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Pre-storage Seed Hardening Effects on Germination, Vigour and Seedling Growth of Jute Species: *Corchorus capsularis* L. and *Corchorus olitorius* L.

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Authors' contributions

This work was carried out in collaboration between all authors. Author MNU designed the study, wrote the protocol, executed the experiment, performed the statistical analysis and wrote the first draft of the manuscript. Author MMH reviewed the design and supervised the study. Authors SMMA and MAS contributed during writing up and editing of manuscript. Author MNH reviewed each draft of the manuscript and final proof submission. All authors read and approved the final manuscript.

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ABSTRACT

The study was conducted at the Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur from September 2008 to January 2009 to determine seed hardening effects on germination, vigour and seedling growth of jute seed. Jute seeds of two popular varieties namely CVL-1 under *Corchorus capsularis* L. and O-9897 under *Corchorus olitorius* L. were used in the

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study. Jute seeds were hydrated and dehydrated for 2, 4, 6 and 8 hours to induce seed hardening. Different physiological seed qualitative parameters of harden seeds were compared with unharden control seeds. Large sized seeds, highest germination and seedling root length, dry weight, vigour index and minimum mean germination time was obtained from control treatment. On the contrary, small sized seeds, lowest germination and seedling root length, dry weight, vigour index were recorded from the seeds of the 8 hours hydration. Maximum water absorption rate, electrical conductivity, mean germination time and minimum seedling shoot length were found from 8 hours hydrated seeds. The lowest water absorption rate, electrical conductivity was observed from 2 hours hydrated seeds. In case of two species, *Corchorus capsularis* showed better performance than *Corchorus olitorius*. Seedling vigour index was found to be positively correlated with viability and seedling dry weight. Similarly, seed size was found to be positively correlated with viability percentage, seedling dry weight and seedling vigour index. Leachate conductivity showed negative relationship with viability percent, seedling dry weight, seedling vigour index and seed size.

Keywords: Corchorus capsularis L.; Corchorus olitorius L.; electrical conductivity; germination test; seedling vigour index.

1. INTRDUCTION

Jute, known as the golden fiber, is an important traditional cash crop in Bangladesh. In fact, jute is the second most important natural fiber in terms of global consumption after cotton [1]. Although there are more than 40 species of jute available, only two species are cultivated commercially, namely, *Corchorus capsularis* L. (commonly known as white jute) and *Corchorus olitorius* L. (commonly known as Tossa/traditional jute) [2]. Bangladesh contributes nearly 39% of total raw jute supply cultivated on 39% of the total global jute area, with an average yield of 1.53 t ha^{-1} during the period 1961-2002 [3]. It is generally grown under rainfed condition in anticipation of early rain or sometimes after a brief spell of showers. Due to irregular rainfall, poor and uneven germination is common which ultimately reduces the yield of jute.

Recently, many seed invigoration techniques are being used to improve germination rate, synchronize germination and increase seedling stand of field crops [4,5]. Among the invigoration techniques, seed hardening is very simple one. Seed hardening also called wetting and drying or hydration-dehydration is performed by repeated soaking and drying of seeds in water [6-8]. But mid-storage seed hardening treatments are very effective for the maintenance of viability and vigour of seed [9,10]. The principle behind the mid-storage treatments is to allow the stored seeds to uptake moisture for certain preventive, corrective or restorative actions before drying back for restorage. The beneficial effect of seed hardening is primarily due to pre-enlargement of the embryo [11] and subsequently improvement of germination capacity of seed [7].

In general, delay in germination of stored aged seed occurs due to damage of cell wall which needs to repair before germination [12]. Such damage may be repaired by seed hardening as there is considerable evidence that repair processes are occurring soon after imbibitions of aged seeds [13,14]. A good number of studies [15-18] indicated that relatively short seed hardening treatments can either improve the tolerance of seeds to subsequent adverse storage conditions or improve the vigour of aged seeds of cereal, oil and vegetables. However, it needs to be workout whether the maintenance of viability and vigour of stored jute seeds is possible through pre-storage seed hardening treatments. Therefore, the present study was undertaken to determine the efficacy of seed hardening on seed quality of two jute species *viz., C. capsularis* L. and *C. olitorius* L. and identify the effective seed hardening period for their improvement of physiological quality.

