

The quality of jute mallow (*Corchorusolitorius* L.) seeds exposed to different hot water-steeping and cooling protocols

Absract

Steeping of jute mallow (*Corchorusolitorius*) seed in hot water at high temperature for enhanced germination, seems to be the most favoured of all other methods. Literature however, appears to be silent on the cooling protocol to adopt to ensure high quality after a seed lot may have been steeped in hot water. Seeds of two cultivars of this crop were subjected to nine hot water/cooling treatments and then dried back. They were then thinly spread and stored in open glass dishes at 83% relative humidity and 33 °C. The moisture content of seeds steeped in water at 80 and 97 °C increased from about 5-6% prior to storage to about 10-11% after 6-18 WAS. Steeping of seeds at 80 and 97 °C for 5 seconds significantly enhanced germination. Cultivar 'Amugbadu' seeds steeped in cold water immediately after steeping in water at 97 °C survived better during storage than those that were simply left to gradual cooling in ambient condition. 'Oniyaya' seeds exhibited no differential response to cooling protocol. Unsteeped (control) seeds and those steeped at 40 and 60 °C prior to storage, had greater longevity than seeds steeped at 97 °C (irrespective of cooling protocol) and 80 °C prior to storage. Furthermore, whereas seeds of the latter group germinated slower and less uniformly as storage progressed, a gradual increase in the values of these vigour indices were recorded in the former group of seeds. Generally 'Oniyaya' seeds were of higher quality than those of 'Amugbadu'.

Key words: *Corchorus olitorius*, seed dormancy, steeping, storage, germination rate and synchronization

Introduction

Dormancy poses a serious problem to successful seed germination and seedling establishment in jute mallow and different methods have been employed to alleviate the problem. Oladiran (1986) reported the effectiveness of hot water-steeping in this respect which has been confirmed by other reports (Ayanlaja *etal.*, 2001; Velempini, *etal.*, 2003; Emongor *etal.*, 2004). Nkomo and Kambizi (2009) recorded best germination of *Corchorusolitorius* seeds when they were first prechilled at 6 °C for 3½ days before they were incubated at 35°C. Exposure of the seed of this

crop to dry heat at 90 °C for 5 or ten minutes has also been reported to break dormancy by Denton *etal.* (2013). According to Halford (1993), the temperature required to break seed dormancy in *C. cunninghamii* in Australia ranged between 80-100 °C. It was therefore concluded that soil heating from bush fire would promote the germination of seeds of this species. Emongor *etal.* (2004) and Chauhan and Johnson (2008) reported the effectiveness of sulphuric acid and seed coat scarification respectively. Earthworm cast leachate has also been found effective in dormancy breaking in *C. olitorius* seeds (Ayanlaja *etal.*, 2001). Of all the methods stated above, though not an exhaustive list, the use of hot water appears to be the most favoured as water is cheaply available and can be more safely handled by all users.

The usual practice when hot water is used to break seed dormancy in this crop is to immediately steep treated seeds in cold water which is assumed to bring down seed temperature and so reduce damages that may occur to the embryo by the treatment at high temperature. Ajayi and Fakorede (2001) recorded better germination and seedling growth when maize seeds that had been stored in deep freezer and refrigerator were first left to equilibrate in ambient condition for some days before they were tested at a temperature higher than that in which they were stored. It is possible that exposure of jute mallow seeds to extreme temperatures in quick successions may damage the embryo. This study aimed at determining the effect hot water-steeping/cooling protocol may have on seed quality in two different cultivars of *C. olitorius* in a bid to enhance seed germination.

