e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:04/April-2024 Impact Factor- 7.868 www.irjmets.com

OPTIMIZING SEED PERFORMANCE: A COMPREHESIVE REVIEW OF AGRICULTURAL PRETREATMENT STRATEGIES

Yashvi Patel[*1], Parth Desai[*2], Dr. Hitesh Solanki[*3]

[*1,2,3]Department Of Botany, Bioinformatics And Climate Change Impacts Management, School Of Science, Gujarat University, Ahmedabad, India.

DOI : https://www.doi.org/10.56726/IRJMETS51845

ABSTRACT

Farmers have been treating seeds for generations to protect them from viruses and pests, long before the nature of plant diseases was understood. The use of seed treatment has evolved into a very valuable, Effective and ecologically friendly component of agricultural production techniques. For the majority of crop and horticultural seeds, Seed improvement technologies like physical, chemical and biological pretreatment – developed by the agricultural seed industry – are standard procedures. Physical approaches, which were previously utilized to improve plant output, offer advantages over conventional methods that involve chemicals. Further, biological pretreatment appears to be a promising technique because it is environmentally benign and does not produce any inhibitors. This review paper addresses the role of such seed pretreatment methods in increasing germination percentages, germination rates and overall seedling development under a variety of environmental can be utilized to attain a number of advantages such as improved emergence through protection from seedborne pathogens, soilborne pathogens and insects; preventing the seed transmission of seedborne pathogens; shielding above – ground plant parts from infection by airborne pathogens or feeding by insect pests and disease vectors; and enhanced crop vigor and uniformity. All of these advantages help to maximize crop quality and output while reducing adverse effects by using crop protection agents effectively. Treatment of seeds reduces the possibility of selection pressure for disease or pest resistance while enabling highly targeted administration of low, homogeneous dosages of substance. Seed application of crop protection chemicals offers distinct advantages over other approaches. It is a dependable technology that ensures uniform crop establishment across a wide range of conditions, soil and cultural practices; nevertheless, the benefits provided by seed treatments cannot be replicated because most of the target diseases and pests cannot be controlled once planted.

Keywords: Seed Treatment, Dormancy, Seed Germination, Crop Yield, Sustainable Agriculture.

I. INTRODUCTION

The term "seed treatment" describes the process of applying different materials or treatments to seeds before to planting with the goals of maximizing germination, safeguarding against pests, diseases and environmental stressors ad enhancing overall crop output. The purpose of this procedure is to guarantee better plant development in the initial phases of growth and maximize seed performance (Jogaiah, 2020).

Many crops have undergone presowing Seed treatments in order to break dormancy and achieve an earlier and more consistent emergence (Puppala & Fowler, 2003). The activation of seed resources, when combined with outside components, could lead to effective plant growth and a high yield. Seed treatment is the first step towards achieving this (Hasanuzzaman & Fotopoulos, 2019).

The application of bioformulations to seeds on the spermosphere of plants is commonly achieved by seed treatment. In order to administer bacterial and fungal biocontrol agents, seed treatment is another technique used. To effectively apply biofertilizers. Seed must be coated with biocontrol agents, also known as PGPR. Covered biofertilizers become colonized and multiply when seeds are sown. This helps them protect plants from different kinds of crop – related seed – borne infections or boost plant growth and vigor through a variety of biological processes (Jambhulkar & sharma, 2013).

Many strategies, such as seed coating, soaking, priming and hardening have been employed to increase seed germination and promote the growth of healthy seedlings (Basra *et al.*, 2003)

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:04/April-2024 Impact Factor- 7.868 www.irjmets.com

1. TYPES OF SEED PRETREATMENT:

There are numerous physiological and non – physiological methods for improving seed performance and overcoming environmental limitations.

1.1 Physical Pretreatments:

Physical ways of stimulating plant growth have gained popularity recently since they have less negative environmental effects. It is possible to induce beneficial biological changes in crop plants using physical means without having an impact on the environment. Physical therapy speeds up the dill seed's growth, development and yield (Govindaraj *et al.*, 2017).

Presoaking, moistening and humidification are examples of seed hydration strategies that make up the physiological treatments for enhancing stand establishment and seed germination. In order to maximize the pre – germinative metabolic process and facilitate quick germination seeds can be primed physiologically by regulated hydration and drying (Dawood, 2018).

1.1.1 Scarification :

Scarification is the term for any procedure intended to increase the seed coat's permeability to gasses and water, assisting in seed germination. The process of scarification involves weakening, opening or changing the seed coat in some other way in order to promote germination. Scarification is frequently applied mechanically, with rice water, coconut water and acid. Scarification is a method used to make seeds of plants that are ordinarily difficult to cultivate from seed viable(Singh *et al.*, 1965 ; Priyadharshini & Lekha, 2021).

There are different types of scarification methods each suited to the specific needs of different plant species. Like, mechanical scarification, chemical scarification, Heat scarification, Sand paper scarification etc.