2. MATERIALS AND METHODS

2.1 Seed Material and Design of the Experiment

Jute seeds of *Corchorus capsularis* L. (cv. CVL-1) and *Corchorus olitorius* L. (cv. O-9897) were collected from Bangladesh Jute Research Institute and multiplied at the Bangabandhu Sheikh Mujibur Rahman Agrcultural University (BSMRAU), Gazipur during September 2008 to January 2009 to obtain sufficient quantity of fresh seed. The harvested seed crop was spread over the threshing floor for drying in the sun. After drying in sun for five days, seeds were threshed by beating with sticks. Then seeds were cleaned and further dried for another six days in the sun.

The initial seed moisture contents were 8.6 and 8.5% and germination were 95 and 96% in *C. capsularis* and *C. olitorius*, respectively. Then seeds of both the species were stored separately for one year in gunny bag at ambient condition in the Seed Science and Technology Laboratory of BSMRAU, Gazipur during February 2009 to February 2010 to allow deterioration of seed quality over time. The laboratory experiment was conducted in Complete Randomized Design (CRD) with four replications.

2.2 Seed Hardening

Fresh jute seeds (50 g) of both the species were hydrated by soaking in the double volume of tap water for 2, 4, 6 and 8 hours in plastic pot maintaining 30°C and 70% relative humidity in an incubator. After hydration of seeds in different time, excess water was drained out with the help of sieve. The seeds were spread over newspaper under the ceiling fan and surface dried with blotter paper and weighed carefully for determination of water uptake due to hydration. Afterwards, the seeds were transferred to dryer at 35°C for 24 hours and dried back at its nearest original moisture content [19].

2.3 Germination Test

One hundred pure seeds of each treatment combination were placed in Petri dish containing filter paper soaked with distilled water. For each test, four Petri dishes were used. The Petri dishes were placed in germinator at 30°C in 12/12 hours alternative dark and light for 5 days. Seedlings were counted every day up to the completion of germination at fifth day. A seed was considered to be germinated as the seed coat ruptured and radicle came out up to 2 mm length. Germination percentage was calculated using the following formula [20].

Germination (%) =

$$\frac{\text{Number of seeds germinated}}{\text{Number of seeds tested}} \times 100$$

2.4 Mean Germination Time

Mean germination time (MGT) was calculated according to the equation of Ellis and Roberts [21] as under:

$$\text{Mean germination time (MGT)} = \frac{\sum dn}{\sum n}$$

Where, n is the number of seeds, which were germinated on day d, and d is the number of days counted from the beginning of germination.

2.5 Seedling Vigour Index

Ten seedling samples from each petri dish were uprooted on the day 5 of the germination test and dried at 70°C for 72 hours for dry matter yield. Fresh weight and dry weight of those samples were measured. Seedling vigour index was calculated according to the following formula [22].

Seedling vigour index =

Germination (%) × total seedling dry matter

2.6 Electrical Conductivity Test

For electrical conductivity test, 2 g seeds of each sample were taken in a conical flask containing 50 ml de-ionized water and were incubated at 20°C for 20 hours [23]. After 20 hours, water of the beaker containing seeds was decanted in order to separate the seeds. The electrical conductivity of the decanted water containing seed leachate was measured with a conductivity meter (Model–CM- 30ET). Four replicates of measurements were made for each sample of seed.

2.7 Statistical Analysis

Analysis of variance (ANOVA) of the collected data was carried out, using MSTAT-C software. Excel software was used to draw figures. Means were compared by applying least significant difference (LSD) test at 5% probability [24]. Functional relationships among the parameters were established through correlation and regression analysis.

