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EFFECT OF HYDRO AND OSMO PRIMING ON THE PHYSIOLOGICAL QUALITIES OF STORED COTTON SEED (*Gossypium Spp.* L.)

H. Saleh, A.I. Yahaya, H. Abubakar and R.A. Sami

Department of Plant Science, Institute for Agricultural Research- Samaru, Ahmadu Bello University, Zaria-Nigeria

ABSTRACT

Planted seeds require the highest probability of survival and plants need to grow as efficiently as possible to help support improved productivity to meet the increasing demands of society for both food and fiber. However, poor seed germination in field is a major challenge to cotton farmers in the Guinea savanna zone of Nigeria. Therefore, this study seeks to determine the physiological qualities (germination and vigour) of the Nigerian cotton varieties with a view to determine the most efficient cotton seed priming treatment method for the farmers. Six (6) IAR commercial cotton varieties (SAMCOT 8,9,10, 11, 12, and 13) and treatments (polyethylene glycol 6000 20% solution, hot water and a control) were studied in a factorial experiment based on completely randomized design with two replications. Eight parameters were considered for data collection viz germination percentage, percentage of first count, germination rate, root and shoot length, root and shoot fresh weight, and seedling dry weight. The data collected were subjected to statistical analysis using the analysis of variance (ANOVA). The best variety with highest first count germination, total germination and germination index was SAMCOT 8 under 20 hours treatment with polyethylene glycol 20% solution followed by SAMCOT 11. Soaking seeds in hot water for 30 seconds gave the highest first count germination. The Control had the least total germination and germination index. It could therefore be concluded that application of PEG 6000 20% solution for 20 hours is effective for SAMCOT 8 and 10 while PEG treatment for 15 hours is better for SAMCOT 13.

Keywords: Cotton; priming; polyethylene glycol; germination; vigour

INTRODUCTION

The cotton sector contributes significantly to the economies of a number of developing countries, as well as to the livelihoods of millions of rural smallholder farmers worldwide. The world production of cotton was valued at about USD 46 billion, while global trade reached USD 15 billion (FAOstat, 2021). Moreover, the cotton industry employs an estimated 150 million people across 75 countries, making the cotton sector an important contributor to the achievements of the 2030 Agenda for Sustainable Development (FAO, 2021). The leading cotton producing countries worldwide in 2021 includes China (6,423 metric tons), India (6,162 metric tons), United States (3,181 metric tons) and Brazil (2,341 metric tons) while in Africa Benin Republic is the leading producer with 316 metric tons (Statista 2021). Nigeria used to be Africa's leading cotton producer and 12th largest in the world.

Increasing the yield and the fibre quality of cotton is the main goal of most breeding programs (Mert *et al.*, 2003). Many studies were conducted to produce cottons with high germination and emergence rates in various environmental conditions. Germination is one of the most salt-sensitive plant growth stages and severely inhibited with increasing salinity (Sosa *et al.*, 2005) while rapid seed germination and emergence is an important factor in crop successful establishment (Harris *et al.*, 1999). Cotton is considered a moderately salt tolerant crop, but its yield is markedly affected due to poor germination and subsequent abnormal plant development (Ashraf, 2002). Seed priming treatments such as osmo-priming, hydro-priming, matric-priming and hormone-priming have been employed to accelerate the germination, seedling growth and yield in most of the crops under normal and stress conditions (Basra *et al.,* 2003).

Different cultivars may respond differently to low soil moisture at planting, which raises the possibility of choosing particular varieties for better establishment in adverse conditions. It is also possible that different varieties may respond differently to seed priming.

Polyethylene glycol (PEG) has been used by several investigators to impose water stress on plants and seeds, by decreasing the osmotic potential of the growing medium (Singh *et al.*, 2015). This can help one understand how seeds may respond to physical conditions at planting.

Cotton growth and development includes germination, emergence, seedling growth, reproduction, and maturation which help to support improved productivity to meet the increasing demands of society for both food and fiber. However, poor seed germination which lead to reductions in yield is a major challenge to cotton farmers in the Guinea savanna zone of Nigeria.

The poor cotton seed germination that results from the low viability poses a major threat to the efforts by the Federal government of Nigeria to revamp the ailing textile industry that depends solely on the production of cotton. Therefore, any technology that can enhance germination, seedling vigour and stand count per unit area of the cotton field should be appreciated.