1. Mechanical Scarification:

In order to break the physical dormancy, the seed coat can be manually scarified by piercing, nicking, cutting, filing or burning with the use of a knife, needle, hot wire burner, abrasion paper, hot water treatment or acid treatment (Catalan & Macchiavelli, 1991 ; Kobmoo & Hellum, 1984; Khasa, 1992 ; Kobmoo & Hellum, 1984).

Figure 1: Different Types of Mechanical Scarification

2. Heat scarification:

One of the most widely used techniques is heat scarification due to its ease of usage and simplicity. In heat scarification two primary heating sources are ovens (Harrington, 1916 ; Staker, 1925 ; Stewart, 1926 ; Lute, 1927 ; Rincker, 1954; Rutar *et al.*, 2001) and hot water bath (Uzun & Aydin, 2004 ; Patane & Gresta, 2006 ; Can *et al.*, 2009).

The effectiveness of heat scarification varies greatly based on the heating apparatus, treatment duration and temperature. When the right treatment duration and temperature are applied, heat scarification using dry heat in an oven appears to be beneficial for reducing hard seed and improving germination (Harrington, 1916 ; Stewart, 1926 ; Lute, 1927 ; Rincker, 1954 ; Tomer & Maguire, 1989 ; Rutar *et al.*, 2001). Different investigations used a range of temperatures (below 40°C to over 100°C) and treatment durations (one minute to 21 hours) with varying degrees of success reported. For example at treatment temperatures of 40° to 50°C, heat scarification had no effect on hard seed reduction (Harrington, 1916 ; Lute, 1927 ; Rutar *et al.*, 2001).

IRJMETS
e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:04/April-2024 Impact Factor- 7.868 www.irjmets.com

1.1.2 Hot water treatment:

Hot water treatment has been discovered that, in comparison to other treatments, hot water seed pretreatment is an efficient way to boost germination rates. According to research hot water treatment can greatly increase the germination rates is hot water seed preparation. Seeds are soaked in hot water for predetermined amounts of time at regulated temperatures. Pathogens are decreased and seed quality is improved with this approach. Variations in temperature and length can have an impact on the percentage of germination that occurs after hot water treatment, according to studies (Kim & Wangchuk, 2022).

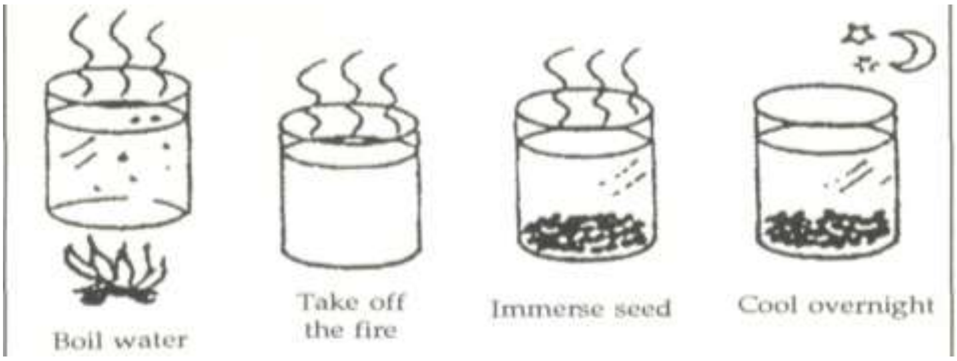

Figure 2: Hot-water treatment of seeds

A viable substitute to increase agricultural production yield while enhancing plant storage and protection could be the application of physical variables (Aladjadjiyan, 2012).

Compared to traditional chemical – based treatments, physical techniques of invigorating seeds have a number of advantages. First, they use less fertilizer, which lessens pollutions of the raw materials produced on farms, Another benefit is that seeds can be physically disinfected both before and after they are stored (Aladjadjiyan, 2012)

One of the practical and affordable methods for developing uniform seed in the majority of field crops is this one. Additional advantages include crop output, maturity, photo and thermo – dormancy release, effective nutrient uptake and efficient water use (Hill *et al*., 2008 ; Bagheri 2014 ; Lara *et al*.,2014 ; Dutta 2018).

1.1.3 Other Possible Physical Techniques:

Additional potential methods involves the application of electromagnetic waves (EWs), magnetic fields (MFs), ultrasounds (US), high temperatures, non – thermal plasma and ionizing radiations (IR) (Farkas & Mohacsi-Farkas, 2011).