3. RESULTS AND DISCUSSION

3.1 Water Absorption at Hydration

Water uptake by jute seeds increased with the increase of hydration duration (Fig. 1). In *C. capsularis* seeds water uptake rate ranged from 44.50 to 87.50%, whereas in *C. olitorius* seeds it ranged from 38.50 to 73.50%. The maximum water uptake was recorded in both the species when jute seeds were imbibed for 8 hours and it was minimum at 2 hours imbibition. In general, the rate of water uptake was higher in *C. capsularis* than in *C. olitorius* seeds and this variation was associated with variation in oil content of jute seed [19]. As *C. olitorius* contains higher quantity of oil than *C. capsularis*, it maintained lower potential to absorb water under hydrated condition. Besides, *C. olitorius* possesses lower cellular content of osmotic solutes than in *C. capsularis* seeds which reduced water absorption rate in *C. olitorius* seeds. Dehydration reduced seed moisture content and it ranged from 8.6 to 8.7% in *capsularis* and 8.2 to 8.3% in *olitorius* seed (Fig. 2). Differences in seed moisture content in each species after hydration-dehydration treatment and their original moisture are very narrow which indicated that seeds are dried back properly after hydration for safe storage life.

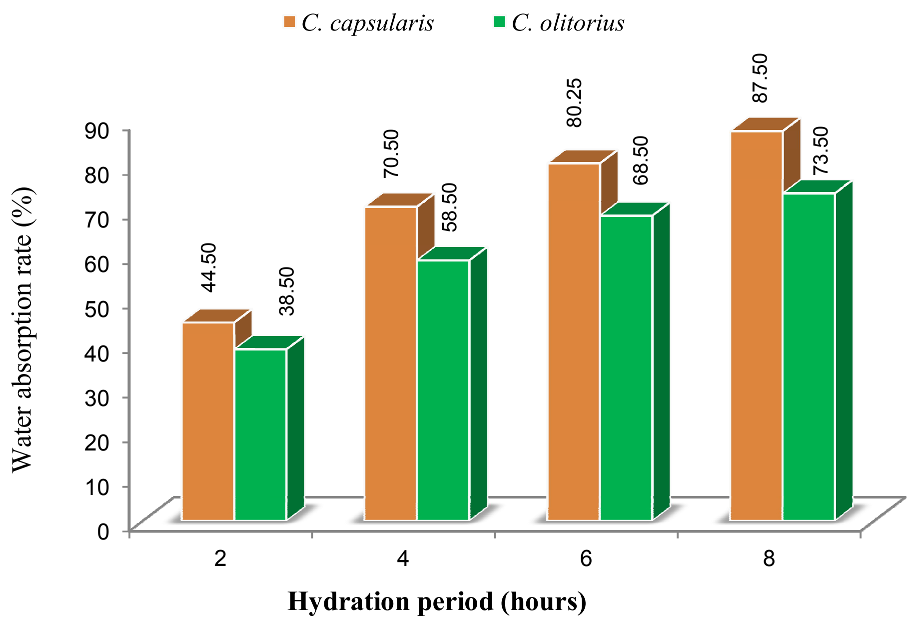

Fig. 1. Water absorption rate (%) of jute seed at different hydration period

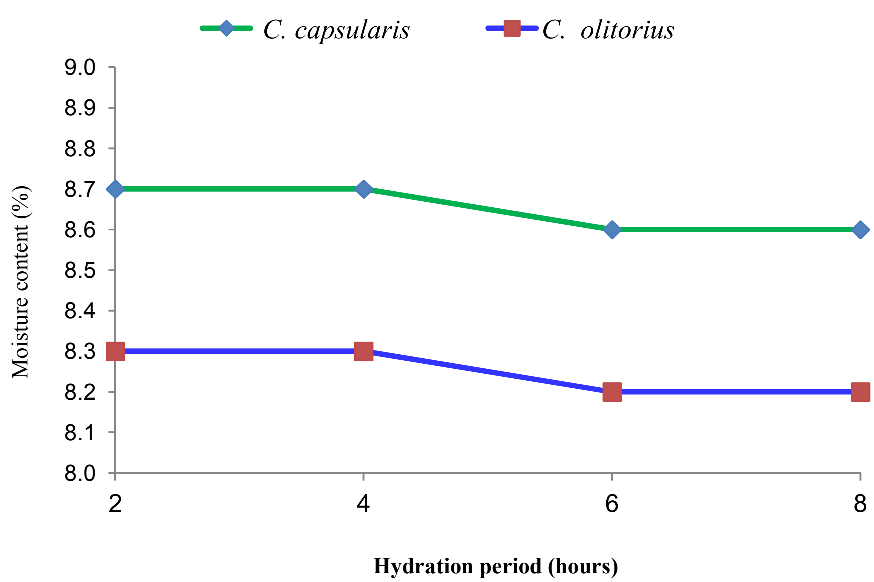

Fig. 2. Moisture content of jute seed at hydration-dehydration treatments

3.2 Seed Size

Seed size of jute was expressed in gram on the basis of 1000-seeds weight. Thousand seed weight of two jute species changed due to seed hardening (Table 1). The maximum seed size was found in control treatment and seed size decreased gradually with the increase of hydration-dehydration period. The lowest seed size was observed at 8 hours hydration-dehydration