ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2716-6678 (Online)
CODEN: FAMOCP

Food & Agribusiness Management (FABM)

DOI: http://doi.org/10.26480/fabm.02.2023.77.81

CrossMark

RESEARCH ARTICLE

EFFECT OF DIFFERENT SEED PRIMING METHODS ON RICE (*Oryza sativa* L.) CV SUKKHA DHAN-3

Biraj Poudel*, Aakash Pangeni, Ankit Baral , Archana Bhatt, Apeksha Neupane , Sushanta Poudel

Institute of Agriculture and Animal Science, Tribhuvan University, Nepal
****Corresponding Author Email: poudelbiraj85@gmail.com***

ARTICLE DETAILS

Article History:

Received 26 April 2023
Revised 29 May 2023
Accepted 02 July 2023
Available online 12 July 2023

ABSTRACT

Priming is control hydration of seeds in a solution of low osmotic potential to initiate germination to ensure uniform and efficient germination of seed. Erratic seed germination is a major problem of rice production that causes poor crop establishment, crops susceptible to abiotic stress, and insect, and disease infestation resulting in poor yield. Different seed priming methods can be a useful technology for farmers to solve this problem. To ascertain the impact of different seed priming methods an experiment was carried out in the Horticulture Lab of Campus of Live Sciences, Dang with 12 treatment combinations with 3 replications laid out in factorial Completely Randomized Design (CRD). The treatments entailed; hydro-priming in tap water, hydro-priming in distilled water, polyethylene glycol PEG 6000 (5%), Ascorbic acid (2%), KNO_3 (2%), Salicylic acid (2%), $ZnSO_4$ (5%), NaCl (5%), $MgCl_2$ (5%), $CaCl_2$ (2%), Gibberellin (300ppm) and No priming as Control. The seeds were soaked for 24 hours in treatments followed by 12 hours of drying. The Priming treatment with $ZnSO_4$ (5%) showed the most promising results for germination percentage (82%), root: shoot ratio (1.91), germination rate (5.47), germination energy (76.67) and seedling vigor. $ZnSO_4$ (5%) was followed by PEG 6000(5%), distilled water, and KNO_3 (2%). Beside this, root length (9.94cm) was found highest in PEG 6000(5%) followed by $ZnSO_4$ (5%), KNO_3 (2%), and distilled water. Shoot length (8.003cm), Speed of germination (90.38), and germination rate index (76.67) were highest in KNO_3 (2%). This study concludes that $ZnSO_4$ (5%) showed the best result among all treatments and all the priming treatments showed better performance except Salicylic acid (2%) and No priming (Control). The study concluded that besides Salicylic acid (2%), seed priming was found to be more effective than no priming and in enhancing seed performance by activating overall metabolic processes of seed.

KEYWORDS

Germination, Harmonal Priming, Production, Rice

1. INTRODUCTION

Priming is a controlled hydration treatment followed by redrying that enables metabolic activities to begin prior to radical emergence (Sivritepe et al. 2003; Sivritepe et al., 2005). Better seed quality is a prime need to meet the current standards of the agriculture market (Osburn and Schroth, 1989). Different priming methods like hydropriming, osmopriming, halopriming, and hormonal priming, are used to induce pre-germination changes (Goswami et al., 2013). Seeds that undergo priming exhibit higher germination rates, high levels of biotic and abiotic stress resistance, and improved crop yield (Paparella et al., 2015). Seed Priming is done to ensure uniform and efficient germination of seeds by enzyme activation and breaking of dormancy of seeds which will aid to boost crop stand, establishment, and production. A germination trails of 11 varieties of upland rice conducted by revealed that seed priming owed to early and synchronized emergence of seed (Harris and Jones, 1997).

