

1
2
3
4
5
6
7
8
9
10

Upholding seed quality with mid-storage invigoration treatments in rice (*Oryza sativa* L.)

ABSTRACT

The groundbreaking research investigated the impact of mid-storage invigoration treatments on seed quality parameters in rice. The experimental design used in the study was Completely Randomized Design with three replications. The experiment was conducted at the Regional Agricultural Research Station, Pattambi, Kerala Agricultural University. The objective of the study was to understand the effect of mid-storage invigoration treatments on seed storage under ambient conditions. An experiment was conducted to evaluate the effect of ten different treatments on the quality of seeds, specifically the germination percentage, seed vigour index I, electrical conductivity, and mean germination time. The treatments tested were control- untreated seeds, hydration and dehydration treatment 1l/kg, ascorbic acid 10g/kg, calcium chloride 10g/kg, albizzia leaf powder 2g/kg, neem cake 5g/kg, neem leaf powder 2g/kg, neem oil 2ml/kg, red chilli powder 1g/kg and vayambu leaf powder 2g/kg. The rice variety Jyothi was used. Results showed that all the mid-storage invigoration treatments significantly improved the germination rate of the treated seeds when compared to the control under ambient storage conditions. Neem oil when used showed the highest germination percentage after five months of storage. In the last month of storage, neem oil showed a significantly higher vigour index which was comparable to hydration dehydration treatment and red chilli powder. Germination percentage and seedling vigour index I are positively associated with seed quality. Electrical conductivity and mean germination time are negatively correlated with seed quality. The least electrical conductivity was recorded in hydration dehydration treatment. Neem oil and hydration dehydration treatment had low mean germination time. Based on the research conducted, neem oil, hydration-dehydration, and red chili powder are the most effective treatments for improving the longevity of seeds. These eco-friendly and cost-effective mid-storage invigoration seed treatments can help farmers enhance the quality of their seeds and extend their storage life.

11
12
13
14
15
16
17
18
19

Keywords: Midstorage invigoration, germination %, seedling vigour index I, electrical conductivity, Mean germination time.

1. INTRODUCTION (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

Rice production is anticipated to increase globally, stressing its importance in tackling food security issues [1]. The availability of high-quality seeds is critical to ensuring a bountiful harvest and sustainable agriculture. High-quality seeds lead to better germination rates,

20 resulting in healthier seedlings. Improved germination directly translates to higher yield
21 potential for paddy crops. Farmers who use viable seeds can expect better productivity
22 compared to those using subpar seeds. It is essential to emphasize the economic
23 significance of viable paddy seeds for small-scale farmers and support their efforts to obtain
24 the best possible seeds for their farming operations [2]. Therefore, it is imperative to ensure
25 that farmers have access to high-quality seeds and that they are stored and distributed
26 correctly. With the right seeds, farmers can improve their yields and income, contributing to
27 food security and economic development [3].

28 Rice cultivation by small-scale farmers plays a significant role as it ensures food security,
29 provides essential nutrients and generates income. The practice of preserving, utilizing, and
30 exchanging viable seeds is prevalent for subsistence among these farmers. Prolonged seed
31 storage significantly enhances this essential activity, ensuring a sustainable supply of seeds
32 for subsequent seasons. Small-scale farmers in Kerala face the challenge of preserving
33 paddy seeds for extended periods to ensure successful crop cycles. Farmers can consider
34 storing seeds in ambient storage, which is a cool, dry, and well-ventilated room that can
35 preserve seed quality for up to six months. Long-term storage plays a critical role in
36 maintaining seed quality and minimizing the need for frequent seed purchases. As the seed
37 is hygroscopic in nature, its quality is being affected due to variations in the environmental
38 conditions viz., relative humidity, temperature, moisture content, gaseous exchange,
39 packaging material etc [4]. A practical solution is needed to tackle this problem and ensure
40 the quality of the seeds.