Predicting seed and seedling performance in the field is difficult because the seeds are subjected to a wide range of climatic and soil conditions from year to year. Therefore, laboratory tests to determine potential seedling performance over this wide range of possible conditions are required. In response to this need, the purpose of this study was to identify accurate, reliable, and economically feasible seed priming method that predict seedling vigor for use by the farmer and the seed industry.

Cotton farmers do experience many vacant spots in the cotton fields after emergence. This always necessitates subsequent supply to fill the vacant spaces and the seedling emerged later were suppressed by the older plants and will eventually lower the yield beside the operational cost. A better understanding of the quality of seed to be planted would give an idea on whether improvement on its germination is necessary, this will in turn provide a better solution to germination problem. Therefore, the major objective of this research was to determine the most efficient cotton seed priming method for better germination and vigour.

MATERIALS AND METHODS

Study Area

The research was conducted at seed technology laboratory of the Institute for Agricultural Research (IAR), Ahmadu Bello University, Samaru-Zaria. Samaru is located on latitude 11^0 11`N, and longitude 7^0 38'E. Materials used during the experiment include: Stored samples of six IAR commercial cotton varieties (SAMCOT 8,9,10, 11, 12, and 13) from 2018 cropping season harvest (1kg each variety), Polyethylene glycol salt (6000) 20% solution, hot water, petri dishes/beakers, graduated cylinder, germination boxes, river sand, electric kettle, seed moisture tester, wheelbarrow, sieve and container (bucket).

Experimental Design

The initial germination test was conducted in the laboratory using germination boxes filled with sand. The experiments consist of six varieties of cotton as treatments with four replications and 6 pots per replicate. Twenty-five seeds from each variety were sown per pot in a completely randomized design (CRD).

Data Collection

The seeds were watered at 2 days interval and germination counts were recorded daily based on the number of seeds that germinated from fourth day after planting referred to as "first count" until day twelve referred to as "final count" day. Evaluation was done by separating the seedlings in the germination box into different categories; normal and abnormal seedlings and the sand were sieved from each box to count the number of dead seeds and fresh ungerminated seeds from each box. The data collected were expressed as percentage normal seedlings (%NS), percentage abnormal seedlings (%AS), percentage fresh ungerminated seeds (%FU) and percentage dead seeds (%DS).

Vigor test: This was assessed on the "Speed of germination**"** which is the number of seeds that germinated per day divided by the number of days added together from day 4 to day 12 and is expressed as Germination Index (GI).

$$G.I. = \frac{\text{No of seeds germinated per Day4}}{4} + \frac{\text{No of seeds germinated per Day5}}{5} + \dots \frac{\text{No of seeds germinated per Day } n}{n}$$

Experiment 2: Effects of different Invigoration period on Cotton seeds germination and Vigor

Having identified the initial germination and vigor of each variety, the seeds were invigorated using two priming methods (Hydro priming and Osmo-priming); that is hot water treatment at two different regimes (1 minute and 30 seconds), polyethylene glycol (PEG 6000 20% solution) for a period of 20 hours and 15 hours and a control (no treatments applied/non primed).

One hundred seeds from each variety were immersed into the hot water treatment for a period of 1 minute and another 100 seeds for 30 seconds. The primed seeds were subjected to germination test without re-drying replicated two times with six germination boxes per plot using sand as substratum, 50 seeds were sown in each box. Another 100 seeds from each variety were subjected to germination test without priming as a control. The experiment was laid as 6×5 factorial in Split Plot Design with 2 replications having 30 germination boxes per replicate and 50 seeds of each treatment combination sown per box (ISTA Rules, 2012).

The second priming method consists of two sets of 100 seeds from each variety immersed in polyethylene glycol 6000 20% solution in beakers for 20 hours and 15 hours respectively. The primed seeds were dried to their initial moisture content under lab condition for one day. The dried seeds were subjected to germination test using germination boxes and sand as substratum in the laboratory as stated above having priming materials as the main plots and cottonseed varieties as subplots. Germinations counts (number of seeds germinated daily) were recorded daily from day four after planting to day twelve while percentage total germination (%TG) was recorded as: total no. of seeds germinated/total no of seeds x 100.

The root length (cm) and shoot length (cm) were measured with ruler and the values recorded. Roots and shoot of 10 samples in each treatment was placed in paper envelope and oven dried at 80 °C for 2 hours. The dried samples were weighed with a digital scale. Weight of the empty envelope recorded initially and was subtracted from the overall dried weight.