Rice (*Oryza sativa* L. var. *Indica*) is the most important cereal crop in world agriculture as well as in Nepal. It is a major staple food for more than half of the world's population, especially in Southeast Asia, and the most important staple food crop of Nepal (Sharif, 2014). Erratic seed germination and crop establishment are major constraints on rice production (Bourgne et al., 2000). Accelerating and homogenizing the germination process is critical for optimal crop establishment, resource efficiency, and higher yields for which seed priming could play a vital role (Harris, 1996). Seed Priming is used commercially in recent days to boost seed vigor in terms of seed germination and stress tolerance potential (Anwar et al., 2020). According to a number of authors hormonal priming is known to reduce germination time, impart high seed vigor, and improved germination under stress (Sukjfto et al., 2020; Khan et al., 2020; Gnawali and Subedi, 2021). This simple, low-cost and low-risk technique can be a useful technology for farmers to boost production (Ibrahim, 2019).

Hence, this study is conducted to study the effect of hydro priming and hormonal priming on rice and identify the most promising and effective priming treatment that can be adopted by farmers.

2. MATERIAL AND METHODOLOGY

2.1 Description of Experimental Site

The research was carried out at the lab of the Institute of Agriculture and Animal Science (IAAS), Campus of Live Sciences, Tulsipur, Dang district of Nepal during the year 2021 from September 27 to October 11.

2.2 Seed Material

The main season drought-resistant Rice (Oryza sativa) variety called Sukkha-dhan 3 with a minimum of 80% Germination percentage, 98%

Quick Response Code	Access this article online	
	Website: www.fabm.org.my	DOI: 10.26480/fabm.02.2023.77.81

Cite the Article: Biraj Poudel, Aakash Pangeni, Ankit Baral, Archana Bhatt, Apeksha Neupane, Sushanta Poudel (2023). Effect Of Different Seed Priming Methods on Rice (Oryza sativa L.) Cv Sukkha Dhan-3. *Food & Agribusiness Management, 4(2): 77-81.*

physical and 97% physical purity having 125-day cropping period and high production capacity of 2.5 to 3.6 t/ha were used.

2.3 Sterilization

The germination chamber, Petri-plates, wash bottles, experimental trays and all other required tools were surface sterilized with 98% ethanol to avoid contamination.

2.4 Treatment Details

The experiment was conducted in Completely Randomized Design (CRD) with 12 treatments (table 1) and 3 replications.

Table 1: Different Priming Agents Used in The Experiment.

Treatment	Priming Agent
T1	Hydropriming (tap water)
T2	Hydropriming (distilled water)
T3	PEG 6000 (5%)
T4	Ascorbic Acid (2%)
T5	KNO_3(2%)
T6	Salicylic acid (2%)
T7	$ZnSO_4$(5%)
T8	NaCl (5%)
T9	$MgCl_2$(5%)
T10	$CaCl_2$(2%)
T11	Gibberellin(300ppm)
T12	No priming (Control)

2.5 Preparation of Priming Solution

All the priming solutions were prepared in 100 ml solution. The calculation of priming treatment was done using a formula given by Harvey (2000).

Weight-to-volume % (%w/v) = gm solute/100 ml solution

Parts per million (ppm) = mg of solute/liter of solution

2.6 Post Priming Operations

After 24 hours, the primed seeds were taken out and allowed to dry in Petri dish containing blotting paper for 12 hours until moisture absorbed by seeds was reduced to about its original weight. Out of 200 seeds primed 150 seeds were selected for each treatment.

2.7 Medium of Germination

Whatman filter paper was used as a substrate that covered the base of petri-plates uniformly. Uniform distribution of seeds was made linearly in sterile petri plates to test for germination. And following that, it was placed in the germinator for 7 hrs daylight at a temperature of 27^0C, with a relative humidity of 85%.

2.8 Data Collection Parameter

2.8.1 Imbibition Rate

The initial seed weight was measured by a weighing machine. Imbibition rate was taken by comparing the weight of the seeds soaked in every treatment with their initial seeds weight. Imbibition rate of seeds in every treatment was measured using formula given by (Khan, 2009).

$$\frac{\text{Final weight - Initial weight}}{\text{Initial weight}} \times 100\ \%$$

2.8.2 Initiation of Germination

The first germination was recorded in every 24-hour period. These data are recorded to calculate different germination and emergence test parameters.