in both the species. Decrease in seed size due to hydration-dehydration might be attributed to initiation of metabolic activity of seed after water imbibition. Metabolic activity of seed is energy expensive and thus jute seeds might have lost some weight at the time of hydration-dehydration processes.

3.3 Seed Viability

The viability of fresh jute seeds expressed by germination percentage was not influenced profoundly by pre-storage seed hardening treatments (Fig. 3). In *C. capsularis* jute seeds, the maximum (95%) germination was found at control treatment which was statistically similar to all other treatments except 8 hours hydration followed by dehydration. The lowest (92%) germination was observed at 8 hours hydration-dehydration treatment. Similar trend was also noticed in case of *C. olitorius* jute seeds. The results indicated that hydration treatment for 8 hours was too long for both the jute species as it resulted in the lowest germination percentage. Among the hydration treatments, 6 hours hydration showed better germination as compared to other treatments. Several authors [25-27] mentioned different germination behavior of different field crops under extremely varying conditions of hardening done prior to plantation. However, improvement in germination of the freshly harvested highly viable seed is difficult but this technique can act towards the protection against deteriorative senescence during storage [28].

Table 1. Pre-storage seed hardening effects on seed size of jute

Hydration period (hours)	Seed size (g per 1000-seeds)	
	C. capsularis	***C. olitorius***
Control	3.333	2.043
2+ D	3.304	1.963
4+ D	3.296	1.961
6+ D	3.291	1.977
8+ D	3.276	1.938
$LSD_{(0.05)}$	0.03	0.03

D indicates dehydration for 24 hours

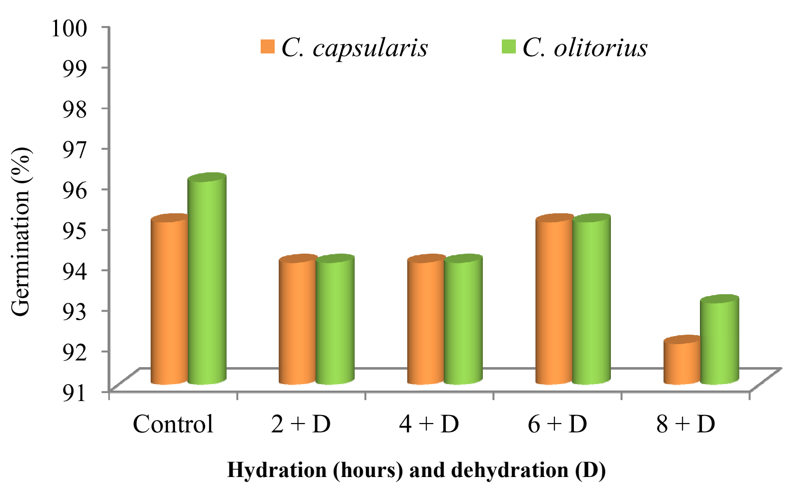

Fig. 3. Germination of jute seed at different levels of pre-storage seed hardening