54

55 **Materials and Method**

56 Samples of *Corchorus olitorius* seeds of cultivars 'Oniyaya' and 'Amugbadu' harvested in
57 November, 2012 were subjected to nine treatments: St1) seeds steeped in hot water at 97 °C for 5
58 seconds as recommended by Oladiran (1986) and then spread out on absorbent paper to cool
59 down and dry in ambient condition (temperature of about 30 °C and relative humidity of about
60 30%); St2) seeds steeped as in St1 followed immediately by steeping in cold water; St3) seeds
61 steeped as in St1 followed immediately by steeping in hot water at 80 °C; St4) seeds steeped as
62 in St1 followed immediately by steeping in hot water at 60 °C; St5) seeds steeped as in St1
63 followed immediately by steeping in warm water at 40 °C; St6) seeds steeped in hot water at 80
64 °C followed immediately by steeping in cold water; St7) seeds steeped in hot water at 60 °C
65 followed immediately by steeping in cold water; St8) seeds steeped in warm water at 40 °C
66 followed immediately by steeping in cold water; St9) control (non-treated). Seeds of the different
67 treatments were left to dry on absorbent paper in ambient condition for seven days. The moisture
68 content at which seeds equilibrated with the ambient condition was then determined using the high
69 constant temperature oven method (ISTA, 2005). Samples of each of the treatments were thinly
70 spread in glass Petri dishes and placed in an incubator at 33 ± 0.5 °C and at $83 \pm 2.5\%$ for a
71 period of 20 weeks. Seed samples were drawn for germination test at two-weekly interval. In
72 addition to the nine treatments listed above, samples of the untreated (St9-control) seeds were
73 steeped as in St2 above following storage for 12-20 weeks to obtain St10. This was to ascertain
74 the viability of the untreated seeds at these points. Samples of St7 and 8 were similarly tested at
75 18 and 20 weeks to obtain St11 and 12 respectively. On each of the testing days, four replicates of
76 50 seeds each were counted and spread on distilled water-moistened filter paper and incubated at
77 30 °C for 16 days. Germination counts were taken every-other-day and the final cumulative

figures were expressed as a percentage of the total seed incubated for each treatment. To further index seed quality, germination rate was determined using the expression recommended by Labouriau (1983) while germination synchronization was determined using the formula adopted by Ranal and Santana (2006) based on an idea expressed by Primack (1980). Seed moisture content for St1-9 were again tested at 6 and 18 weeks of storage to determine if there had been changes to the moisture levels compared to what was recorded at the beginning of storage. Seed germination data (in percentages) were transformed to arcsin values before they were statistically analysed. All data were analysed using the SAS statistical package (SAS, 1999). The least significant difference method (LSD) and Duncan Multiple Range Test were used for mean separation where significant differences were obtained.

Results

Prior to storage (0WAS), moisture contents of St1-9 ranged between 4.8-6.1 and 4.6-6.4% for “Amugbadu” and “Oniyaya” respectively (Table 1) and by six weeks after storage (6WAS), the values had risen considerably to about 10.5% in all seeds steeped in hot water at 97 and 80 °C (i.e. St1-6) with little or no changes at 18WAS. Relatively slight moisture increases were recorded in untreated seeds and in those steeped at 40 and 60 °C. Steeping of seeds at 97 °C (irrespective of cooling protocol) and at 80 °C (St1-6) significantly enhanced germination. Though seeds steeped in hot water at 60 °C generally germinated higher than those steeped at 40 °C and the control, especially for ‘Amugbadu’ from 0-14WAS, the maximum values were still low. Seed germination behaviour in the two cultivars varied with storage period. There was no significant interaction between steeping treatment and cultivar within the first six weeks of storage. Table 2 shows that seed germination was significantly higher in ‘Amugbadu’ than in ‘Oniyaya’ across steeping treatments at 0WAS (Table 2). By 2WAS the germination of

103 'Oniyaya' seeds had improved and was statistically similar to that of 'Amugbadu' up to 6WAS.
104 The interaction between steeping treatment and cultivar on seed germination was significant
105 from 8WAS (Table 3). It is obvious that seeds of 'Oniyaya' steeped at 80 and 97 °C germinated
106 significantly higher than those of 'Amugbadu' from 8 to 20WAS. Germination percentages
107 remained at fairly high levels in 'Oniyaya' for about 12/14WAS in St1-6 (Table 3) as against
108 about 6WAS in 'Amugbadu' (data not shown); generally, no significant differences were
109 recorded between cultivars in St7-9. Table 3 shows further that the cooling protocol adopted
110 following steeping of seeds in hot water at 97 °C affected the longevity of seeds of the two
111 cultivars differently. 'Amugbadu' seeds that were steeped in cold water immediately after hot
112 water exposure (St2) germinated significantly higher at 8 to 12WAS than seeds that were left to
113 cool gradually under ambient condition (St1). Seeds that were steeped at 80, 60 and 40 °C
114 following steeping at 97 °C before cold water-steeping (St3-5) were only significantly lower in
115 germination than St1 seeds at 8WAS. Seeds steeped at 80 °C only, followed immediately by cold
116 water-steeping (St6) survived better than St1 seeds during 8-20WAS. In cultivar 'Oniyaya' there
117 was generally no differential response to cooling protocol in seeds steeped at 97 °C. Seeds
118 steeped at 80 °C only (St6) germinated significantly higher than St1 at 16-20WAS. Table 4 shows
119 that germination was greatly enhanced (*ca* 78-89%) when seeds of both varieties from the
120 control treatment (St9) were steeped in hot water at 97 °C for 5 seconds (St10) following 12-20
121 weeks of storage. Also, seeds of the two varieties previously subjected to 40 and 60 °C steeping
122 prior to storage (St8 and 7 respectively in Tables 3) and which germinated poorly throughout the
123 storage period, had improved germination when subjected to hot water steeping at 97 °C for 5
124 seconds at 18 and 20WAS (St12 and 11 respectively in Table 4). However, "Oniyaya" seeds that
125 were previously subjected to 60 °C before they were again steeped at 97 °C (i.e. St12),

germinated significantly lower (59 and 39% at 18 and 20WAS respectively) than seed of St10 and 11.