2.8.3 Root Length, Shoot Length and Seedling Length.

The root length and shoot length of fifteen sample plants from each experimental unit was measured with the help of measuring scale at final day of experiment i.e., 12^{th} day. Seedling length was calculated by adding root length and shoot length. Root length and shoot length also helps to measure root to shoot ratio.

Seedling length = Root length + Shoot length

2.8.4 Fresh Weight and Dry Weight

The seedling weight of the same fifteen sample plants from each experimental unit were measured with the help of weighing machine and noted after that they were kept in hot air oven for 12hrs at 90°C (Bhardwaj et al., 2012). After 12 hrs they were taken out of oven and weighed again to obtain seedling dry weight.

2.8.5 Seed Germination Parameter

Different seed germination parameters were considered which includes.

- Germination percentage was calculated by using the following formula (Basnet et al., 2018)
  Germination (%) = $\frac{\text{Total Number of normal seedlings germinated}}{\text{Total number of seeds sown}} \times 100\ \%$
- Germination energy was calculated by using following formula; (Islam et al., 2012)
  Germination energy (GE) = $\frac{\text{Number of seeds germinated over day 3 or 5 or 7}}{\text{Total number of seeds sown}} \times 100\ \%$
- Germination rate was the average no. of seeds that germinate over 5 days (Sedghi et al., 2010)
  Germination rate = $\frac{\text{Number of seeds germinated over day 5}}{5}$
- Germination rate index (GRI) was calculated by following formula (Subedi et al., 2015)
  GRI= (G1/1) + (G2/2) + (G3/3) + ……. + (G12/12) +…..+ ($G_{n/}$n)

It means sum of no. of seed germinated on day 1 divided by 1, no of seed germinated on day 2 divided by 2 likewise no. of seed germinated over day 12 divided by 12 upto n days.

- Speed of germination was calculated by using formula; (Krishnasamy, 1990)
  Speed of germination = $\frac{\text{Number of seeds germinated over day 3}}{\text{Number of seeds germinated over day 7}} \times 100\ \%$
- Mean germination time was calculated by using formula; (Sedghi et al., 2010)
  MGT = $\frac{\Sigma\ FX}{\Sigma\ [(F1*1) + (F2*2) + (F3*3) + \ldots + (Fn*Xn)}$

Where, F= Total seed germinated in X = Total no. of days
F1 = Seed germinated in day 1, Fn = Seed germinated in day n, Xn = n days

- There are different formulas for calculating seedling vigor. In our experiment we calculated seedling vigor by using following formulas given by (Dhakal & Subedi, 2020; Gnawali & Subedi, 2021)

Seedling vigor I = $\frac{\text{Mean root length of sample plants}}{\text{Mean shoot length of sample plants}} \times 100\ \%$

Seedling vigor II = Seedling dry weight × Germination

2.9 Statistical Analysis

After collection of data from experiment, the tabulation of data was done in Microsoft Excel 2007. The mean value of data of different parameters was recorded in the study and was analyzed by R-STAT in the computer software. Data were subjected to Analysis of Variance (ANOVA) to evaluate the significance of the treatment effect. Means of each other within the parameters will be compared by Duncan's Multiple test (DMRT) 5% level of significance.

3. Result and Discussion

3.1 Germination Percentage (%)

Different type of seed–priming is found to improve seed germination in a number of studies (Srivastava et al. 2010). It ensures seedling proper emergence and growth by activating the metabolism prior to germination like activating DNA repair and antioxidant enzymes (Paparella et al., 2015). A more coordinated manner of germination, more vigorous seedling with higher resistance to abiotic stress is seed in primed seed compared to unprimed ones (Benincasa et al., 2016).

The result reveals that the germination percentage of different treatment is highly significant (P≤0.001) with the highest germination percentage of 82% in the case of $ZnSO_4$ (5%) followed by 80.67% in PEG 600 (5%), 80% in KNO_3 (2%) and 78.67% in $CaCl_2$ (2%) least 6% in case of Salicylic acid (2%) and 70% in non-primed (control) treatment respectively.