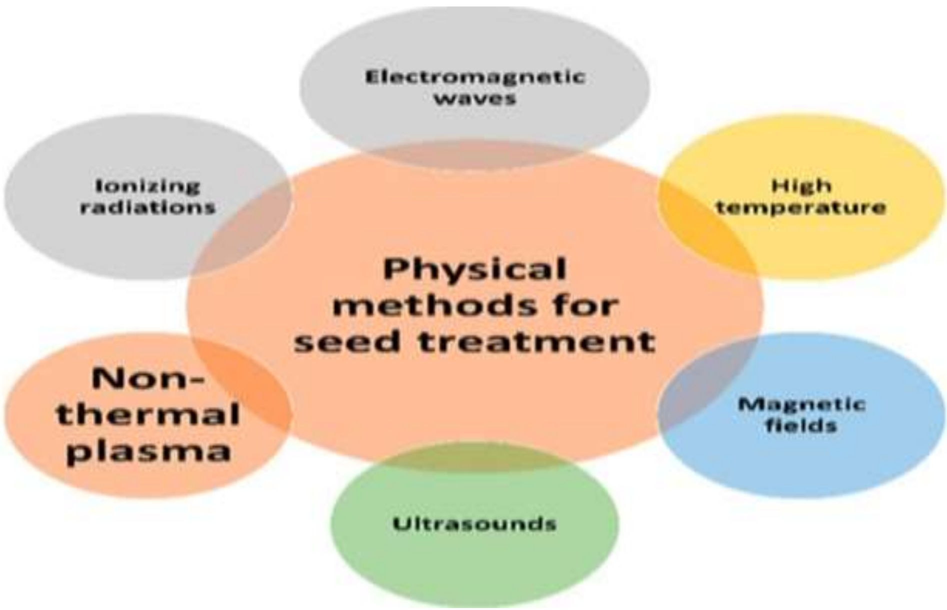

Figure 3: Physical methods for seed treatment

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:04/April-2024 Impact Factor- 7.868 www.irjmets.com

The other methods for encouraging germination include covering seeds, inoculating seeds with advantageous microorganisms and using chemical treatments (Hill *et al.*, 2008 ; Bagheri, 2014 ; Lara *et al.*, 2014 ; Dutta, 2018).

1.2 Chemical Pretreatments:

Chemical pretreatment refers to the use of several chemical techniques to improve the vigor and germination of seeds. By safeguarding seeds from pests, illnesses and unfavorable environments, these techniques seek to improve seed performance after sowing. Chemical seed dressing is the process of applying pesticides to seeds in order to improve their sowing performance. One of the earliest and most basic approaches for enhancing seed quality and shielding seeds from outside hazards is this one (Weissmann *et al.*, 2023).

Successful plant establishment requires the quick germination of seeds and the development of healthy seedlings (Kaya *et al.*, 2006). When there is a drought the ability of seeds to germinate and healthy seedlings to establish themselves is hindered since there is less water available, which causes decrease in plant intake of water (Farooq *et al.*, 2009). Another significant issue under drought stress is oxidative damage brought on by the generation of reactive oxygen species (ROS) (Gill & Tuteja, 2010). For higher agricultural yields, it is imperative to counteract the negative impacts of drought stress (Ashraf & Rauf, 2001).

1.2.1 Acid Pretreatment:

The literature reveals that diverse chemicals such as sulfuric acid, gibberellic acid, $Ca(NO_3)$, KNO_3, $NH_4(SO_4)_2$, NaCL, Kcl, KH_2PO_4 and $Mg(NO_3)_2$, can be used to treat seeds before sowing, soaking and seed hardening (hydration or dehydration). The concentration of these chemicals changes (Bose *et al.,* 1982) which enhance other biochemical parameters such as nitrate reductase activity and chlorophyll content in various crops and that stimulate water uptake, amylase activity, protease activity and solubilization of nitrogen from endosperm to growing embryonic axis in order to promote seed germination and healthy seedling establishment (Anaytullah & Bose, 2007 ; Mandal & Basu, 1984 ; Bose & Mishra, 1999 ; Bose & Mishra, 2001 ; Bose & Pandey, 2003 ; Sharma & Boss, 2006).