Germination was significantly slower at the onset of storage in the unsteeped seeds (St9) than in those steeped in hot water while all hot water-treated seeds germinated at similar rates irrespective of cooling protocol (Figure 1). As from 2WAS, germination rate of St9 (control) seeds generally improved till the end of storage. This trend was also recorded for St5 seeds from 14-20WAS. For all the seeds steeped at 97 °C (irrespective of cooling protocol), as well as those steeped at 80 °C, germination was consistently fast up to 4WAS followed by a steady decline as from 6WAS. Figure 2 reveals that seeds of the two varieties were statistically similar in germination rate within the first 10 weeks of storage. As from 12WAS however, the superiority of “Oniyaya” over “Amugbadu” became significant. Figure 3 shows that prior to storage (i.e. at 0WAS), seeds generally germinated more uniformly when steeped in hot water at 97 °C irrespective of the cooling protocol adopted (St1-5) and when steeped at 80 °C (St6) than when they were steeped at 40 and 60°C (St7 and 8) or when unsteeped (St9). As storage progressed however, whereas germination became more non-uniform in St1-6, there were gradual improvements in St7-9. Germination was better synchronized in “Oniyaya” than in “Amugbadu” at 12, 14 and 16WAS (Figure 4).

Discussion

The considerable increase in the moisture content of seeds of St1-6 during storage at high relative humidity as recorded in this study is an indication of improved permeability due to the softening of the coats by hot water. It is this change in permeability that must have been responsible for the loss of dormancy (and therefore, enhanced germination), a confirmation that dormancy in this species is physical caused by water-impermeable seed coat (Baskin *et al.*, 2000).

151 Oladiran (1986) had hypothesized that hot water may be alleviating dormancy in *Corchorus* by
152 weakening the seed coat. Ayanlaja *etal.* (2001) postulated that some chemicals secreted by
153 earthworm are also capable of weakening woody seedcoat of jute seed. Steeping in water at 40
154 and 60 °C did not result in substantial seed coat permeability and therefore the seed remained
155 relatively dry (with moisture content of an average of about 5-6%) and retained high level of
156 dormancy. Denton *etal.* (2013) have also reported the ineffectiveness of dry heat of 40-60 °C
157 compared to the effectiveness of 90 °C in breaking *Corchorus olitorius* seed dormancy. The
158 effectiveness of temperatures of 80 and 97 °C in overcoming seed dormancy as recorded here,
159 agrees with that reported by Halford (1993) for *C. cunninghamii*. Based on Halford's report,
160 NSW Department of Environment and Conservation (2004) asserted that temperature of 60-70
161 °C which may be produced by low intensity forest fire may not be sufficient to stimulate
162 *C. cunninghamii* seed germination. However, the ability of some seeds exposed to 60 °C to
163 significantly germinate (though low) better than the untreated ones, whereas most seeds
164 germinated well following exposure to 80-97 °C in the current study, is indicative of variability
165 in the depth of dormancy of the individual *C. olitorius* seeds. This view agrees with that
166 expressed by Madeiras *etal.* (2007) for *Phlox pilosa* seeds. The existence of differential rates of
167 seed dormancy release in *C. cunninghamii* was alluded to in the report by NSW Department of
168 Environment and Conservation (2004). Variability of dormancy depth is seen as a survival
169 strategy (Stewart and McGary, 2010) which ensures the perpetuation of species. The poorer
170 longevity of 'Amugbadu' seeds that were subjected to gradual cooling in ambient condition
171 following hot water-steeping compared with those that were steeped in cold water immediately,
172 indicates that hot water steeping at 97 °C must have resulted in embryo damage and that the
173 extent of such damage could be reduced by immediately steeping treated seeds in cold water.