3.4 Leachate Conductivity

Electrical conductivity of seed leachate differed significantly between two jute species as well as between seeds hydrated at different duration periods (Fig. 4). The results of electrical conductivity showed that leakage was the maximum of 8 hours hydrated-dehydrated seeds and the lowest in 2 hours hydrated-dehydrated seeds in both the species. Comparing two species leaching was higher in *C. olitorius* than in *C. capsularis* seeds. Hydration-dehydration treatments significantly increased leaching of leachates from the jute seeds indicating that it has damaging effect on cell membranes. This finding is supported by observations of other workers [29,30] in other field crops. The result shows that hydration of seeds for two to six hours considerably reduce leakage of solutes from dehydrated seeds. A possible explanation is that hydration before dehydration caused an improvement in membrane integrity as it has been shown that the membrane bilayers under dehydrated state remain in a disrupted phase but on subsequent rehydration resume their relatively normal structure within 20 minutes [31]. Besides, optimum hydration of seed tissue before dehydration acts as a deterrent for unfavourable conformational changes and fragmentation of cellular macromolecules [32]. It is also noteworthy that for longer than six hours hydration may have a deleterious effect on membrane integrity as would be evident from the data on the amount of solute leakage. The damaging effect of more than six hour hydration was brought about by the gradual shift of treated seeds from their dehydration insensitive to dehydration sensitive phase as a result of increased vacuolation of germinating seeds due to increased hydration at longer period [32].

3.5 Seedling Growth

The root length, shoot length and seedling dry weight of jute seeds treated with hydration-dehydration are presented in Table 2. Significant differences were observed between the species and duration of hydration-dehydration treatment. The maximum root length, shoot length and seedling dry weight was found from control treatment in both species of jute seeds except shoot length of *C. capsularis* at 6 hours hydration. Thus root length of jute seedlings ranged from 2.50 to 3.53 cm in *C. capsularis,* 2.00 to 3.15 cm in *C. olitorius* and shoot length ranged from 4.40 to 4.75 cm and 2.33 to 3.60 cm, respectively. Seedling dry weight varied from 1.81 to 2.11 mg in *C. capsularis* and 1.02 to 1.21 mg in *C. olitorius*. The minimum root length, shoot length and seedling dry weight was recorded when seeds were hydrated for 8 hours. However, 6 hours hydration-dehydration treatment showed better shoot length in *C. capsularis* than others and comparable to control treatment. In general, seedling growth was better in *capsularis* than olitorius seed because of its larger seed size. Large seed produced more seedlings dry matter due to its large initial capital in seed reserve which might enhance the seedling growth [33].

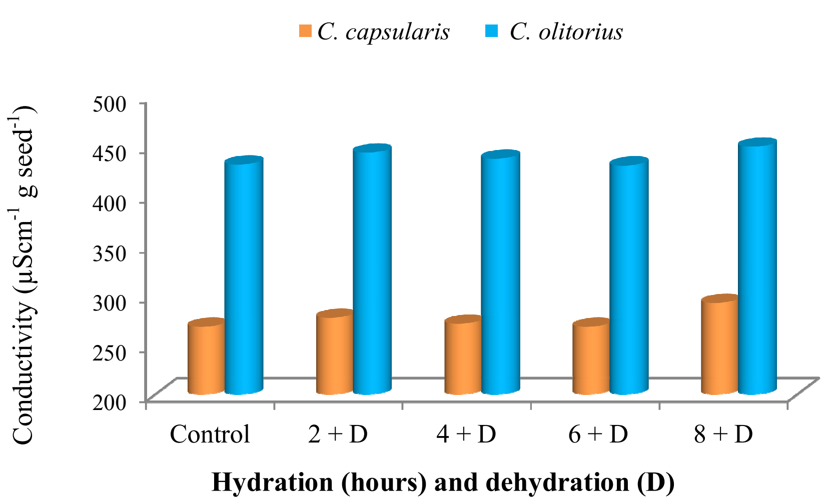

Fig. 4. Pre-storage seed hardening effect on electrical conductivity of jute seeds