Seed priming with inorganic salts like $CaCl_2$, KNO_3, $ZnSO_4$ improves the antioxidant enzyme activities involved in seed germination and alters the mobilization of organic substances to different parts of the embryo. When

compared to hydro-primed seeds, seed priming with $ZnSO_4$ resulted in greater catalase, superoxide dismutase, and peroxidase activity (Aboutalebian & Nazari, 2017). Research conducted by Foti et al (2008) found 87% germination in maize seeds primed with ZnSo4 whereas the unprimed seed showed 57% germination percentage. Researcher concluded that the significant ($P<0.05$) increase in germination percentage could be from the osmotic solution that lowered the osmotic potential in seed environment during priming. This resulted in faster imbibition that advanced the germination process.

3.2 Root Length (RL), Shoot Length (SL)And Root: Shoot Ratio (R:S Ratio)

Significant improvement in radicle and plumule length may be attributed to earlier germination induced by primed over un-primed seeds, which resulted in vigorous seedlings with more root and shoot length than the seedlings from unprimed seeds (Farooq et al., 2005). Therefore, seed priming boosts the imbibition and metabolic processes resulting in enhanced seed germination, germination uniformity, seedling growth and development followed by increased physiological parameters like fresh weight, dry weight, root length, and shoot length in both normal and stress conditions (Ansari et al., 2012).

The result reveals that the root length of different treatment is differ significantly, with the highest root length of 9.94 cm in PEG 600 (5%) followed by 9.65 cm in $ZnSO_4$ (5%), 9.623 cm in KNO_3 (2%) and 9.16 cm in distilled water, and least 0.94 cm, 8.34 cm, and 8.4 cm in case of Salicylic acid (2%), Ascorbic acid (2%) and non-primed (control) treatment respectively. Also shoot length of different treatment is highly significant with the highest shoot length observation of 9.9 cm in of KNO_3 (2%) followed by 6.57 cm in Gibberellin (300ppm) and least 0.46 cm and 5.13 cm in case of Salicylic acid (2%) and $ZnSO_4$ (5%) treatment, respectively. And Root: Shoot ratio was non-significant with highest ratio of 1.9 in $ZnSO_4$ (5%) and lowest of 1.21 in KNO_3 (2%).

3.3 Germination Rate and Germination Rate Index (GRI)

The result revealed the highest Germination rate of 5.47 in $ZnSO_4$ (5%), followed by 5.38 in distilled water and least 0.38 and 4.5 in case of Salicylic acid (2%), and non-primed(control) treatment respectively. Similarly, GRI of different treatment is highly significant with the highest GRI of 69.76 in the case of KNO_3 (2%) followed by 69.07 in distilled water and least 4.48 and 46.99 in case of Salicylic acid (2%) and non-primed (control) treatment respectively. Many studies have reported that hydropriming of seeds improved the seed germination and seedling emergence of rice (Basra et al., 2005).

3.4 Germination Energy (GE)

Germination energy (GE) was found highly significant with the highest Germination energy of 76.67 in $ZnSO_4$ (5%), followed by 75.33, 74.67, 74 in distilled water, $CaCl_2$ (2%) and PEG 600 (5%) respectively and least 5.33 and 64 in case of Salicylic acid (2%), and non-primed (control) treatment respectively. Pigeon pea seeds treated with inorganic salt like $CaCl_2$ or $ZnSO_4$ showed improvements in soluble sugars, free amino acids, and proteins during germination under salinity stress (Verma & Srivastava, 1988). Studies have reported that Hydro priming, KNO_3 - 2% and PEG – 5% showed significantly higher GE than control and NaCl – 3.6%. However, no priming substances used brought significant alterations to GE when used in varied levels (Subedi et al., 2015).

3.5 Seedling Vigor

Seedling vigor is the indicator of seedling establishment and growth (Singhal & Bose, 2020). Analysis of variance has showed the significant effect on seedling vigor of primed/treated seeds. Highest vigor was observed in $ZnSO_4$ (5%), followed by PEG 600 (5%) and distilled water and least in case of Salicylic acid (2%), Gibberellin (300ppm), KNO_3 (2%) and No Priming (Control) treatment. Seed priming can break seed dormancy, curtail seedling emergence time, improve seedling vigor, and leads to better germination and growth of plants (Mondal et al., 2011).

