Owolabi, FolaLi, H., Abdulwahab, T., Asniza, M., Abdul Khalid, S.H., Sharma, T., Dohare, N., Kumari, M., Singh, U.K., Khan, A.B., Borse, M.S., Patel, R., Paez, A., Reading, F., 2012. We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists TOP 1 % Intech, 13. <https://doi.org/10.1016/j.colsurfa.2011.12.014>
- Zargar, M., Rebouh, N., Pakina, E., Gadzhikurbanov, A., Lyashko, M., Ortskhanov, B., 2017. Impact of climate change on cereal production in the highlands of eastern Algeria. *Research on Crops*, 18 (4), Pp. 575–582. <https://doi.org/10.5958/2348-7542.2017.00098.5>
- Zheng, M., Hussain, S., Tao, Y., Jiang, Q., Peng, S., Huang, J., Cui, K., Nie, L., 2016. Seed priming in dry direct-seeded rice: consequences for emergence, seedling growth and associated metabolic events under drought stress. *Plant Growth Regulation*, 78 (2), Pp. 167–178. <https://doi.org/10.1007/s10725-015-0083-5>