Data Analysis

Data collected were subjected to analyses of variances (ANOVA) using General Linear Model module of SAS version 9.0 as described by Kaps and Lamderson (2004).

RESULTS

The result from analysis of variance for six IAR commercial varieties of cotton showed highly significant difference ($p<0.05$) for first day count, total germination, and germination index (Table 1).

Table 1: Mean squares from the analysis of variance for germination and vigour traits of six IAR commercial cotton varieties at Samaru in 2021

Source of Variation	Df	PFC	PTG	GI	RL	SL	SW	RW	SDW
Replication	1	173.40	437.40	48.30	22.43	6.14	0.73	0.0026	0.0031
Variety(T)	5	347.43**	635.27**	155.9**	10.42NS	2.47NS	1.38NS	0.0114NS	0.0321NS
Treatment(V)	4	224.77**	346.00**	76.05**	10.23NS	7.21*	0.62NS	0.05NS	0.0153NS
T × V	20	161.33**	44.20NS	18.97*	5.44NS	2.64NS	0.60NS	0.014NS	0.0170NS
Error	29	31.88	53.54	6.97	4.50	2.31	1.37	0.021	0.0154
CV %		13.69	12.87	9.17	25.26	14.11	19.54	15.84	17.67

df- Degree of freedom, CV- Coefficient of variability, PGFC- % Germination of first count, PTG- Total germination, GI- Germination index, RL- Root length, SL- Shoot length, SW- Seedling fresh weight, RW- Root fresh weight, SDW- Seedling dry weight.
NS = not significant at P >0.05; * = significant at P <0.05; ** = highly Significant at P <0.01

However, there was no significant difference ($p>0.05$) on root length, shoot length, seedling fresh weight, root fresh weight, and seedling dry weight. The values for percentage germination of first count, total germination, germination index and shoot length under treatments were highly significant, while root length, seedling fresh weight, root fresh weight and seedling dry weight showed no significant differences. Moreover, varieties and treatments interactions for first count day were highly significant and significant for germination index but all other parameters recorded no significant difference interaction.

The means for the varieties on first day count, total germination and germination index showed significant differences (Table 2). The response of the varieties on first count day recorded a range of 48.20 to 32.00 with SAMCOT 8 having the highest means of (48.20) followed by SAMCOT 11 (47.00). SAMCOT 12 (42.00) ranked third followed by SAMCOT 9 (40.00) and SAMCOT 13 (37.80). However, SAMCOT 10 recorded the least value (32.00).

Table 2: Mean varietal response to first count, total germination, and germination index at Samaru in 2021.

Varieties (V)	PFC	PTG	GI
SAMCOT 8	48.20[a]	64.80[a]	33.24[a]
SAMCOT 9	40.00[c]	50.80[cd]	26.67[c]
SAMCOT10	32.00[d]	45.60[d]	22.86[d]
SAMCOT11	47.00[ab]	65.60[a]	32.76[a]
SAMCOT12	42.00[bc]	59.80[ab]	29.75[b]
SAMCOT13	37.80[c]	54.40[bc]	27.43[bc]
CV (T)	2.05	2.05	2.05

CV (T) - Critical value of t, PGFC – Percentage germination of first count, PTG – Percentage total germination, GI – Germination index.

For varietal response on total germination (PTG), SAMCOT 11 (65.60) and SAMCOT 8 (64.80) recorded the highest germination percentage followed by SAMCOT 12 (59.80) and SAMCOT 13 (54.40), the least percentage total germination was recorded on SAMCOT 10 (45.60). Germination index (seed vigor) was very high with SAMCOT 8 (33.24) and SAMCOT 11 (32.76) followed by SAMCOT 12 (29.75) and SAMCOT 13 (27.43).

The mean difference between the treatments on first count day, total germination and germination index and shoot length were significant (Table 3). First count day percentage (PFC) was significantly affected by seed priming treatments. Superior first count day was observed from seeds primed with HOT water 30 seconds (45.20) followed by Polyethylene glycol 6000 15 hours (44.33) while the lowest first count day percentage was recorded from the control (34.83). There was no significant difference among other priming agents in terms of inducing effective germination on first count day; Hot water 1 minute (43.00) and polyethylene glycol 6000 20 hours (38.83). Total germination percentage was significantly affected by seed priming treatments. The higher germination was observed from seeds primed with polyethylene glycol 6000 20 hours (63.67) and the lowest germination percentage was from the control (34.83). The difference among other priming agents in terms of inducing effective germination is not significant; polyethylene glycol 6000 15 hours (57.83), HOT water 30 seconds (57.67) and HOT water 1 minute (56.33). However, cotton speed of germination (GI) was significantly affected by seed priming treatments. Greater germination index (GI) was observed from seeds primed with polyethylene glycol 6000 for 20 hours (31.03) and the lowest germination index was from the control (24.60).