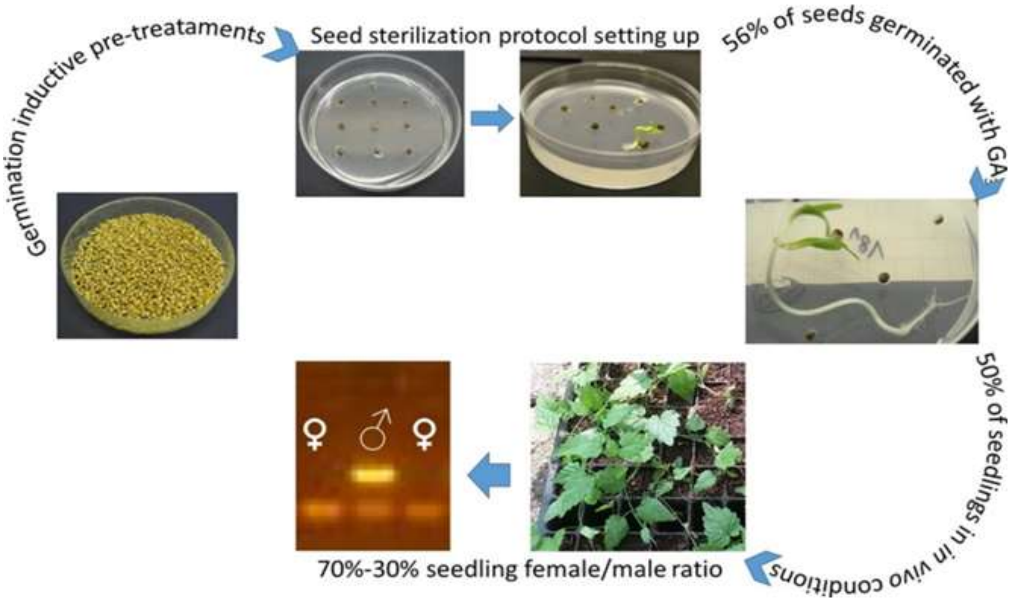

Figure 4: Chemical scarification with the use of gibberellic acid

1.2.2 Seed Priming:

The purpose of seed priming therapy is to increase most seeds germination, growth and yield under both stress and regular circumstances (Ashraf & Foolad, 2005 ; Iqbal & Ashraf, 2006 ; Mohammadi, 2009).

When seeds are hydrated under controlled conditions prior to planting, they start to germinate but are then dried again before germination reaches the radical/epicotyl extension stage. This technique is known as "seed priming" (Heydecker & Coolbaer, 1977 ; Bradford, 1986). Priming can provide more uniform and quick germination and establishment by reducing the diversity in seed germination rate within a population (Taylor

e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:06/Issue:04/April-2024 Impact Factor- 7.868 www.irjmets.com

et al., 1998 ; Jisha *et al*., 2013 ; Paparella *et al*., 2015 ; Bhanuprakash & Yogeesha, 2016). It can also provide you more resistance to osmoticum (salt), moisture and heat challenges(Bruggink, 2005) so it can be advantageous for plant establishment in hostile conditions (Kildisheva, 2019).

Different Types Of Priming :

- Hydro – Priming
- Chemo – or Hormone – Priming
- Osmo – Priming
- Matrix Priming

The Priming Process:

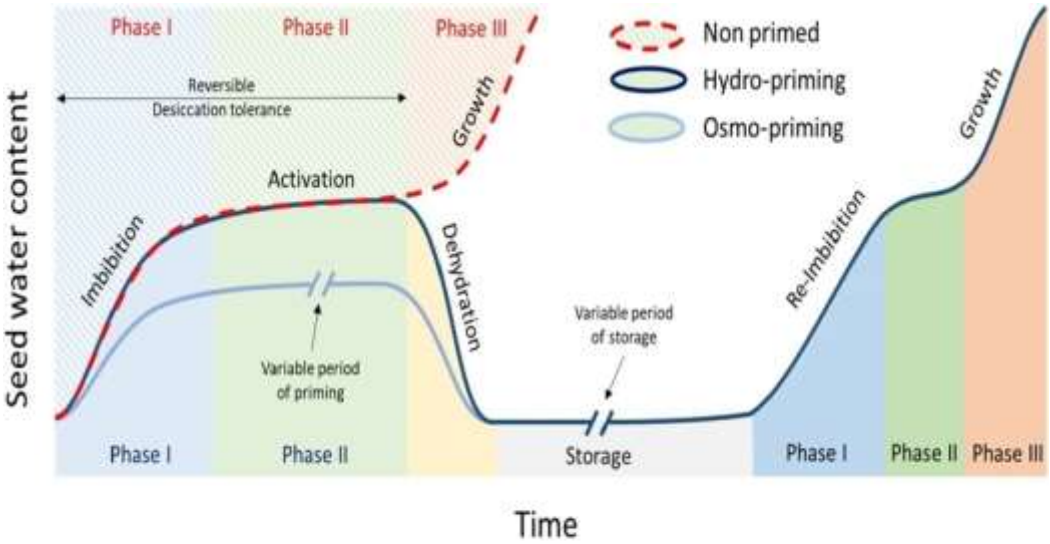

Figure 5: Seed water uptake can be divided into three phases: imbibition, the initiation of germination (activation), and embryo and radicle/epicotyl growth (growth). In seed priming, imbibition is interrupted at the beginning of the growth phase and seed are dried back to be stored

1.3 Biological Pretreatment:

Biological agents or materials are applied as part of biological seed pretreatment techniques to improve seed germination and vigor. Through the use of natural ingredients and processes, these techniques seek to enhance seed performance (Weissmann *et al*., 2023).

Nowadays, chemical preparations are the primary means of safeguarding seed against pests and diseases because of their high level of effectiveness (Shahbaz *et al*., 2018). However, it leads to several worldwide issues (Lal, 2015). Utilizing advantageous microorganisms to treat seeds in order to promote germination and seedling growth is known as biological seed pretreatment or biopriming. This method makes use of the beneficial interactions that naturally occur between microbes and seed to shield seeds from disease, improve nutrients intake and enhance general health of seedlings (Chakraborti *et el*., 2022).