174

175 The poor germination of ‘Oniyaya’ seeds steeped in hot water at 60 °C compared with the values
176 obtained for the untreated seeds following exposure to steeping at 97 °C at 18 and 20WAS, is an
177 indication that the earlier exposure to 60 °C (despite immediate steeping in cold water) damaged
178 the seed embryo even when the treatment did not result in considerable dormancy alleviation.
179 The greatest damage to seed longevity was occasioned by steeping of seed at 80-97 °C. The
180 poorer storability of hot water-steeped seeds as recorded in this study is in agreement with recent
181 report by Tolorunse *et al.* (2013) which revealed that potential seed longevity was adversely
182 affected even by 2-second hot water-steeping. Ibrahim *et al.* (2013) also reported lower
183 germination value for seeds stored following hot water steeping in comparison to unsteeped
184 seeds, though the difference between the two seed lots was insignificant. That treated ‘Oniyaya’
185 and ‘Amugbadu’ seeds still gave acceptable germination percentages at 12/14 and 6WAS
186 respectively despite the adverse effect of hot water steeping on potential seed longevity in the
187 two cultivars used in this study is noteworthy. This result runs contrary to the report by
188 Schippers (2000) that hot water steeped seeds cannot be stored. Better longevity of such seeds
189 will even be attained if storage is in more conducive environment of lower humidity and
190 temperature. The significant variation in seed longevity of the two jute varieties in this study
191 agrees with the view expressed by McDonald (1999) that this trait may be species or variety
192 specific. Differences in seed longevity among varieties have also been reported in other crops
193 (Kamaswara and Jackson, 1996; Mrda *et al.*, 2010; Adebisi *et al.*, 2012). The poorer germination
194 recorded as from 8WAS for ‘Amugbadu’ seeds that were previously steeped at 97 °C compared
195 with ‘Oniyaya’ is an indication of faster deterioration in the former.

196 The enhanced total germination, germination rate and synchronization before storage due to hot
197 water-steeping can be attributed to improved seed coat permeability. Katzman *etal.* (2001) stated
198 that seed treatments may overcome dormancy and enhance germination by altering the physical
199 integrity of seed coverings. This alteration could also constitute damage to the seed coat. Damage
200 to seed coat has been reported to result in seed deterioration in soybean and also reducing storage
201 ability and germination rate (Okabe, 1996). Subsequent decline in performances in respect of
202 total germination, germination rate and synchronization is indicative of decline in seed vigour.
203 However, whereas a decline in seed vigour is normally known to occur before loss of
204 germination (Demir and Mavi, 2008), the two occurred around the same time (*ca* 8WAS) in this
205 study for seeds exposed to 80-97 °C.

206 According to Koornneef *etal.* (2002) both dormancy and germination are influenced by the
207 combined effects of the potential growth of the embryo and the resistance of the surrounding
208 tissues. The significantly better germination of seeds of ‘Amugbadu’ than ‘Oniyaya’ at 0WAS
209 following steeping at 80 and 90 °C, with substantial improvement in the latter as storage
210 progressed as recorded in this study may therefore, suggest that the coats of ‘Oniyaya’ seed still
211 placed significant restraint on the embryo even after steeping and that this was relaxed by
212 2WAS. The subsequent decline in the percentage germination, germination rate and
213 synchronization of the seeds of both cultivars could be adduced to decline in embryo potential
214 growth. Aging has also been reported to result in delayed and decreased germination in other
215 crops (Hacisalihoglu *etal.*, 1999). Contrary to the trend above, the improvement in seed
216 germination rates and synchronization recorded for untreated seeds and those exposed to only 40
217 and 60 °C steeping as seeds aged could be assumed to be due to the weakening of the seed
218 coverings as storage progressed. According to Welbaum *etal.* (1998) germination speed is

influenced by a co-action of the embryo's growth potential and a reduction in the physical strength of surrounding seed coverings.