41 Simple and affordable technologies are more suitable for small scale farmers involved in
42 seed storage to ensure viable seed input for succeeding season. Adapting mid-storage
43 invigoration treatments is a highly effective solution that can help maximize the quality and
44 longevity of valuable seed assets. The cost-effective treatments are effective choices for this
45 purpose. This act as a cornerstone in preservation and protection of upgraded seeds in seed
46 storage. Several studies have demonstrated the efficacy of these mid-storage treatments for
47 paddy seeds. A study [5] found that neem oil treatment significantly improved the seed
48 quality parameters of paddy seeds during storage. Similarly, it was reported [6] that
49 hydration and dehydration treatment helped in maintaining the moisture content of paddy
50 seeds, preventing their deterioration during storage. Additionally, it was demonstrated [7] the
51 effectiveness of red chili powder in controlling pests and fungal growth in stored paddy
52 seeds.

53 During storage, midstorage invigoration treatments changes induce changes in seed quality
54 parameters such as germination percentage, seedling vigor index I, mean germination time
55 and electrical conductivity which plays a vital role in preserving seed viability. Germination
56 percentage measures the proportion of viable seeds in a given sample, while seed vigor
57 index indicates the overall seed quality by measuring the seedling growth rate and vigor.
58 These parameters are useful for predicting seed longevity and quality, as well as for
59 identifying seed lots that require immediate use or disposal. Several studies have shown the
60 importance of seed quality parameters during seed storage. In a study [8], it was found that
61 the germination percentage of seeds decreased significantly with increasing storage time,
62 indicating a decline in seed viability. Similarly, it was reported [9] that seed vigor index was a
63 better predictor of seedling emergence than germination percentage, highlighting its
64 importance in assessing seed quality during storage. Seed viability and vigor decrease over
65 time during storage, leading to reduced seed germination and establishment. These findings
66 emphasize the need for careful monitoring of seed quality parameters during seed storage to
67 maintain seed viability and ensure successful crop production.

68 Other important factors that affect seed viability during storage are electrical conductivity and
69 mean germination time. Electrical conductivity is an indicator of seed deterioration and is
70 associated with the leakage of electrolytes from damaged cells. High electrical conductivity
71 values indicate poor seed quality while low values are indicative of good quality seeds [10].
72 The electrical conductivity of seeds increases with damage to the cell membranes and loss

73 of membrane integrity, leading to reduced seed quality and viability. Therefore, reducing
74 electrical conductivity is essential to ensure long-term storage and conservation of plant
75 genetic resources. Several studies have highlighted the importance of reducing electrical
76 conductivity and mean germination time during seed storage. A study [11] found that
77 reducing electrical conductivity during storage improved seed quality and enhanced the
78 performance of seeds. Mean germination time, on the other hand, measures the average
79 time taken for seeds to germinate under optimal conditions, and is used as an indicator of
80 seed vigor. The longer the mean germination time, the lower the seed vigor and viability.
81 Therefore, a lower mean germination time is desirable to ensure high seed quality and long-
82 term storage [12].

83 Various compounds and techniques are used for seed treatments in midway through storage
84 to invigorate the seeds and are efficient in preserving high viability and vigour of seeds.
85 However, there is a need to identify cost effective and eco-friendly midstorage invigoration
86 treatments which are easily adoptable by small scale farmers. In this context this article
87 explores midstorage invigoration treatment interventions in paddy seed storage focusing on
88 the popular variety Jyothi. By investigating the efficacy of these treatments, the study aims to
89 provide insights into the most effective as well as farmer friendly treatments that enhance
90 seed quality and storage period contributing to higher seed production and productivity.

91 92 **2. MATERIAL AND METHODS**

93 **2.1 Experimental Design**

94 Ten treatments were applied to paddy seeds of the Jyothi variety at six months of age. Seed
95 quality parameters like germination percentage, seedling vigor index (I), electrical
96 conductivity, and mean germination time were measured before and after treatments at
97 monthly intervals. The observations were recorded until the seed germination rate dropped
98 to 80%. A Completely Randomized Design (CRD) was used for the analysis of seed quality
99 parameters. For every treatment, three replications were examined, with a quarter of a
100 kilogram of seeds per replication. After that, the seeds were placed in gunny bags and left to
101 ambient conditions. Experiment ran from October 2022 to March 2023, using seeds from
102 both treatments and control groups.