3.6 Mean Germination Time (MGT)

MGT showed the rapidity of germination; hence, the lower the value of MGT, the earlier is the germination (Hasanuzzaman & Fotopoulos, 2019). MGT showed the rapidity of germination; hence, the lower the value of MGT, the earlier is the germination. The result shows that MGT of different treatment is non-significant and lowest is in Salicylic acid (2%), distilled water followed by $ZnSO_4$ (5%) and highest in case of $MgCl_2$ (2%) and PEG 600 (5%) treatment.

3.7 Fresh Weight and Dry Weight

The result shows that Fresh weight and Dry weight of sample plants of different treatment is highly significant with highest fresh weight of 1.27gm in NaCl (5%) followed by 1.26gm PEG 600 (5%) and lowest with no weight in Salicylic acid (2%) and No Priming (Control) treatment. Although, dry weight was found highest in no primed seed (Control). But, according to results of (Koirala et al., 2018) effect of different types of priming treatment on shoot length, fresh weight, dry weight of 20 days old seedling was statistically non-significant.

3.8 Seedling Length

The analysis of results obtained shows that seedling length of different treatment is highly significant, with highest seedling length of 17.63cm in KNO_3 (2%) followed by 16.21cm in PEG 600 (5%) and lowest of 1.4cm and 13.87cm in Salicylic acid (2%) and No Priming (Control) treatment respectively.

3.9 Speed of Germination

The data analysis showed that germination speed of different treatments was non-significant. The highest germination speed was recorded in KNO_3 (2%) and lowest in Salicylic acid (2%) and No Priming (Control) treatment. The result shows that germination speed of different treatments is non- significant with highest germination speed in KNO_3 (2%) and lowest in Salicylic acid (2%) and No Priming (Control) treatment. According to (Subedi et al., 2015) Hydro priming, KCl – 1%, KNO_3-2%, NaCl– 1.8%, PEG – 5% and $CaCl_2$ – 1% showed higher GS than control and NaCl – 3.6%. There was statistical similarity among varied doses of all chemicals except NaCl, where increase in salt concentration significantly reduced the GS.

Table 2: Effect of Different Seed Priming Method on Germination and Different Parameters of Rice.

Treatment	GP (%)	RL (Cm)	SL (Cm)	R:S ratio	GR	GRI	GE
Tap water	72^{bc}	8.5167^{a}	6.4167^{bc}	1.33667^{a}	4.9033^{abc}	63.693^{ab}	68.667^{abcd}
Distilled water	77.33^{abc}	9.16^{a}	5.7733^{bcd}	1.59^{a}	5.38^{ab}	69.07^{a}	75.33^{ab}
PEG 600 (5%)	80.67^{a}	9.94^{a}	6.27^{bc}	1.5867^{a}	5.1433^{abc}	64.1967^{ab}	74^{abcd}
Ascorbic acid (2%)	77.33^{abc}	8.34^{a}	6.006^{bcd}	1.39^{a}	5.24^{abc}	68.8467^{a}	73.33^{abcd}
KNO_3 (2%)	80^{a}	9.623^{a}	8.003^{a}	1.2133^{a}	5.28667^{abc}	69.7667^{a}	74^{abcd}
Salicylic acid (2%)	6^{d}	0.94^{b}	0.4667^{e}	1.2833^{a}	0.38^{d}	4.48^{e}	5.33^{e}
$ZnSO_4$ (5%)	82^{a}	9.65^{a}	5.13^{d}	1.9067^{a}	5.47667^{a}	64.23^{ab}	76.667^{a}
NaCl (5%)	72^{bc}	8.61^{a}	5.893^{bcd}	1.4667^{a}	4.6167^{c}	54.5467^{cd}	64.67^{cd}
$MgCl_2$ 2%)	76^{abc}	8.913^{a}	6.233^{bc}	1.44^{a}	4.667^{c}	58.7667^{bc}	65.33^{bcd}
$CaCl_2$ (2%)	78.67^{ab}	8.926^{a}	6.34^{bc}	1.41667^{a}	5.33^{abc}	66.6267^{ab}	74.67^{abc}
Giberellin (300ppm)	76^{abc}	8.53^{a}	6.576^{b}	1.2933^{a}	4.80667^{abc}	58.6033^{bc}	67.33^{abcd}
No Priming (Control)	70^{c}	8.4^{a}	5.456^{cd}	1.5633^{a}	4.573^{c}	46.9933^{d}	64^{d}
Grand mean	70.67	8.2975	5.713889	1.45722	4.650278	57.485	65.11
SEM (±)	22.44	0.969244	0.3564167	0.190425	0.20422	24.57434	40
LSD (5%)	7.98357	1.65905	1.006055	0.73568	0.7615426	8.35792	10.6593
CV, %	6.70409	11.86505	10.44834	29.94582	9.717904	8.623556	9.7134
F test	***	***	***	***	***	***	***