Table 2. Effect of pre-storage seed hardening on seedling growth of two species of jute

Hydration periods (hours)	Root length (cm)		Shoot length (cm)		Seedling dry weight (mg plant^{-1})	
	C. capsularis	*C. olitorius*	*C. capsularis*	*C. olitorius*	*C. capsularis*	*C. olitorius*
Control	3.53	3.15	4.75	3.45	2.11	1.21
2 + D	2.83	2.45	4.53	3.03	1.96	1.16
4 + D	3.13	2.38	4.55	2.90	1.94	1.11
6 + D	2.50	2.62	4.73	3.18	1.95	1.18
8 + D	2.33	2.00	4.40	2.33	1.82	1.02
$LSD_{(0.05)}$	0.14	0.14	0.20	0.13	0.06	0.06

D indicates dehydration for 24 hours

Table 3. Pre-storage hardening effects on seedling vigour index and mean germination time of jute seeds

Hydration period (hours)	Seedling vigour index		Mean germination time (days)	
	C. capsularis	*C. olitorius*	*C. capsularis*	*C. olitorius*
Control	156.5	116.2	1.09	1.02
2 + D	152.4	108.7	1.14	1.05
4 + D	149.9	109.1	1.14	1.06
6 + D	154.3	111.6	1.10	1.03
8 + D	144.6	95.3	1.15	1.09
$LSD_{(0.05)}$	0.33	0.50	0.04	0.02

D indicates dehydration for 24 hours

Table 4. Bivariate correlation analysis results of different seed quality attributes of jute seed obtained from hydration-dehydration treatments

Variables	Viability		Seedling dry weight		Seedling vigour index		Seed size	
	C. capsularis	*C. olitorius*	*C. capsularis*	*C. olitorius*	*C. capsularis*	*C. olitorius*	*C. capsularis*	*C. olitorius*
Seedling dry weight	0.909*	0.868*	-	-	-	-	-	-
Seedling vigour index	0.968**	0.911*	0.984**	0.996**	-	-	-	-
Seed size	0.977**	0.959**	0.892*	0.857*	0.949**	0.895*	-	-
Leachate conductivity	-0.975**	-0.926**	-0.814*	-0.876*	-0.901*	-0.902*	-0.971**	-0.821*

*** Correlation (r) is significant at the 0.01 level of probability (2-tailed) and*
** Correlation (r) is significant at the 0.05 level of probability (2-tailed)*

3.6 Seedling Vigour

Pre-storage hardening effects of jute seeds exhibited a significant effect on seedling vigour index (Table 3). The highest seedling vigour index (156.5) was observed in *capsularis* seed in control treatment. A similar trend was also observed in *olitorius* seed (116.2). Seedling vigour is the multiplying factor of germination percentage and seedling dry weight. As such the highest germination percentage and highest seedling dry weight obtained from control treatments resulted the highest seedling vigour in two species of jute.

3.7 Mean Germination Time

Mean germination time (MGT) was significantly influenced by the different period of hydration over the two species of jute (Table 3). In both the species, the maximum MGT was recorded from the seeds hydrated for 8 hours followed by dehydration. This means that the seeds hydrated for 8 hours took longer period of time to germinate as a consequence of reduction in seed vigour. The lowest MGT was observed in seeds of control treatments which indicated the faster germination of seeds of control treatments. Bewley and Black [34] showed that seeds of low physiological quality need considerable time to recognize their membranes and then slowed down the germination process. In comparison of two species, lower MGT was required in *C. olitorius* than in *C. capsularis* seeds which might be due to differences in thickness of seed coat of the species.