103 **2.2 Treatment variables**

104 Six months old Jyothi seeds, were subjected to ten mid-storage invigoration treatments.
105 These treatments included control-untreated seeds (T₁), hydration-dehydration
106 (1l/kg of seeds) (T₂), ascorbic acid (10g/kg of seeds) (T₃), calcium chloride (10g/kg of seeds)
107 (T₄), albizzia leaf powder (2g/kg of seeds) (T₅), neem cake (5g/kg of seeds) (T₆), neem leaf
108 powder (2g/kg of seeds) (T₇), neem oil (2ml/kg of seeds) (T₈), red chilli powder (1g/kg of
109 seeds) (T₉) and vayambu leaf powder (2g/kg of seeds) (T₁₀).

110 **2.3 Environment variables**

111 The research was carried out at the Regional Agricultural Research Station at Pattambi,
112 Palakkad, which is roughly 60 kilometers north of Palakkad on the banks of the
113 Bharathapuzha River. This location has a warm, humid tropical climate with relative humidity
114 levels over 70% for the majority of the year. Geographically, the field is located at 10.81°N
115 latitude and 76.19°E longitude.

116 117 **2.4 Seed quality analysis**

118 To evaluate seed quality during seed storage, mid-storage treatments were applied to seeds
119 of the Jyothi variety. Important metrics such as germination percentage, seedling vigor index
120 I, mean germination time, and electrical conductivity were calculated.

121 **2.4.1 Germination percentage**

122 Germination tests were conducted on rice seeds using a standard method recommended by
123 [13] and [14]. Four replicates of 100 seeds were placed in petri-dishes containing moistened
124 filter papers and kept in a germinator at a temperature of 25°C for two weeks. Observations

125 were recorded daily, and the final count was taken on the 14th day. Germination rate (%) was
126 calculated based on the radicle emergence of at least 2 mm .

127
$$\text{Germination \%} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds}} \times 100$$

128 **2.4.2 Seedling vigour Index I**

129 The seedling viability index -I was calculated according to the formula [15]

130
$$\text{Vigour index I} = \text{Germination (\%)} \times \text{seedling length (cm)}$$

131

132 **2.4.3 Electrical conductivity**

133 Electrical Conductivity was tested using four replicates of five grams of grains weighed to
134 two decimal places per treatment. After that, the seeds were allowed to soak in 25 milliliters
135 of distilled water and left for 12 hours in an incubator set at 25 ± 10°C. After collecting the
136 seed leachate, distilled water was added to get the volume up to 25 milliliters. The electrical
137 conductivity of the seed leachate was tested using a digital conductivity bridge, and the
138 mean findings were expressed as desi Siemens per meter (dSm⁻¹) with a cell constant of 1.0
139 [16] and [17].

140 **2.4.4 Mean germination Time**

141 The seeds that were placed on a paper medium to germinate have started sprouting. They
142 were checked daily at the same time, and any seedlings with a radicle protruding 2mm in
143 length were removed from the test. This was continued until all the normal seedlings had
144 germinated to the prescribed size. The mean germination time was then calculated referring
145 to [18],[19] and [20].

146
$$\text{Mean Germination Time (MGT)} = \frac{\sum(n \times d)}{N}$$

147

148 where n = number of seeds germinated on each day, d = number of days from the beginning
149 of the test, and N = total number of seeds germinated at the termination of the experiment

150 **2.5 Statistical analysis**

151 The recorded data was statistically analyzed using the General R-shiny based Analysis
152 Platform Empowered by Statistics (GRAPES), developed by Kerala Agricultural University
153 [21]. The data obtained from seed quality analysis were analyzed using Analysis of Variance
154 (ANOVA) based on the Complete Randomized Design (CRD). The mid-storage invigoration
155 treatments were ranked based on seed quality parameters in seed storage using Duncan's
156 Multiple Range Test (DMRT).

157 **3. RESULTS AND DISCUSSION**

158 To ensure efficient seed storage, uniform germination, seedling vigor index, electrical
159 conductivity and mean germination time are the most important elements. By improving the
160 quality of the seed and enhancing its vigor, midstorage invigoration treatments can extend
161 the storage period and promote good seed germination and crop establishment. In this
162 study, we investigated the impact of different midstorage invigoration seed treatments on
163 seed quality parameters for longer storage under ambient conditions of paddy variety Jyothi.