The main ones are the decline in naturally occurring fertility of the soil the deterioration and loss of agricultural land, which is made worse by changes in the agrochemical properties of the soil as a result of chemical intrusion, the development of infections resistant to chemical medications and dangerous insects (Lucas *et al*., 2015 ; Cessna & Westcott, 2018).

1.3.1 Symbiotic Seed Treatment:

The Development of technologies for the production and use of biological preparations based on bacterial that produce vitamins, organic acids, antibiotics, and other biologically active substances, as well as symbiotic and associative nitrogen – fixing and phosphate – mobilizing microorganisms has been done for this reason (Gurav *et al*., 2017).

It is believed that all plants in natural environments work in symbiosis with internal fungi called endophytes (Rodriguez *et al*., 2009). The vitality and survival of plants that flourish in harsh environments are greatly influenced by these close relationships. It has been demonstrated for instance that fungus endophytes help plants in geothermal and coastal environments adapt to heat and salt stress (Rodriguez *et al*., 2008). Plants cannot thrive in these environments without their endophytes, suggesting that symbiotic mechanisms are involved in stress adaption (Lamichhane *et al*., 2022).

1.3.2 Microbial inoculation:

Biological seed treatments are made up of plant and algal extracts as well as microorganisms such as bacteria and fungus (Lamichhane *et al*., 2022).

The degradation of lignin and hemicellulosic biomass was accomplished by means of biological pretreatment microorganisms such as brown, white, and soft rot fungi. Because they need less energy and do less environmental harm the biological pretreatment employing white rot fungus that can break down lignin appears promise (Chen *et al*., 2010).

Applying advantageous microbes to seed to promote plant growth and provide stress resistance is known as microbial seed pretreatment. Research has demonstrated that adding microorganisms such as fungi and bacteria to seeds can greatly enhance a variety of seedling characteristics including fresh and dry weight, root and shoot length and seed germination (Cardarelli *et al*., 2022 ; Wackett, 2020).

This technique which increases plant health and productivity while lowering the need for pesticide inputs is regarded as a sustainable approach in agriculture (Paravar *et al*., 2023).

2. BENIFITS OF SEED PRETREATMENT:

The term “seed pretreatment” describes a range of techniques used on seed before to planting with the goal of maximizing germination boosting the health of the seedling and advancing the overall performance of the crop. Seed pretreatment has a number of benefits.

1. **Increased Germination Rate:**
   - Germination rates can be considerably increased by treating seeds. In a study involving tomato seeds for instance, it was discovered that priming with polyethylene glycol (PEG) enhanced germination in situations involving water stress (Sarabi *et al*., 2012).
2. **Uniform Germination:**
   - A batch of seeds will germinate at a similar pace if pretreatment techniques are used which can help promote more uniform germination. A stable position in the field depends on achieving this. Hydro priming enhanced germination consistency according to research on rice seeds (Ashraf *et al*., 2001).
3. **Acceleration of Germination :**
   - Crops can establish more quickly thanks to specific pretreatment methods that can quicken the germination process. In the case of chickpea seeds, for example : research showed that salicylic acid and kinetin seed priming speed up germination (Munir *et al*., 2019).
4. **Enhanced Seedlings Vigor :**
   - Vigorous seedlings are essential to the early establishment of crops. It has been demonstrated that pretreatment techniques like osmo priming and hornone priming increase seedling vigor. An investigation on maize seeds revealed that osmo priming with polyethylene glycol enhanced the vigor of the seedlings (Kaya *et al*,. 2006).
5. **Improved stress Tolerances :**
   - Plants that are seed treated may be able to with stand stress. Priming with ascorbic acid for instance, enhanced seedling growth under salt stress conditions according to study on wheat seeds (Farooq *et al*., 2008).
6. **Reduced Seedling Establishment Time:**
   - When seedlings are pretreated, they can establish more quickly and effectively, which is especially advantageous during short growth seasons. According to a study on sunflower seeds, hydropriming sped up the sprouting of seedlings (Tabatabaie & Nazari, 2011).

7. **Increased Crop Yield:**

- Higher crop yields can be attributed to pretreatment-induced improvements in germination and seedling vigor. After priming with calcium chloride, a research on maize seedlings revealed an increase in yield. (Hameed et al., 2013).

II. CONCLUSION

A crucial method in contemporary agriculture to improve crop productivity and output is seed pretreatment. Physical, chemical and Biological pretreatments are the techniques that are used to maximize seed germination maintain consistency and promote the health of the seedlings. Further enhancing plant resistance to diseases and advancing sustainable agriculture methods is the application of biocontrol agents through seed treatment. In particular, physical techniques like heat treatment and scarification along with chemical treatment like priming and acid pretreatment play a major role in triggering germination quickly and reducing the effects of environmental stresses. Additionally, the use of helpful microbes in symbiotic seed treatment is an example of a sustainable methods that improves plant stress tolerance. Seed pretreatment is unique in that it has the ability to speed up seedling growth despite the obstacles facing global agriculture.