References

- Adebisi, M. A., Abdul-Rafiu, A. M., Abdul, R. S., Daniel, I. O. and Tairu, F. M. (2012). Seed longevity and vigour of watermelon (*Citrillus lanatus* Thumb Mansf.) seeds stored under ambient humid tropical conditions. *Nigerian Journal of Horticultural Science*, 17: 169-176.
- Ajayi, S. A. and Fakorede, M. A. B. (2001). Effect of storage environments and duration of equilibration on maize seed testing and seedling evaluation. *Maydica*, 46: 267-275.
- Ayanlaja, S.A., Owa, S. O., Adigun, M. O. Senjobi, B. A. and Olaleye, A. O. (2001). Leachate from earthworm castings breaks seed dormancy and preferentially promotes radical growth in jute. *HortScience*, 36(1): 143-144.
- Baskin, J. M., Baskin, C. C. and Li, X. (2000). Taxonomy, anatomy and evolution of physical dormancy in seeds. *Plant Species Biology*, 15: 139-152.
- Chauhan, B. and Johnson, D. E. (2008). Seed germination and seedling emergence of Nalta jute (*Corchorusolitorius*) and Redweed (*Melochiaconcatenate*): Important broadleaf weeds of the tropics. *Weed Science*, 56 (6): 814-819.
- Demir, I. and Mavi, K. (2008). Controlled deterioration and accelerated aging tests to estimate the relative storage potential of cucurbit seed lots. *HortScience*, 43 (5): 1544-1548.
- Denton, O. A., Oyekale, K. O., Adeyeye, J. A., Nwangburuka, C. C. and Wahab, O. D. (2013). Effect of dry heat treatment on the germination and seedling emergence of *Corchorusolitorius* seed. *Agricultural Science Research Journals*, 3(1): 18-22.
- Emongor, V. E., Mathowa, T. and Kabelo, S. (2004). The effect of hot water, sulphuric acid, nitric acid, gibberellic acid and ethephon on the germination of *Corchorus (Corchorustridens)* seed. *Journal of Agronomy*, 3: 196-200.
- Hacisalihoglu, G., Taylor, A. G., Paine, D. H., Hilderbrand, M. B. and Khan, A. A. (1999). Embryo elongation and germination rates as sensitive indicators of lettuce seed quality: priming and aging studies. *HortScience*, 34(7): 1240-1243.

Halford, D. (1993). '*Corchoruscunninghamii*- A conservation assessment', Report to the Australian Nature Conservation Agency, Project No. 317.

Ibrahim, H., Oladiran, J. A. and Mohammed, H. (2013). Effects of seed dormancy level and storage container on seed longevity and seedling vigour of jute mallow (*Corchorusolitorius*). African Journal of Agricultural Research, 8(16): 1370-1374.

ISTA (2005). International rules for seed testing. Edition 2005. International Seed Testing Association. Bassersdorf, Switzerland.

Kamaswara, R. M. and Jackson, M. T. (1996). Seed production environment and storage longevity of Japonica rice (*Oryzasativa* L.). Seed Science Research, 6: 17-21,

Katzman, L. S., Taylor, A. G. and Langhans, R. W. (2001). Seed enhancements to improve spinach germination. HortScience, 36(5): 979-981.

Koorneef, M., Bentsink, L. and Hilhorst, H. (2002). Seed dormancy and germination. Current Opinion in Plant Biology, 5: 33-36.

Labouriau, L. G. (1983). A germinacao das sementes. Organizacao dos Estados Americanos. Programa Regional de Desenvolvimento Cientifico e Tecnologico Serie de Biologia. Monografia 24.

Madeiras, A. M., Boyle, T. H. and Autio, W. R. (2007). Germination of *Phloxpilosa* L. seeds is improved by gibberellic acid and light but not scarification, potassium nitrate, or surface disinfestations. HortScience, 42(5): 1263-1267.

McDonald, M. D. (1999). Seed deterioration: physiology, repair and assessment. Seed Science and Technology, 27:177-237.

Mrda, J., Crnobarac, J., Dusanic, N., Radic, V., Miladinovic, D., Jovic, S. and Miklic, V. (2010). Effect of storage period and chemical treatment on sunflower seed germination. HELIA, 33 (53): 199-206.

Nkomo, M. and Kambizi, L. (2009). Effect of pre-chilling and temperature on seed germination of *Corchorusolitorius* L. (Tiliaceae) (Jews mallow), a wild leafy vegetable. African Journal of Biotechnology, 8(6): 1078-1081.

NSW Department of Environment and Conservation (2004). Draft Recovery Plan for *Corchoruscunninghamii*, NSW Department of Environment and Conservation, Hurstville. 17p