Table 3: Effect of Different Seed Priming Methods on Different Parameters of Rice.

Treatment	Mean germination time (MGT)	Seedling vigor – I	Seedling vigor – II	Live weight	Dry weight	Speed of germination
Tap water	0.2367^{a}	96.133^{d}	17.453^{b}	1.09^{b}	0.243^{abc}	82.68^{ab}
Distilled water	0.23^{ab}	123.08^{bc}	19.040^{ab}	1.21^{ab}	0.246^{ab}	85.29^{a}
PEG 600 (5%)	0.26^{a}	127.93^{b}	17.50^{b}	1.26^{a}	0.216^{c}	76.71^{ab}
Ascorbic acid (2%)	0.24^{a}	107.67^{bcd}	17.52^{b}	1.18^{ab}	0.226^{abc}	81.83^{ab}
KNO_3 (2%)	0.2467^{a}	96.82^{cd}	17.61^{ab}	1.21^{ab}	0.22^{bc}	90.38^{a}
Salicylic acid (2%)	0.16^{b}	13.093^{e}	0^{c}	0^{d}	0^{d}	55.55^{b}
$ZnSO_4$ (5%)	0.2467^{a}	155.1^{a}	20.21^{a}	1.13^{ab}	0.24^{ab}	79.82^{ab}
NaCl (5%)	0.2567^{a}	105.96^{bcd}	17.08^{b}	1.27^{a}	0.23^{abc}	72.32^{ab}
$MgCl_2$ (2%)	0.2667^{a}	110.04^{bcd}	18.47^{ab}	1.21^{ab}	0.243^{abc}	88.93^{a}
$CaCl_2$ (2%)	0.24^{a}	110.44^{bcd}	17.04^{b}	1.20^{ab}	0.216^{c}	84.07^{a}
Giberellin (300ppm)	0.253^{a}	98.34^{cd}	18^{ab}	1.16^{ab}	0.236^{abc}	84.45^{a}
No Priming (Control)	0.2567^{a}	108.95^{bcd}	17.49^{b}	1.06^{b}	0.25^{a}	62.59^{ab}
Grand mean	0.2413889	104.4642	16.452	1.084	0.215278	78.72
SEM (±)	0.001869	247.845	2.537	0.0095	0.0003	78.41
LSD (5%)	0.0728	26.52973	2.684197	0.16447	0.02918	28.1183
CV, %	17.91	15.07	9.681	8.99	8.0456	21.196
F test		***	***	***	***	

Means followed by the same letter(s) in a column are not statistically different at 5%level of significance (P≤0.05); SEM: Standard Error of Mean; CV: Coefficient of Variation; LSD: Least significant difference; ***: Significant at 0.001 level of significance.

4. Conclusion

This study concludes as seed priming was found to improve seed performance at early stages of plant and is effective enhancing seed performance by activating overall metabolic processes of seed which could help to increase final crop yield by ensuring better stand establishment. All other treatments except Salicylic acid (2%) and No priming (Control) performed better in the experiment which suggest seed priming with different agents on right concentration can enhance seed performance than non-primed seeds. Hence, treatment of seeds with $ZnSO_4$ (5%) seems to be a more effective technique for improving the performance of *sukkha dhan-3* variety of rice.