164 The results of the study are discussed below.

165 **Table 1. Effect of seed treatment on electrical conductivity of six month old seeds**
166 **stored under ambient storage condition**

167

Treatments	1mas	2mas	3mas	4mas	5mas
T ₁ :Control	0.791	0.816	0.907	0.997	1.943
T ₂ :Hydration - dehydration	0.637	0.692	0.759	0.813	1.012
T ₃ :Ascorbic	0.702	0.729	0.804	0.880	1.530

acid					
T ₄ :Calcium chloride	0.702	0.734	0.817	0.900	1.743
T ₅ :Albizzia leaf powder	0.780	0.798	0.881	0.910	1.808
T ₆ :Neem cake	0.780	0.802	0.900	0.997	1.757
T ₇ :Neem leaf powder	0.776	0.805	0.907	1.000	1.833
T ₈ :Neem oil	0.778	0.797	0.889	0.977	1.450
T ₉ :Redchilli powder	0.789	0.801	0.897	0.993	1.730
T ₁₀ :Vayambu leaf powder	0.788	0.809	0.901	0.990	1.890
C.D(0.05)	0.006	0.004	0.009	0.007	0.051
SE(m)	0.002	0.001	0.003	0.002	0.017

168 *1Mas –one month after storage,2Mas- two months after storage, 3Mas- three months after storage,
169 4Mas- four months after storage, 5Mas- 5 months after storage

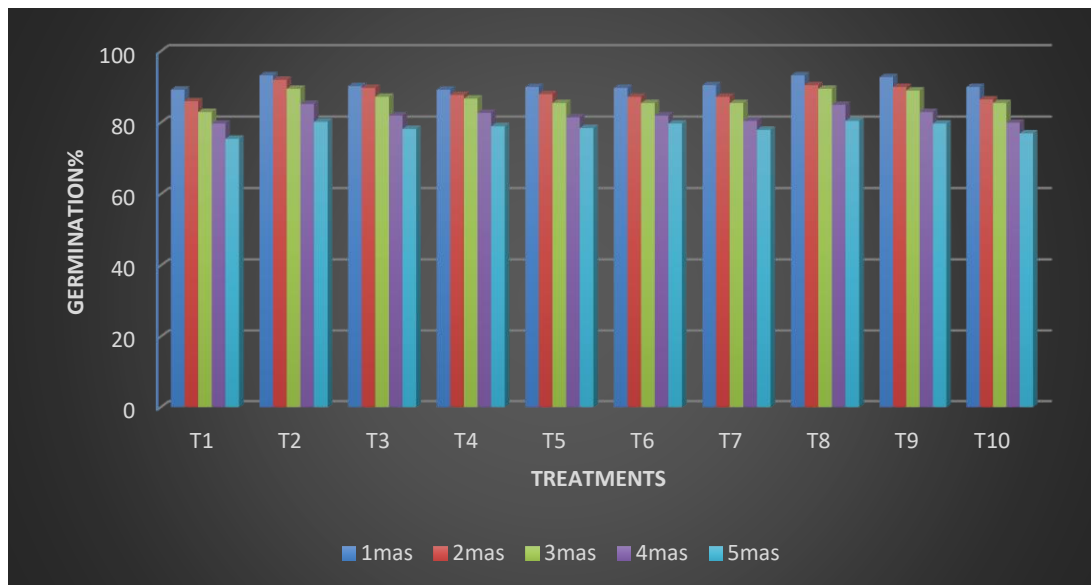
170 **Table 2. Effect of seed treatment on mean germination time of six month old seeds**
171 **stored under ambient storage condition**

172

Treatments	1mas	2mas	3mas	4mas	5mas
T ₁ :Control	4.37	4.39	4.54	4.69	5.00
T ₂ :Hydration - dehydration	4.07	4.14	4.43	4.38	4.53
T ₃ :Ascorbic acid	4.12	4.34	4.60	4.54	4.55
T ₄ :Calcium chloride	4.15	4.30	4.61	4.60	4.61
T ₅ :Albizzia leaf powder	4.12	4.31	4.60	4.56	4.60
T ₆ :Neem cake	4.15	4.26	4.62	4.59	4.61
T ₇ :Neem leaf powder	4.18	4.34	4.63	4.60	4.63
T ₈ :Neem oil	4.06	4.14	4.37	4.40	4.45
T ₉ :Redchilli powder	4.11	4.17	4.44	4.39	4.43
T ₁₀ :Vayambu leaf powder	4.28	4.37	4.50	4.53	4.79
C.D(0.05)	0.11	0.084	0.066	0.083	0.133
SE(m)	0.038	0.029	0.023	0.029	0.046