The differences among other priming agents in terms of enhancing germination and seed vigour was not significant, however polyethylene glycol 6000 15 hours (30.40) ranked second followed by HOT water 30 seconds (29.30) and HOT water 1 minute (28.63). Cotton seeds treated with polyethylene glycol for 15 hours produced plants with longest shoot length (11.69) when compared to those treated with other priming agents and Hot water 30 seconds which had the shortest shoot length plants (9.54). For Hot water 1 minute (10.92) and untreated (control – 10.20) and polyethylene glycol 20 hours (10.83) cotton plant shoot length was not significantly different within the treatments (Table 3).

Table 3: Percentage of first day count, percentage total germination, germination index and shoot length as affected by various treatments at Samaru in 2021.

Treatments (T)	PFC	PTG	GI	SL
PEG 6000 (20HRS)	38.83^{bc}	63.67^{a}	31.03^{a}	10.83^{a}
PEG 6000 (15HRS)	44.33a	57.83ab	30.40ab	11.69a
HOT H_20 (1min)	43.00ab	56.33b	28.63b	10.92a
HOT H_20 (30secs)	45.20a	57.67ab	29.30ab	9.54b
CONTROL	34.83c	48.67c	24.60c	10.92a
CV (T)	2.05	2.05	2.05	2.05

PFC = Percentage of first day count, PTG = percentage total germination, GI = germination index, SL = shoot length
CV (T) = Critical value of t

There was no significant difference in the interaction between varieties and treatments with respect to percentage total germination, root length, shoot length, seedling weight, root fresh weight and seedling dry weight (Table 4).

Table 4: Mean Performance for percentage total germination, root and shoot length, seedling fresh weight, root weight and seedling dry weight as affected by varieties and treatments interaction at Samaru in 2021.

Varieties (V)	PTG	RL	SL	SW	RW	SDW
SAMCOT 8	64.80^{a}	7.42^{bc}	10.73^{a}	5.79^{ab}	0.93^{a}	0.62^{b}
SAMCOT 9	50.80^{cd}	8.86^{ab}	11.23^{a}	5.89^{ab}	0.91^{a}	0.65^{ab}
SAMCOT 10	45.60^{d}	7.16^{c}	10.12^{a}	5.47^{b}	0.88^{a}	0.74a
SAMCOT11	65.60^{a}	9.70^{a}	10.62^{a}	6.57^{a}	0.97^{a}	0.75^{a}
SAMCOT12	59.80^{ab}	9.18^{ab}	11.48^{a}	6.11^{ab}	0.88^{a}	0.75^{a}
SAMCOT13	54.40^{bc}	7.95^{bc}	10.50^{a}	6.13^{ab}	0.91^{a}	0.71^{ab}
Mean	56.83	8.38	10.78	6.00	0.91	0.70
LSD	6.70	1.94	1.40	1.10	0.13	0.11
CV %	12.87	9.17	14.11	19.54	15.84	17.67
Treatments (T)						
PEG 6000 (20hrs)	63.67^{a}	6.96^{b}	10.83^{a}	5.79^{a}	0.86^{b}	0.68^{a}
PEG 6000 (15hrs)	57.83^{ab}	8.64^{ab}	11.69^{a}	6.18^{a}	0.94^{ab}	0.74^{a}
HOT H_20 (1min)	56.33^{b}	9.13^{a}	10.92^{a}	6.22^{a}	0.85^{b}	0.67^{a}
HOT H_20 (30secs)	57.67^{ab}	9.17^{a}	9.54^{b}	5.72^{a}	1.00^{a}	0.68^{a}
Control	48.67^{c}	8.00^{ab}	10.92^{a}	6.10^{a}	0.92^{ab}	0.74^{a}
Mean	58.63	8.38	10.78	6.00	0.91	0.70
LSD	6.11	1.77	1.27	1.00	0.121	0.104
CV%	12.87	9.17	14.11	19.54	15.84	17.67
V × T	NS	NS	NS	NS	NS	NS

PEG- Polyethylene glycol 20% 6000, LSD- Least significant difference, CV- Coefficient of variability, PTG- Percentage total germination, RL- Root length, SL- Shoot length, SW- Seedling fresh weight, RW- Root fresh weight, SDW- Seedling dry weight, NS – Not significant, V × T – Variety and Treatment interaction.