3.8 Correlation Analysis

The relationship among different seed quality attributes of *C. capsularis* and *C. olitorius* species was determined through the bivariate correlation analysis (Table 4). Seedling vigour index showed positively correlated with viability and seedling dry weight. Similarly, seed size was positively correlated with viability percentage (r = 0.977, 0.959), seedling dry weight (r = 0.892, 0.857) and seedling vigour index (r = 0.949, 0.895). The results revealed that bolder the seed size higher the viability, seedling dry weight and seedling vigour index which indicated that the seed size is related to seed metabolism and ultimately seedling growth rate [35]. As larger seed contain higher amount of reserve and metabolize those reserves towards the germinating seedling which consequently enhanced seedling growth rate [33]. Conversely, the negative relationship between leachate conductivity with viability percent (r = -0.975, -0.926), seedling dry weight (r = -0.814, -0.876), seedling vigour index (r = -0.901, -0.902) and seed size (r = -0.971, -0.821) indicated that more leachates were escaped from poor quality seeds as induced by hydration-dehydration treatments and lowered the viability and the seed vigour of two species of jute.

4. CONCLUSION

The present study revealed that most of the attributes were highest in control treatments (except water absorption rate, electrical conductivity and mean germination time). Hence, it can be concluded that pre-storage seed hardening could not significantly improve seed quality of jute seeds of *C. capsularis* and *C. olitorius*.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Basu G, Roy AN. Blending of jute with different natural fibres. J. Nat. Fibers. 2008;4:13-29.
2. Kazal MMH, Rahman S, Alam MJ, Hossain ST. Financial and economic profitability of selected agricultural crops in Bangladesh; NFPCSP-FAO Research Grant Report #05/11; Food Planning and Monitoring Unit, Ministry of Food, Government of Bangladesh: Dhaka, Bangladesh; 2013.
3. Gupta D, Sahu PK, Banerjee, R. Forecasting jute production in major contributing countries in the world. J. Nat. Fibers. 2009;6:127-137.
4. Khan AA. Pre-plant physiological seed conditioning. Annu. Rev. Hort. Sci. 1992;132-179.
5. Lee SS, Kim JH. Total sugar, α-amylase activity and germination after priming of normal aged rice seeds. Korean J. Crop Sci. 2000;44:2108-111.
6. Pen Aloza APS, Eira MTS. Hydration-dehydration treatments on tomato seeds. Seed Sci. Technol. 1993;21:309-316.
7. Lee SS, Kim JH, Hong SB, Yun SH. Effect of humidification and hardening treatment on seed germination of rice. Korean J. Crop Sci. 1998;43:157-160.