173
174

*1Mas –one month after storage,2Mas- two months after storage, 3Mas- three months after storage, 4Mas- four months after storage, 5Mas- 5 months after storage



176

177

178

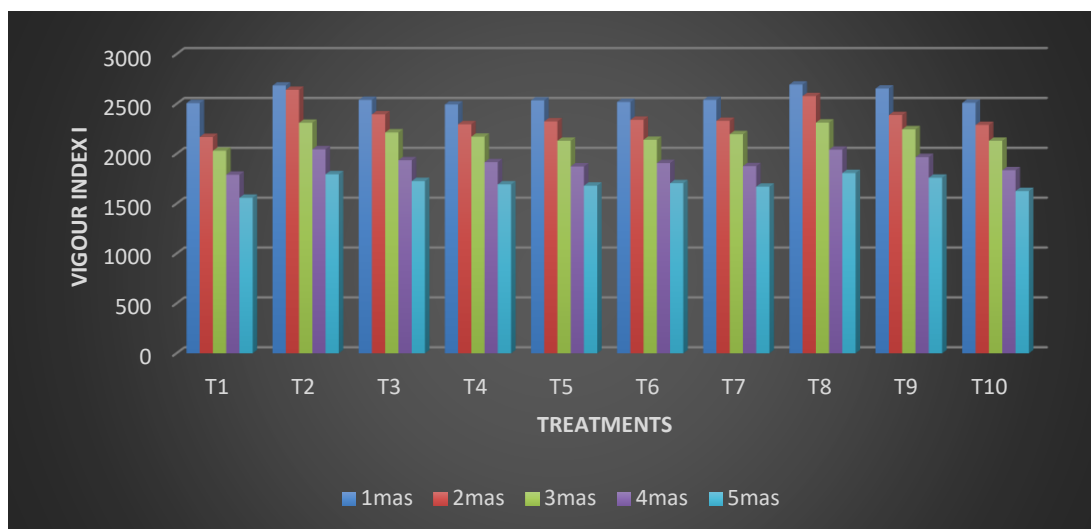
179

180

181

*Mas – months after storage

Fig.1. Effect of seed treatment on germination percentage of six month old seeds stored under ambient storage condition



182

183

184

185

186

187

188

189

190

191

192

193

194

*Mas – months after storage

Fig. 2. Effect of seed treatment on seedling vigour index I of six month old seeds stored under ambient storage condition.

3.1 Impact of midstorage invigoration seed treatments on seed quality

The analysis of variance for seed quality parameters revealed significant variation, as illustrated in Figs. 1, 2, and Table 1,2. The specifics are as follows.

Germination percentage

The results of the study on the impact of seed treatments on germination percentage over time are presented in Fig 1. From the first month of storage, there were significant differences in germination percentage among the treatments. The germination percentage gradually decreased with increase in storage period. The highest germination percentage

195 after one month of storage was observed in T₈, which used neem oil at a rate of 2ml/kg
196 (93.25%). T₂, which used hydration-dehydration treatment at a rate of 1l/kg, and T₉, which
197 used red chilli powder at a rate of 1g/kg, had a germination percentage of 92.75%. The
198 lowest percentage was recorded in T₁, which was the control group, with a germination
199 percentage of 89.25%.

200 Around four months after being stored, the T₁-control group of seeds were no longer able to
201 maintain 80% germination, unlike the other treated seeds. During the storage period, every
202 other treatment group, except for T₂ (hydration-dehydration treatment 1l/kg) and T₈ (neem oil
203 2ml/kg treatment), lost minimal germination percentage.

204 All the mid-storage invigoration treatments were able to significantly improve the germination
205 rate of the treated seeds compared to the control group under normal storage conditions.
206 The treatments were able to maintain the Minimum Seed Certification Standard of 80%
207 germination rate. The neem oil and hydration-dehydration treatments showed the best
208 results over the other treatments by increasing the storage duration of two months and
209 maintaining minimum germination percentage under normal storage conditions.