- Okabe, A. (1996). Inheritance of seed coat cracking and effective selection method for resistance in soybean. *Japan Agricultural Research Quarterly*, 30: 15-20.
- Oladiran, J. A. (1986). Effect of stage of harvesting and seed treatment on germination, seedling emergence and growth in *Corchorusolitorius* 'Oniyaya'. *Scientia Horticulturae*, 28: 227-233.
- Primack, R. B. (1980). Variation in the phenology of natural populations of montane shrubs in New Zealand, *Journal of Ecology*, 68: 849-862.
- Ranal, M. A. and Santana, D. G. (2006). How and why to measure the germination process? *Revista Brasileira de Botanica*, 29(1): 1-11.
- SAS (1999). Statistical Analysis software (SAS). System for windows. SAS User's Guide; Statistics, Version 9.1. SAS Institute Inc. Cary. NC, USA. P. 1028.
- Schippers, R.R. (2000). *African indigenous vegetables. An overview of the cultivated species*. Chatham, UK. Natural Resources Institute/ACP-EU Technical Centre for Agricultural and Rural Cooperation.
- Stewart, J. R. and McGary, I. (2010). Brief exposure to boiling water combined with cold-moist stratification enhances seed germination of New Jersey tea. *HortTechnology*, 20(3): 623-625.
- Tolorunse, K. D., Ibrahim, H. and Oladiran, J. A. (2013). Hot water-steeping enhanced germination of jute mallow (*Corchorusolitorius*) seeds. *Advanced Crop Science*, 8: 542-548.
- Velempini, P., Riddoch, I. and Batisani, N. (2003). Seed treatment for enhancing germination of wild okra (*Corchorusolitorius*). *Experimental Agriculture*, 39: 441-447.
- Welbaum, G. E., Bradford, K. J., Yim, K. O., Booth, D. T. and Oluoch, M. O. (1998). Biophysical, physiological and biochemical processes regulating seed germination. *Seed Science Research*, 8: 161-172.

Table 1. Percentage moisture content (on wet weight basis) of seeds of the various treatments at the onset and after 6 and 18 weeks of storage at 83% relative humidity and 33 °C.

Cultivar	Steeping Treatment	Storage period (weeks)		
		0	6	18
‘Amugbadu’	St1	5.5	9.9	9.4
	St2	6.0	10.4	10.4
	St3	5.8	10.6	9.5
	St4	5.6	9.5	10.0
	St5	6.1	10.4	10.0
	St6	5.9	10.0	10.0
	St7	5.1	7.0	6.1
	St8	5.3	5.6	5.1
	St9	4.8	5.4	5.5
‘Oniyaya’	St1	4.6	10.5	11.3
	St2	5.0	10.6	11.0
	St3	5.9	10.6	10.7
	St4	6.3	10.1	10.3
	St5	6.1	9.7	10.4
	St6	6.4	10.2	9.8
	St7	4.7	5.4	5.0

St8	5.3	5.5	5.7
St9	5.8	4.9	5.6

361

362

363

364

365

366

367

368

369

370

371

372

373

374

375 Table 2. Mean effect of cultivar on seed germination percentage at 0-6WAS

Cultivar	Storage period (weeks)			
	0	2	4	6
‘Amugbadu’	62a	62a	60a	59a
‘Oniyaya’	51b	60a	58a	61a

376

377 Means followed by the same letter in a column are not significantly different at $P \geq 0.05$ using the
 378 Duncan’s Multiple Range test.

379

380

381

382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397

398 Table 3. Interaction effect of cultivar and steeping treatment on the germination percentage of
399 *Corchorusolitorius* seeds at 8-20WAS

Cultivar	Steeping treatment	Storage period (weeks)						
		8	10	12	14	16	18	20
‘Amugbadu’	St1	57de	40c	29c	13de	5def	3d	1ef
	St2	65bc	57b	46b	12de	11cde	7d	3def
	St3	52e	54bc	37bc	10de	8cdef	5d	1ef
	St4	52e	49bc	38bc	12de	15cd	5d	4def
	St5	49e	51bc	39bc	13de	7cdef	2d	1ef
	St6	72abc	58b	46b	32c	18c	16c	7cd
	St7	15f	16d	9d	24cd	5def	4d	6cd
	St8	4g	1f	4de	4ef	1f	1e	3def
	St9	5g	6ef	4de	1fg	1f	4d	4def
‘Oniyaya’	St1	84a	79a	75a	66ab	38b	40b	35b

St2	89a	84a	75a	63b	47ab	45ab	61a
St3	71abc	85a	71a	66ab	33b	52a	34b
St4	86a	88a	72a	77a	50a	57a	52a
St5	84a	85a	74a	79a	49a	41b	33b
St6	81a	83a	74a	77a	53a	50a	56a
St7	6fg	8de	6de	13de	1f	2e	13c
St8	2g	1f	3e	0g	1f	2d	1f
St9	2g	5ef	3e	6ef	3ef	4d	3def

Means followed by the same letter in a column are not significantly different at $P \geq 0.05$ using the Duncan's Multiple Range test.

St1 = steeped at 97 °C for 5 seconds and air-cooled at room temperature; St2 = steeped at 97 °C for 5 seconds and immediately steeped in cold water; St3 = steeped at 97 °C for 5 seconds followed by 5 seconds steeping at 80 °C, followed by steeping in cold water; St4 = steeped at 97 °C for 5 seconds followed by 5 second steeping at 60 °C followed by steeping in cold water; St5 = steeped at 97 °C for 5 seconds followed by 5 seconds steeping at 40 °C followed by steeping in cold water; St6 = steeped at 80 °C for 5 seconds followed by steeping in cold water; St7 = steeped a 60 °C and immediately steeped in cold water; St8 = steeped at 40 °C for 5 seconds and immediately steeped in cold water; St9 = control (no hot water steeping).