References

Aboutalebian, M. A., & Nazari, S. 2017. Seedling emergence and activity of some antioxidant enzymes of canola (Brassica napus) can be increased by seed priming. The Journal of Agricultural Science, 155(10), 1541-1552. DOI: https://doi.org/10.1017/S0021859617000661

Ansari, O., Choghazardi, H. R., Sharif Zadeh, F., & Nazarli, H. 2012. Seed reserve utilization and seedling growth of treated seeds of mountain rye (Secale montanum) as affected by drought stress. Cercetări Agronomice în Moldova, 45(2), 43-48.

Anwar, A., Xianchang, Y. U., & Yansu, L. I. 2020. Seed priming as a promising technique to improve growth, chlorophyll, photosynthesis and nutrient contents in cucumber seedlings. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 48(1), 116-127.

Basnet, M., Shakya, S. M., Shrestha, S. M., & Mishra, K. 2015. Effect of nitrogen and off-season bulb size on onion seed production. Journal of the Institute of Agriculture and Animal Science, 41-46. DOI: https://doi.org/10.3126/jiaas.v33i0.20681

Basra, S. M. A., Farooq, M., Tabassum, R., & Ahmad, N. 2005. Physiological and biochemical aspects of seed vigor enhancement treatments in fine rice. Seed Sci. Technol, 33, 623-628.

Bhardwaj J, Anand A, Nagarajan S. 2012. Biochemical and biophysical changes associated with magnetopriming in germinating cucumber seeds. Plant Physiology and Biochemistry, 57: 67–73. https://doi.org/10.1016/j.plaphy.2012.05.008

Bourgne, S., Job, C., & Job, D. 2000. Sugarbeet seed priming: solubilization of the basic subunit of 11-S globulin in individual seeds. Seed Science Research, 10(2), 153-161. doi:10.1017/S0960258500000167

Dhakal, P., & Subedi, R. 2020. Influence of Mannitol Priming on Maize Seeds Under Induced Water Stress. Journal of Agriculture and Crops, 6(3), 27-31. DOI: 10.32861/jac.63.27.31

Farooq, M., Basra, S. M. A., Ahmad, N., & Hafeez, K. 2005. Thermal hardening: a new seed vigor enhancement tool in rice. Journal of Integrative Plant Biology, 47(2), 187-193. DOI: https://doi.org/10.1111/j.1744-7909.2005.00031.x

Foti, R., Abureni, K., Tigere, A., Gotosa, J., & Gere, J. 2008. The efficacy of different seed priming osmotica on the establishment of maize (Zea mays L.) caryopses. Journal of Arid Environments, 72(6), 1127-1130.

Gnawali, A., & Subedi, R. 2021. Gibberellic Acid Priming Enhances Maize Seed Germination Under Low Water Potential. Indonesian Journal of Agricultural Science, 22(1), 17-26. DOI: http//dx.doi.org/10.21082/ijas.v.22.n1.2021.p.17–26

Goswami, A., Banerjee, R., & Raha, S. 2013. Drought resistance in rice seedlings conferred by seed priming: role of the anti-oxidant defense mechanisms. Protoplasma, 250, 1115-1129.

Harris, D. 1996. The effects of manure, genotype, seed priming, depth and date of sowing on the emergence and early growth of Sorghum bicolor (L.) Moench in semi-arid Botswana. Soil and Tillage Research, 40(1-2), 73-88.

Harvey, D. 2000. Modern analytical chemistry (Vol. 1). New York: McGraw-Hill.

Hasanuzzaman, M., & Fotopoulos, V. 2019. Priming and pretreatment of seeds and seedlings. Springer Singapore.