210 Hydration dehydration improved the germination of seeds. This is in accordance with the
211 results of Adhikary and Mandal [22] which states that the act of pre-soaking seeds activates
212 repair mechanisms and metabolic processes that occur during water absorption, resulting in
213 improved germination rates. Neem oil was found to be significantly more effective at keeping
214 the storage insect under control and preserving high seed quality in storage which has been
215 found concurrent with the results of [23]. Dry treatments with red chilli powder 1g/kg was
216 recommended for the improvement of storability of seeds. This was evident with the results
217 of Sengupta et al [24].

218 **Seedling vigour index I**

219 Based on the data presented in Fig 2, it is evident that there were significant differences in
220 the treatments for the various months of storage in terms of the vigour index. The mean
221 vigour index gradually declined after reaching its peak in the first month of storage. In the
222 first month of storage, T₈-neem oil 2ml/kg (2694) showed a significantly higher vigour index
223 which was comparable to T₂-hydration dehydration treatment 1l/kg (2684) and T₉-red chilli
224 powder 1g/kg (2654). The lowest value was found in the control group (2508). Similar trends
225 were observed in the third and fifth months of storage.

226 Neem oil treatment was found to significantly increase seedling vigour index I. This is similar
227 with the results of Archana et al [25]. T₂-hydration dehydration treatment resulted in a
228 greater seedling vigour index [26].

229 **Electrical conductivity**

230 During the storage period, the conductivity gradually increased despite the various
231 treatments applied as represented in table 1. Seed degradation indicated by seed solute
232 leakage can be measured by electrical conductivity It has been found that biological
233 membranes control the flow of substances into and out of cells, suggesting that they are
234 crucial for the viability and vigor of seeds. Under ambient storage conditions, it was observed
235 that in the first month, T₁- control had the highest electrical conductivity of seed leachate
236 (0.791 dSm⁻¹), while the least EC was recorded in T₂- hydration dehydration treatment
237 (0.637 dSm⁻¹) and T₃- ascorbic acid (0.702 dSm⁻¹). At the end of storage, the highest
238 electrical conductivity was recorded in T₁- control (1.943 dSm⁻¹), which is consistent with the
239 findings of Kavita, Yogeeshha [27] and Al Maskri et al [28]. As electrical conductivity points to
240 seed solute leakage, lower EC values are correlated with the good seed quality parameters.
241 In the last month of storage lower electrical conductivity values were ascertained in the
242 seeds treated with T₂- hydration dehydration treatment (1.012 dSm⁻¹) and T₈-neem oil 2ml/kg
243 (1.450 dSm⁻¹) brought about prolonged seed storage.

244 **Mean germination time**

245 The average germination time is a crucial factor in determining the quality of any seed lot, as
246 it reflects the speed of germination. According to Zhang et al [29], the mean germination time
247 can be used to evaluate seed vigor. In this study, the mean germination time increased

248 during the storage period, as shown in Table 2. Initially, T₈-neem oil and T₂-hydration
249 dehydration treatment had low mean germination times (4.06 and 4.07 days, respectively),
250 but they increased to 5 days in the control group (T₁). However, at the end of storage, seeds
251 treated with T₉-red chilli powder, T₈-neem oil, and T₂-hydration dehydration treatment had
252 mean germination times of 4.43, 4.45, and 4.53 days, respectively. These treatments were
253 superior to all other treatments at the end of the storage period. The highest mean
254 germination time of 5 days was observed in the control group (T₁). These findings are
255 consistent with those of Garoma et al. [30]. The reduced lag phase is associated with an
256 increase in the mean germination time.

257 **4. CONCLUSION**

258 The study on Jyothi paddy seeds subjected to various mid-storage invigoration treatments
259 showed significant impacts on seed quality parameters. Out of all the treatments, neem oil,
260 hydration-dehydration, and red chilli powder yielded the most favorable outcomes for
261 enhanced seed longevity. The research findings imply that farmers could potentially
262 augment seed quality and prolong seed storage by employing eco-friendly and economically
263 viable midstorage invigoration seed treatments. Farmers have easy access to three useful
264 resources: neem oil, hydration-dehydration techniques, and red chilli powder. By
265 incorporating these readily available solutions into their seed storage practices, farmers can
266 extend the seed storage duration and make use of the paddy seeds for next crop season
267 with maintaining the required minimum germination potential.

268 **Acknowledgements**

269 The authors express gratitude to Kerala Agricultural University for financial support and to
270 the Department of Seed Science and Technology, College of Agriculture, Vellanikkara,
271 Regional Agricultural Research Station, Pattambi, Department of Plant Pathology, College of
272 Agriculture, Vellanikkara for technical support.