Table 4. Germination percentages of previously untreated seeds that were subsequently steeped at 97 °C for 5 sec. (St10) and those previously steeped at 40 and 60 °C prior to storage that were subsequently steeped at 97 °C for 5 sec. (St11 and 12 respectively) following storage for the periods indicated.

Cultivar	Steeping treatment	Storage period (weeks)				
		12	14	16	18	20
'Amugbadu'	St10	84a	86a	78a	83ab	85a
	St11	-	-	-	84ab	72b
	St12	-	-	-	72b	77ab
'Oniyaya'	St10	89a	82a	80a	82ab	82a
	St11	-	-	-	90a	84a

St12 - - - 59c 39c

Means followed by the same letter in a column are not significantly different at $P \geq 0.05$ using the Duncan's Multiple Range test.

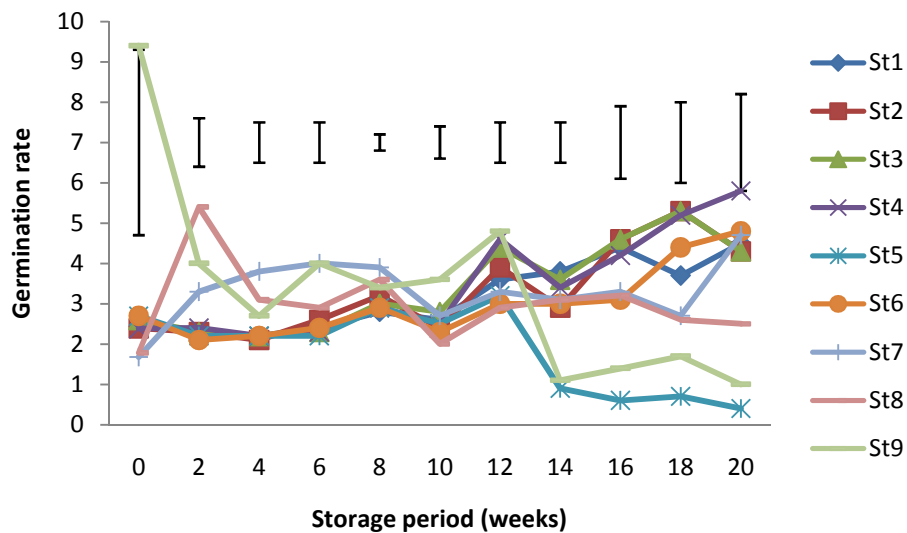


Fig. 1 Mean effect of steeping treatment on seed germination rate following storage