III. REFERENCES

[1] Aladjadjiyan, A. (2012). Physical factors for plant growth stimulation improve food quality. Food production-approaches, challenges and tasks, 270.

[2] Anaytullah, B. B., & Bose, B. (2007). Nitrate-hardened seeds increase germination, amylase activity and proline content in wheat seedlings at low temperature. PhysiolMolBiol Plants, 13, 199-207.

[3] Ashraf, M., & Foolad, M. R. (2005). Pre-sowing seed treatment—A shotgun approach to improve germination, plant growth, and crop yield under saline and non-saline conditions. Advances in agronomy, 88, 223-271.

[4] Ashraf, M., &Rauf, H. (2001).Inducing salt tolerance in maize (Zea mays L.) through seed priming with chloride salts: Growth and ion transport at early growth stages.ActaPhysiologiaePlantarum, 23, 407-414.

[5] Bandana Bose, B. B., & Mishra, T. (2001). Effect of seed-soaking with Mg-salts on water uptake efficiency of germinating seeds of mustard.

[6] Bandana Bose, B. B., & Pandey, M. K. (2003). Effect of nitrate presoaking of okra (Abelmoschusesculentus L.) seeds on growth and nitrate assimilation of seedlings.

[7] Basra, S. M. A., Zia, M. N., Mehmood, T., Afzal, I., &Khaliq, A. (2002).Comparison of different invigoration techniques in wheat (Triticumaestivum L.) seeds.Pakistan Journal of Arid Agriculture (Pakistan), 5(2).

[8] Bhanuprakash, K., & Yogeesha, H. S. (2016). Seed priming for abiotic stress tolerance: an overview. Abiotic stress physiology of horticultural crops, 103-117.

[9] Bose, B., & Mishra, T. (1999). Influence of pre-sowing soaking treatment in Brassica juncea seeds with Mg-salts on growth, nitrate reductase activity, total protein content and yield responses. Physiology and Molecular Biology of Plants, 5, 83-88.

[10] Bose, B., Srivastava, H. S., &Mathur, S. N. (1982).Effect of some nitrogenous salts on nitrogen transfer and protease activity in germinating Zea mays L. seeds.Biologiaplantarum, 24, 89-95.

[11] Bradford, K. J. (1986). Manipulation of seed water relations via osmotic priming to improve germination under stress conditions. HortScience, 21(5), 1105-1112.

[12] Bruggink, G. T. (2005). Flower seed priming, pregermination, pelleting and coating. In Flower seeds: biology and technology (pp. 249-262). Wallingford UK: CABI Publishing.

[13] Cardarelli, M., Woo, S. L., Rouphael, Y., & Colla, G. (2022). Seed treatments with microorganisms can have a biostimulant effect by influencing germination and seedling growth of crops. Plants, 11(3), 259.

[14] Catalan, L. A., & Macchiaveloli, R. E. (1991). Improving germination in Prosopis flexuosa DC and P. alba Griseb. with hot water treatments and scarification. Seed Science and Technology, 19(2), 253-262.

[15] Chakraborti, S., Bera, K., Sadhukhan, S., & Dutta, P. (2022). Bio-priming of seeds: Plant stress management and its underlying cellular, biochemical and molecular mechanisms. Plant Stress, 3, 100052.

[16] Ersin, C. A. N., ÇELİKTAŞ, N., Hatipoğlu, R., & Süleyman, A. V. C. I. (2009). Breaking seed dormancy of some annual Medicago and Trifolium species by different treatments. Turkish Journal of Field Crops, 14(2), 72-78.

[17] Farkas, J., &Mohácsi-Farkas, C. (2011).History and future of food irradiation. Trends in Food Science & Technology, 22(2-3), 121-126.

[18] Farooq, M., Basra, S. M. A., Wahid, A., Cheema, Z. A., Cheema, M. A., & Khaliq, A. (2008). Physiological role of exogenously applied glycinebetaine to improve drought tolerance in fine grain aromatic rice (Oryza sativa L.). Journal of Agronomy and Crop Science, 194(5), 325-333.

[19] Farooq, M., Wahid, A., Kobayashi, N. S. M. A., Fujita, D. B. S. M. A., & Basra, S. M. A. (2009). Plant drought stress: effects, mechanisms and management. Sustainable agriculture, 153-188.

[20] Gill, S. S., &Tuteja, N. (2010).Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants.Plant physiology and biochemistry, 48(12), 909-930.