273 **COMPETING INTERESTS**

274 No competing interest exists.

275 **REFERENCES**

- 276 1. Mohidem NA, Hashim N, Shamsudin R, Man HC. Rice for food security: Revisiting its
277 production, diversity, rice milling process and nutrient content. *Agric.* 2002;12(6):741.
- 278 2. Pandey D, Khatiwada SP. Seed quality and its importance in agriculture. *J. Agric. Nat.*
279 *Resour.* 2018;1(1):1-5.
- 280 3. Kumar S. Economic analysis of the impact of seed quality on small scale paddy farmers in
281 India. *J. Agric. Econ.* 2019;35(2):50-60.
- 282 4. Patel JB, Babariya CA, Sondarva J, Ribadiya KH, Bhatiya VJ. Effect of storage conditions,
283 packing materials and seed treatments on viability and seedling vigour of onion (*Allium cepa*
284 *L.*) seeds. *J. Appl. Nat. Sci.* 2017; 9(2): 1054-1067.
- 285 5. Saritha V, Reddy KCS, Rao DG. Studies on seed quality parameters of rice during
286 storage. *Int. J. Curr. Microbiol. Appl. Sci.* 2017;6(1):258-266.
- 287 6. Jood S, Kumar R, Singh S. Effect of storage containers and pre-storage treatments on
288 seed quality of rice. *J. Stored Products Res.* 2011;47(2):150-154.
- 289 7. Kumar R, Kumar P, Singh S. Efficacy of some essential oils against rice weevil, *Sitophilus*
290 *oryzae* (L.) in stored wheat and rice grains. *J. Food Sci. Technol.* 2013;50(5):1028-1033.
- 291 8. Jisha KC, Vijayakumari K, Puthur JT. Seed storage behavior of rice varieties differing in
292 longevity. *J. Crop Sci. Biotechnol.* 2013;16(4):261-268.
- 293 9. McDonald MB, Copeland LO, Bauman, LF. Seed quality: a guide to seed testing and
294 quality control. 4th ed. Springer; 2001.
- 295 10. Ellis RH, Hong TD. Seed longevity-moisture content relationships in hermetic and open
296 storage. *Seed Sci. Res.* 2007;7(02):153-161.
- 297 11. Oluwafemi MO, Muiyiwa AA, Adetunji CO. Electrical conductivity as a tool for predicting
298 seed viability and vigour of okra (*Abelmoschus esculentus* L. *Moench*) seeds during storage.
299 *Int. J. Agron. Agric. Res.* 2017;10(4):46-52.