Ibrahim, E. A. A. 2019. Fundamental processes involved in seed priming. In Priming and Pretreatment of Seeds and Seedlings (pp. 63-115). Springer, Singapore. DOI: 10.1007/978-981-13-8625-1_4

Islam, R., Mukherjee, A., & Hossin, M. 2012. Effect of osmopriming on rice seed germination and seedling growth. Journal of the Bangladesh Agricultural University, 10(452-2016-35564), 15-20. DOI: 10.22004/ag.econ.209260

Khan, H. A., Ayub, C. M., Pervez, M. A., Bilal, R. M., Shahid, M. A., & Ziaf, K. 2009. Effect of seed priming with NaCl on salinity tolerance of hot pepper (Capsicum annuum L.) at seedling stage. Soil and Environment, 28(1), 81-87.

Khan, M. N., Khan, Z., Luo, T., Liu, J., Rizwan, M., Zhang, J., & Hu, L. 2020. Seed priming with gibberellic acid and melatonin in rapeseed: Consequences for improving yield and seed quality under drought and non-stress conditions. Industrial Crops and Products, 156, 112850.

Koirala, N., Poudel, D., Bohara, G. P., Ghimire, N. P., & Devkota, A. R. 2019. Effect of seed priming on germination, emergence and seedling growth of spring rice (Oryza sativa L.) cv. Hardinath-1. Azarian Journal of Agriculture, 6(1), 7-12. DOI:10.29252/azarinj.002

Ministry of Agriculture and Livestock Department. 2018. Retrieved from http://www. moad.gov.np/en

Mondal, S., Vijai, P., & Bose, B. 2011. Role of seed hardening in rice variety Swarna (MTU 7029). Research Journal of Seed Science, 4(3), 157-165. DOI: 10.3923/rjss.2021.157.165

Osburn, R. M., & Schroth, M. N. 1988. Effect of osmopriming sugar beet seed on exudation and subsequent damping-off caused by Pythium ultimum. Phytopathology, 78(9), 1246-1250.

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, 1281-1293.

Sedghi, M., Nemati, A., & Esmaielpour, B. 2010. Effect of seed priming on germination and seedling growth of two medicinal plants under salinity. Emirates Journal of Food and Agriculture, 130-139. DOI https://doi.org/10.9755/ejfa.v22i2.4900

Sharif, M. K., Butt, M. S., Anjum, F. M., & Khan, S. H. 2014. Rice bran: a novel functional ingredient. Critical reviews in food science and nutrition, 54(6), 807-816.

Singhal, R. K., & Bose, B. 2020. Wheat seedlings as affected by Mg (NO3) 2 and ZnSO4 priming treatments. World Scientific News, (144), 13-29.

Sivritepe, N., Sivritepe, H. O., & Eris, A. 2003. The effects of NaCl priming on salt tolerance in melon seedlings grown under saline conditions. Scientia horticulturae, 97(3-4), 229-237.

Srivastava, A. K., Lokhande, V. H., Patade, V. Y., Suprasanna, P., Sjahril, R., & D'Souza, S. F. 2010. Comparative evaluation of hydro-, chemo-, and hormonal-priming methods for imparting salt and PEG stress tolerance in Indian mustard (Brassica juncea L.). Acta Physiologiae Plantarum, 32, 1135-1144.

Subedi, R., Maharjan, B. K., & Adhikari, R. 2015. Effect of different priming methods in rice (Oryza sativa). Journal of Agriculture and Environment, 16, 152-160. DOI: https://doi.org/10.3126/aej.v16i0.19848

Sukifto, R., Nulit, R., Kong, Y. C., Sidek, N., Mahadi, S. N., Mustafa, N., & Razak, R. A. 2020. Enhancing germination and early seedling growth of Malaysian indica rice (Oryza sativa L.) using hormonal priming with gibberellic acid (GA3). AIMS Agriculture and Food, 5(4), 649-665.

Verma, J., & Srivastava, A. K. 1998. Physiological basis of salt stress resistance in pigeon pea (Cajanus cajan L.)-II. Pre-sowing seed soaking treatment in regulating early seedling metabolism during seed germination. Plant Physiology and Biochemistry-New Delhi, 25, 89-94.