[21] Górnik, K., Sas-Paszt, L., Seliga, Ł., Pluta, S., Derkowska, E., Głuszek, S., ... & Mosa, W. F. (2023). The Effect of Different Stratification and Scarification Treatments on Breaking the Dormancy of Saskatoon Berry Seeds. Agronomy, 13(2), 520.

[22] Govindaraj, M., Masilamani, P., Albert, V. A., & Bhaskaran, M. (2017). Effect of physical seed treatment on yield and quality of crops: a review.

[23] Gurav, R., Tang, J., & Jadhav, J. (2017). Novel chitinase producer Bacillus pumilus RST25 isolated from the shellfish processing industry revealed antifungal potential against phyto-pathogens. International Biodeterioration & Biodegradation, 125, 228-234.

[24] Hameed, A., Iqbal, N., Zafar, Z.U., Shahid, M., 2013. Seed priming with CaCl2 improves the stand establishment, yield and quality of late sown wheat (Triticum aestivum L.). Soil & Environment, 32(2), 98-104.

[25] Harrington, G. T. (1916). Agricultural value of impermeable seeds.

[26] Hasanuzzaman, M., & Fotopoulos, V. (2019).Priming and pretreatment of seeds and seedlings. Singapore: Springer Singapore.

[27] Heydecker, W., & Coolbear, P. (1977). Seed treatments for improved performance-survey and attempted prognosis.

[28] Iqbal, M., & Ashraf, M. (2006, January). Wheat seed priming in relation to salt tolerance: growth, yield and levels of free salicylic acid and polyamines. In AnnalesBotaniciFennici (pp. 250-259).Finnish Zoological and Botanical Publishing Board.

[29] Jambhulkar, P. P., & Sharma, P. (2013).Promotion of rice seedling growth characteristics by development and use of bioformulation of Pseudomonas fluorescens. Indian J. Agric. Sci, 83, 136-142.

[30] Jisha, K. C., Vijayakumari, K., & Puthur, J. T. (2013). Seed priming for abiotic stress tolerance: an overview. Acta Physiologiae Plantarum, 35, 1381-1396.

[31] Jogaiah, S. (Ed.). (2020). Biocontrol Agents and Secondary Metabolites: Applications and Immunization for Plant Growth and Protection. Woodhead Publishing.

[32] Kaya, M. D., Okçu, G., Atak, M., Cıkılı, Y., & Kolsarıcı, Ö. (2006). Seed treatments to overcome salt and drought stress during germination in sunflower (Helianthus annuus L.). European journal of agronomy, 24(4), 291-295.

[33] Khasanov, E., Khamaletdinov, R., Mudarisov, S., Shirokov, D., & Akhunov, R. (2020). Optimization parameters of the spiral mixing chamber of the device for pre-sowing seed treatment with biological preparations. Computers and electronics in agriculture, 173, 105437.

[34] Kildisheva, O. A., Erickson, T. E., Madsen, M. D., Dixon, K. W., & Merritt, D. J. (2019). Seed germination and dormancy traits of forbs and shrubs important for restoration of North American dryland ecosystems. Plant Biology, 21(3), 458-469.

[35] Kim, M., Shim, C., Lee, J., & Wangchuk, C. (2022). Hot water treatment as seed disinfection techniques for organic and eco-friendly environmental agricultural crop cultivation. Agriculture, 12(8), 1081.

[36] Kimura, E., & Islam, M. A. (2012). Seed scarification methods and their use in forage legumes. Research Journal of Seed Science, 5(2), 38-50.

[37] Lamichhane, J. R., Corrales, D. C., & Soltani, E. (2022). Biological seed treatments promote crop establishment and yield: a global meta-analysis. Agronomy for Sustainable Development, 42(3), 45.

[38] Liberatore, C. M., Mattion, G., Rodolfi, M., Ganino, T., Fabbri, A., & Chiancone, B. (2018). Chemical and physical pre-treatments to improve in vitro seed germination of Humulus lupulus L., cv. Columbus. Scientia horticulturae, 235, 86-94.

[39] Lucas, J. A., Hawkins, N. J., & Fraaije, B. A. (2015). The evolution of fungicide resistance. Advances in applied microbiology, 90, 29-92.

[40] Lute, A. M. (1927). Alfalfa seed made permeable by heat. Science, 65(1676), 166-166.

[41] Mandal, A. K., &Basu, R. N. (1984).Response of different wheat cultivars to hydration-dehydration treatment for the maintenance of vigour, viability and productivity.

[42] Mohammadi, G. R. (2009). The effect of seed priming on plant traits of late-spring seeded soybean (Glycine max L.). American-Eurasian Journal of Agricultural and Environmental Science, 5(3), 322-326.

[43] Munir, H., Qamer, A., Javed, H., Shahbaz, M., under salt stress. International Rehman, H.U., 2019. Seed priming improves germination and seedling growth of chickpea (Cicer arietinum L.) Journal of Agriculture and Biology, 21(6), 1407-1414.