- 300 12. Demir I, Ermis SITKI, Mavi K, Matthews S. Mean germination time of pepper seed lots
301 (*Capsicum annuum* L.) predicts size and uniformity of seedlings in germination tests and
302 transplant modules. *Seed Sci. Technol.* 2008;36(1):21-30.
- 303 13. ISTA [International Seed Testing association]. International rules for seed testing. *Seed*
304 *Sci. Technol.* 1985;11:354-513.
- 305 14. Ekren S, Gokcol A, Keskinoglu AY, Paylan IC. Optimizing germination performance of
306 Lamiaceae family seeds: insights from research. *J. Plant Diseases Protection.* 2024; 131:
307 999-1008.
- 308 15. Masuthi D, Chavan ML, Rubina SK, Ramangouda SH, Kareen MA, Prabhakar I,
309 Haleshkumar B. Different priming treatments on germination and viability of cluster bean
310 seeds. *Int. J. Adv. Res.* 2015;3(5): 108-111.
- 311 16. Pameri MS, Chaurasia AK, Hekmat AW. Effect of seed treatments on seed quality
312 characters of paddy variety (Vishnu Bhog) during storage. *Int. J. Multidisciplinary Res.*
313 *Develop.* 2016;3(1):371-373.
- 314 17. Marin M, Laverack G, Powell AA, Matthews S. Potential of the electrical conductivity of
315 seed soak water and early counts of radicle emergence to assess seed quality in some
316 native species. *Seed Sci. Technol.* 2018; 46(1): 71-86.
- 317 18. Khan W, Shah S, Ullah A, Ullah S, Amin F, Iqbal B, Ahmad N, Abdel-Maksoud MA, Okla
318 MK, El-Zaidy M, Al-Qahtani WH. Utilizing hydrothermal time models to assess the effects of
319 temperature and osmotic stress on maize (*Zea mays* L.) germination and physiological
320 responses. *Plant Biol.* 2023; 23(1): 414.
- 321 19. Mavi K, Demir I, Matthews S. Mean germination time estimates the relative emergence
322 of seed lots of three cucurbit crops under stress conditions. *Seed Sci. Technol.* 2010; 38(1):
323 14-25.
- 324 20. Eren E, Ermis S, Oktem G, Demir I. Seed longevity potential predicted by radicle
325 emergence (RE) vigor test in watermelon seed cultivars. *Horticulturae.* 2023; 9(2): 280.
- 326 21. Gopinath PP, Parsad R, Joseph B, Adarsh VS. GRAPES: Rshiny Based Analysis
327 Platform Empowered by Statistics General;2020 Available:
328 <https://www.kaugrapes.com/home> Accessed 16 December 2023
- 329 22. Adhikary R, Mandal V. Hydro-priming and hydration-dehydration treatment improve seed
330 invigoration and biotic stress tolerance. *Russian Agric. Sci.* 2019; 45: 35-42.
- 331 23. Amruta N, Sarika G, Umeha U, Maruthi JB, Basavaraju GV. Effect of botanicals and
332 insecticides seed treatment and containers on seed longevity of black gram under natural
333 ageing conditions. *J. Appl. Nat. Sci.* 2015;7(1):328-334.
- 334 24. Sengupta AK, De BK, Mandal AK. Pre-storage seed invigoration treatments for the
335 maintenance of vigour, viability and field performance of high-vigour onion seed (*Allium cepa*
336 L.). *Seed Sci. Technol.* 2005; 33(3): 753-760.
- 337 25. Archana M, Prasad D. Effect of neem formulations and triazophos on soybean against
338 *Meloidogyne incognita*. *An. of Plant Prot. Sci.* 2003;11(2):404-406.
- 339 26. Mewael KA, Ravi H, Koti RV, Biradarpatil NK. Enhancement of seed quality in soybean
340 following priming treatments. *Karnataka J. Agric. Sci.* 2010;23(5):787-789.
- 341 27. Kavita SR, Yogeeshha HS. Effect of Storage Conditions and Containers on Storability of
342 Pole Type Frenchbean cv. Arka Sukomal. *Asian J. Dairy Food Res.* 2022; 41(4): 438-443.
- 343 28. Al-Maskri A, Nagieb M, Hammer K, Filatenko AA, Khan I, Buerkert A. A note about
344 Triticum in Oman. *Genetic Res. Crop Evol.* 2003;50:83-87
- 345 29. Zhang H, Wang WQ, Liu SJ, Moller IM, Song SQ. Proteome analysis of poplar seed
346 vigor. *PloS one*, 2015;10(7):0132509.
- 347 30. Garoma B, Chibsa T, Keno T, Denbi Y. Effect of storage period on seed germination of
348 different maize parental lines. *J. Nat. Sci. Res.* 2017; 7(4): 8-14.
- 349 Manir, M. R., Halder, K. P., Islam, M. S., Rashid, M. M., Begum, S., & Hossain, E. (2022).
350 Seed Quality of Transplanted Aman Rice as Impacted by Rainfed in the Ripening Phase.
351 *Asian Journal of Advances in Agricultural Research*, 20(4), 1-9.
352 <https://doi.org/10.9734/ajaar/2022/v20i4402>

353 Aculey , P., Tandoh , P. K., & Gamenyah, D. D. (2023). Physiological Seed Quality
354 Responses of Three Rice Varieties to Different Storage Materials under Ambient Conditions
355 . Journal of Experimental Agriculture International, 45(9), 135–141.
356 <https://doi.org/10.9734/jeai/2023/v45i92184>

357

358 Dey, S., Paul, S., Nag, A., Banerjee, R., Gopal, G., Mukherjee, A., & Kundu, R. (2021). Iron-
359 pulsing, a novel seed invigoration technique to enhance crop yield in rice: A journey from lab
360 to field aiming towards sustainable agriculture. Science of the Total Environment, 769,
361 144671.

362

363

364

365

366

367

368