Moreover, the difference between SAMCOT 8, 9, 10, 11, 12 and 13 in response to these growth parameters was not significant. Percentage germination of first count was affected by treatments and varieties interaction (P<0.01). There was significant difference (p<0.05) between SAMCOT 8 and 13. SAMCOT 8 treated with polyethylene glycol 6000 20% solution recorded the highest means (64.00) followed by SAMCOT 11 (57.00) treated with hot water 30 seconds (Table 5). SAMCOT 8 and SAMCOT 11 also recorded the highest means in interaction with polyethylene glycol 6000 at 15 hours all with means of (52.00). However, the interaction of hot water 20 minutes with variety showed significant difference with SAMCOT 12 having the highest means (52.00) followed by SAMCOT 11 (49.00) and SAMCOT 10 recorded the least mean (26.00). Moreover, SAMCOT 11 performed better under control (49.00) as compared to other varieties.

Table 5: Mean performance for percentage germination of first count (PGFC) as affected by varieties and treatments interaction at Samaru in 2021.

T × V	PEG6000 (20hrs)	PEG6000 (15hrs)	Hot water (1min)	Hot water (30secs)	Control
Varieties (V)					
SAMCOT 8	64.00	52.00	43.00	50.00	32.00
SAMCOT 9	37.00	40.00	46.00	41.00	36.00
SAMCOT10	41.00	33.00	26.00	36.00	26.00
SAMCOT11	28.00	52.00	49.00	57.00	49.00
SAMCOT12	37.00	38.00	52.00	40.00	43.00
SAMCOT13	26.00	51.00	42.00	47.00	23.00
$LSD_{(0.05)}$	4.7146	4.7146	4.7146	4.7146	4.7146

PEG – Polyethylene glycol 6000 20% solution, T × V – Treatment and Variety interaction.

Table 6: Mean performance for germination index (GI) as affected by varieties and treatments interaction at Samaru in 2021.

T × V	PEG 6000 (20hrs)	PEG 6000 (15hrs)	Hot water (1min)	Hot water (30secs)	Control
Varieties(V)					
SAMCOT8	42.75	33.09	32.65	33.55	24.55
SAMCOT9	27.85	27.85	27.50	26.80	23.37
SAMCOT10	28.50	24.70	19.10	22.25	19.80
SAMCOT11	30.70	33.00	34.00	34.90	31.20
SAMCOT12	29.45	31.10	31.66	28.45	28.10
SAMCOT13	26.95	32.50	27.30	29.80	20.60
$LSD_{(0.05)}$	2.2051	2.2051	2.2051	2.2051	2.2051

PEG – Polyethylene glycol 6000 20% solution, T × V – Treatment and Variety interaction.

The difference between SAMCOT 8 and SAMCOT 13 in response to polyethylene glycol in terms of speed of germination was statistically significant (p<0.05). SAMCOT 8 recorded the highest means (42.75) followed by SAMCOT 11 (30.70). The difference between SAMCOT 9, 10, 12 and 13 was not significant. Similarly, SAMCOT 8 showed significant difference between other varieties in response to polyethylene glycol 6000 (33.09) followed by SAMCOT 11 (33.00) and SAMCOT 13, SAMCOT 10 recorded the least mean (24.70) (Table 6). However, SAMCOT 11 recorded the highest means (34.00) in response to hot water 1 minute treatment followed by SAMCOT 8 (32.65), the difference between

SAMCOT 9, 12 and 13 was not significant whereas SAMCOT 10 recorded the lowest mean (19.10). Moreover, SAMCOT 11 showed the highest mean (34.90) in response to hot water 30 seconds treatment followed by SAMCOT 8 (33.55) while SAMCOT 10 also recorded the least mean (22.25). SAMCOT 11 showed significant difference between other varieties under control (31.20) as compared to SAMCOT 10 (19.80).