I: LSD bar at P=0.05

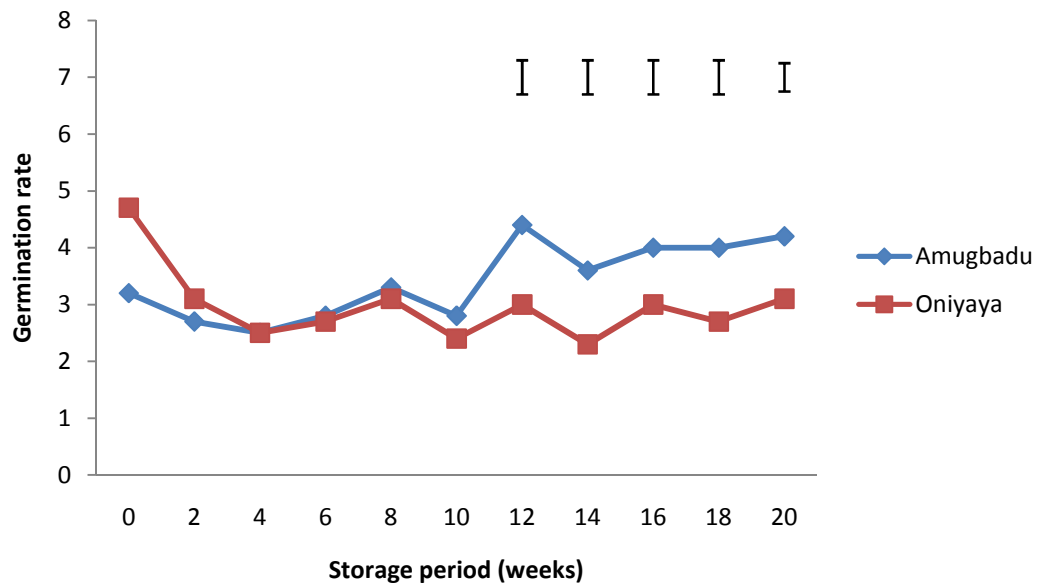
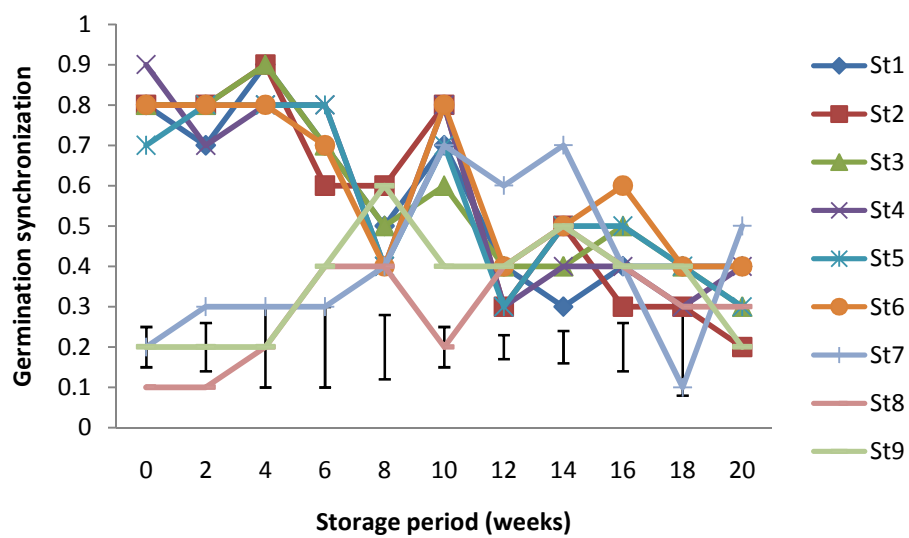


Fig. 2Effect of cultivar on seed germination rate following storage

I: LSD bar at P=0.05



458 **Fig. 3**Effect of steeping treatment on seed germination synchronization following storage

459 **I: LSD bar at P=0.05**

460

461

462

463

464

465

466

467

468

469

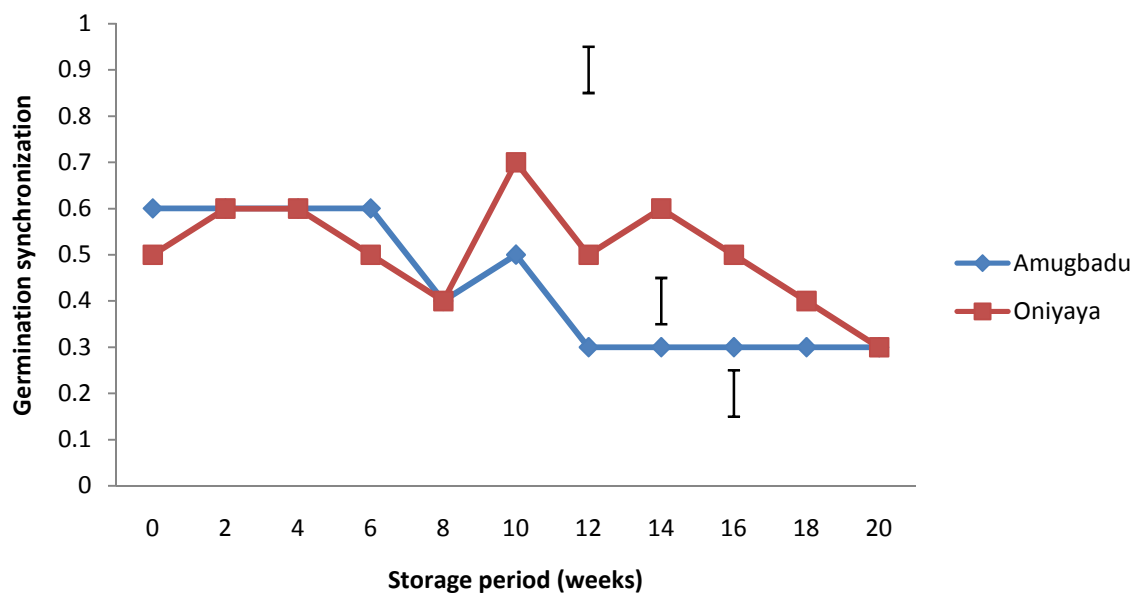


Fig.

4Effect of cultivar on seed germination synchronization following storage

I: LSD bar at P=0.05