[44] Paparella, S., Araújo, S. S., Rossi, G., Wijayasinghe, M. A. L. A. K. A., Carbonera, D., & Balestrazzi, A. (2015). Seed priming: state of the art and new perspectives. Plant cell reports, 34, 1281-1293.

[45] Paravar, A., Piri, R., Balouchi, H., & Ma, Y. (2023). Microbial seed coating: An attractive tool for sustainable agriculture. Biotechnology Reports, 37, e00781

[46] Patanè, C., & Gresta, F. (2006). Germination of Astragalus hamosus and Medicago orbicularis as affected by seed-coat dormancy breaking techniques. Journal of Arid Environments, 67(1), 165-173.

[47] Pedrini, S., Balestrazzi, A., Madsen, M. D., Bhalsing, K., Hardegree, S. P., Dixon, K. W., & Kildisheva, O. A. (2020). Seed enhancement: getting seeds restoration-ready. Restoration Ecology, 28, S266-S275.

[48] Priyadharshini, R., & Lekha, K. (2021). Effect of scarification methods on different forest seeds. International Journal of Environment, Agriculture and Biotechnology, 6, 3.

[49] Puppala, N., & Fowler, J. L. (2003).Lesquerella seed pretreatment to improve germination. Industrial Crops and Products, 17(1), 61-69.

[50] Rincker, C. M. (1954). Effect of heat on impermeable seeds of Alfalfa, Sweet Clover, and Red Clover.

[51] Rodriguez, R. J., Henson, J., Van Volkenburgh, E., Hoy, M., Wright, L., Beckwith, F., ... & Redman, R. S. (2008). Stress tolerance in plants via habitat-adapted symbiosis. The ISME journal, 2(4), 404-416.

[52] Rodriguez, R. J., White Jr, J. F., Arnold, A. E., & Redman, A. R. A. (2009). Fungal endophytes: diversity and functional roles. New phytologist, 182(2), 314-330.

[53] Rutar, R., Stjepanovic, M., Popovic, S., Bukvic, Z., & Pacek, D. (2001). Effect of temperature on germination and hard alfalfa seed. Ciheam, 2, 137-139.

[54] Salim Azad, M., Zedan-Al-Musa, M., & Abdul Matin, M. (2010). Effects of pre-sowing treatments on seed germination of Melia azedarach. Journal of Forestry Research, 21, 193-196.

[55] Sarabi, B., Bolandnazar, S., Ghaderi, N., 2012. The effect of PEG and KNO3 on germination and seed reserve utilization in tomato (Lycopersicon esculentum Mill.) seeds under osmotic stress. International Journal of Agriculture and Biology, 14(3), 463-468.

[56] Siddique, A., & Kumar, P. (2018).Physiological and biochemical basis of pre-sowing soaking seed treatment-an overview. Plant Archives, 18(2), 1933-1937.

[57] Sindhu, R., Binod, P., & Pandey, A. (2016). Biological pretreatment of lignocellulosic biomass–An overview. Bioresource technology, 199, 76-82.

[58] Staker, E. V. (1925). Effect of dry heat on alfalfa seed and its adulterants. Agronomy journal, 17(1).

[59] Stewart, G. (1926). Effect of color of seed, of scarification, and of dry heat on the germination of alfalfa seed and of some of its impurities. Agronomy journal, 18(9).

[60] Tabatabaie, S.J., Nazari, J., 2011. The effect of hydropriming on germination characteristics and seedling emergence of sunflower (Helianthus annuus L.) under low temperatures. Journal of Food, Agriculture and Environment, 9(2), 598-602

[61] Taylor, A. G., Allen, P. S., Bennett, M. A., Bradford, K. J., Burris, J. S., & Misra, M. K. (1998). Seed enhancements. Seed science research, 8(2), 245-256.

[62] Uzun, F., & Aydin, I. (2004). Improving germination rate of Medicago and Trifolium species. Asian Journal of Plant Sciences, 3(6), 714-717.

[63] Wackett, L. P. (2020). Microbial seed treatments: An annotated selection of World Wide Web sites relevant to the topics in microbial biotechnology. Microbial biotechnology, 13(1), 299.

[64] Weissmann, E. A., Raja, K., Gupta, A., Patel, M., & Buehler, A. (2023). Seed Quality Enhancement. Malavika Dadlani, 391.

[65] https://images.app.goo.gl/kK9xZW6Zr9XHdFLV6

[66] https://images.app.goo.gl/HFe7XTLRuVxxDke6A

[67] https://onlinelibrary.wiley.com/cms/asset/fcbc0c74-200e-44d7-a4c3-af53e1f31097/rec13184-fig-0001-m.jpg

[68] https://www.sciencedirect.com/science/article/abs/pii/S0304423818301614

[69] https://apps.worldagroforestry.org/Units/Library/Books/Book%2006/images/10.9_pre_1.jpg