8. Basra SMA, Farooq M, Tabassum R. Physiological and biochemical aspects seed vigour enhancement treatments in fine rice (*Oryza sativa* L.). Seed Sci. Technol. 2005;33:623-628.
9. Basu RN. Physio-chemical control of seed deterioration. Seed Res. 1976;4:15-23.
10. Mandal AK, Basu RN. Maintenance of vigour, viability and yield potential of stored wheat seed. Indian J. Agric. Sci. 1983;53:905-912.
11. Austin RB, Longden PC, Hutchinson J. Some effects of hardening of carrot seed. Ann. Bot. 1969;33:883-895.
12. Priestley DA, Leopold AC. Lipid changes during natural ageing of soybean seeds. Physiol. planatarum. 1983;59:467-470.
13. Davison PA,Taylor RM, Bray CM. Changes in ribosomal RNA integrity in leek (*Allium porrum* L.) seed during osmopriming and drying-back treatments. Seed Sci. Res. 1991;1:37-44.
14. Elder RH, Dell' Aquila A, Mezzina M, Sarsin A, Osborne DJ. DNA ligase in repair and replication in the embryo of rye. Mutat. Res. 1987;181:61-71.
15. Burgass RW, Powell AA. Evidence for repair processes in the invigoration of seeds by hydration. Ann. Bot. 1984;53:753-757.
16. Basu RN, Pan D, Punjabi B. Control of lettuce seed deterioration. Indian J. Plant Physiol. 1979;22:247-253.
17. Punjabi B, Basu RN. Control of age and irradiation-induced seed deterioration in lettuce (*Lactuca sativa* L.) by hydration-dehydration treatments. Proc. Indian Natl. Sci. Acad. 1982;48:242-250.
18. Rao NK, Roberts EH, Ellis RH. The influence of pre-storage and post-storage hydration treatments on chromosomal aberrations, seedling abnormalities and viability of lettuce seeds. Ann. Bot. 1987;60:97-108.
19. Chowdhury SR, Choudhuri MA. Effects of presoaking and dehydration on germination and early seedling growth performance of two jute species under water stress condition. Seed Sci. Technol. 1987;15:23-33.
20. Krishnasamy V, Seshu DV. Germination after accelerated ageing and associated characters in rice varieties. Seed Sci. Technol. 1990;18:147-157.
21. Ellis RA, Roberts EH. The quantification of ageing and survival in orthodox seeds. Seed Sci. Technol. 1981;9:373-409.
22. Bedi S, Kaur R, Sital JS, Kaur J. Artificial ageing of *Brassica* seeds of different maturity levels. Seed Sci. Technol. 2006;34:287-296.
23. Ali SMM, Haque MM, Siddique AB, Mollah AF, Islam MN. Effect of sowing date on the phenology on growth and seed yield of tossa jute (*Corchorus olitorius* L.) in late sown condition. Bangladesh J. Agric. 2005;27&28:91-97.
24. Russell OF. MSTAT-C v.2.1 (a computer based data analysis software). Crop and Soil Science Department, Michigan State University, USA; 1994.
25. Welbaum GE, Bradford KJ. Water relations of seed development and germination in muskmelon (*Cucumis melo* L.). VI. Influence of priming on germination response to temperature and water potential during seed development. J. Expt. Bot. 1991;42:393-399.
26. Prisco JT, Baptista HCR, Pinherio BJL. Hydration-dehydration seeed pre-treatments and its effects on seed germination under water stress conditions. Revista Brasil Bot. 1992;15:31-35.
27. Bray CM. Biochemical processes during the osmopriming of seeds. Seed development and germination (eds. J.Kigel and Galili). New York, Basel, Hong Kong, Marcel Dekker Inc. 1995;767-789.
28. Basu RN. An appraisal of research on wet and dry physiological seed treatments and their applicability with special reference to tropical and sub-tropical countries. Seed Sci. Technol. 1994;22:107-126.
29. Hegarty TW. The Physiology of seed hydration and dehydration, and the relation between water stress and the control of germination: a review. Plant Cell Env. 1978;1:101-119.
30. Mckersie BD, Tomes DT. Effects of dehydration treatments on germination, seedling vigour and cytoplasmic leakage in wild oats and birdsfoot trefoil. Canadian J. Bot. 1980;58:471-476.
31. Webster BD, Leopold AC. The ultra structure of dry and imbibed cotyledons of soybean. American J. Bot. 1977;64:1286-1293.
32. Bewley JD. Physiological aspects of desiccation tolerance. Ann. Rev. Plant Physiol. 1979;30:195-238.

33. Raveendranath V, Sing BG. Effect of seed size on seedling vigour in sunflower (*Helianthus annus* L.). Seed Res. 1991;19:37-42.
34. Bewley JD, Black M. Physiology and biochemistry of seeds in relation to germination. Berlin, Springer- Verlag. 1983;306.
35. Krieg DR, Caroll JD. Cotton seedling metabolism, as influenced by germination, temperature, cultivar and seed physical properties. Agron. J. 1978;70:21-25.

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