DISCUSSION

Results showed significant differences in the germination percentages of the varieties primed with hot water and polyethylene glycol 6000 20% solution under different priming durations. Moreover, treatments had some positive effects on germination percentages, germination index and shoot length of the cultivars when compared to the control. The best variety of cotton that produced the highest first count germination, total germination and germination index was SAMCOT 8 under 20 hours treatment with polyethylene glycol 20% solution (64.00) followed by SAMCOT 11 (57.00) treated with hot water for 30 seconds. This corresponds to the findings of Jie *et al.* (2002) who reported that seed priming with 30% PEG for 24 hours resulted in increase in the cell activity of superoxide dismutase and peroxidase and a rapid increase in the respiratory intensity. This according to him was associated with an increase in germination and vigour and decreased germination percentage and rate under control compared to the primed seeds. Shoot length was high with polyethylene glycol 6000 treatment for 15 hours (11.69) compared to hot water treatment (9.54) for 30 seconds.

Findings of this study revealed significant varietal differences, where SAMCOT 11 recorded higher final percent total germination (65.60) compared to SAMCOT 10 (45.60). Furthermore, significant difference was observed on germination index between SAMCOT 8 (33.24) and SAMCOT 10 (22.86). Percentage of first count was high with SAMCOT 8 (48.20) in comparison with SAMCOT 10 (32.00) and SAMCOT 13 (37.80).The differences among the varieties in terms of percentage germination of first count, percentage total germination and germination index might be due to genetic factors, although it is possible that differences in seed quality resulting from environmental factors (differences in temperature and harvesting techniques by different farmers) and the post-harvest storage conditions of the seed could also have been responsible.

Among the priming agents, application of polyethylene glycol for 15 hours induced greater shoot length (11.69) as compared to hot water treatment for 30 seconds (9.54). This is in line with the findings of Hatice and Yuksel (2015), who found out that most catalase enzyme activity were related to priming with Polyethylene glycol 6000. However, treatment with hot water for 30 seconds recorded the highest germination on first count day. This according to Bolek *et al.* (2013) could be due to genotypic differences in response to hot water application. They however suggested that further work should be done to test different genotypes for cooling and drying time after priming with hot water. Similar findings were also reported by Ghassemi-Golezani *et al.* (2008) on different cotton cultivars; hot water treatment increased the germination percentages of the cultivars by 26.8, 71.4, and 7.2% for Maraş-92 cultivar, Sayar-314 cultivar, and Stoneville-468 cultivar, respectively. Furthermore, all cultivars showed low germination rates after hot water treatment for 60–240 seconds. The favorable response of SAMCOT 11 to hot water treatment at 30 seconds with relatively average emergence, total germination and germination rate might be due to faster water uptake and earlier initiation of metabolism processes, which determine radicle protrusion.

There was no significant difference between seeds primed with polyethylene glycol 6000 20% solution, hot water and control with respect to root and shoot length, seedling and root fresh weight and seedling dry weight. This may be attributed to the homogeneity of the growing medium and the fact that these parameters mostly depend on the conditions they are subjected to after initial germination and seedling emergence unlike germination and vigour that have to do with genotypic and post-harvest qualities of the seed. All the seeds sown under control recorded the least means. This corroborate the findings of Aziza *et al.* (2004) who reported significant decrease in emergence time and increase in final germination count which could be attributed to the fact that seed priming induces range of biochemical changes such as hydrolysis, activation of enzymes and dormancy breaking which are required to start the germination process.

CONCLUSION

The study was conducted to determine the comparative germination and vigor of Six IAR commercial cotton (*Gossypium spp* L.) varieties to different seed priming treatments. Both six varieties produced plants that had similarities in percentage total germination, root lengths, shoot length, shoot length, root fresh weight, seedling fresh and dry weight but differ in percentage germination of first count and germination index.

Cottonseed varieties responded very well to different priming agents in terms of total germination percentage and vigor. SAMCOT 8 gave the highest total germination and germination index in combination with polyethylene glycol 6000 20% treatment for 20 hours. Based on the results obtained in this study, it can be concluded that application of PEG 6000 20% solution for 20 hours is effective for SAMCOT 8 and SAMCOT 10 while PEG treatment for 15 hours be used for SAMCOT 13. Hot water treatment for 30 seconds with SAMCOT 11 and hot water treatment for 1 minute with SAMCOT 12 and SAMCOT 9 will be effective for improving germination and seedling establishment.

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