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Germination and Vigour Responses of Seeds of Three Cassava Varieties to Pre-germination Treatments and Storage Durations

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Authors' contributions

This work was carried out in collaboration between all authors. Authors NAPO, BKB and JMA designed the study, wrote the protocol, performed the statistical analysis, managed the literature searches and wrote the first draft of the manuscript. Authors PKT and SEO contributed to the protocol writing and managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Seeds of three cultivars of cassava were collected from the CSIR-Crops Research Institute at Fumesua in the Ashanti Region of Ghana to determine the effect of storage periods and seed pre-germination treatments on the germination percentage and vigour of seeds from three varieties of cassava. The experiment was conducted under laboratory conditions and a 3 x 3 x 7 factorial in Completely Randomized Design (CRD) with three replications was used. The first factor was cultivar at three levels (Ahwengyanka-1, Ahwengyanka-2 and Aworowa-3); the second factor was pre-germination treatments at seven levels (hot water, cold water, mechanical scarification, three concentrations of acid scarification and no treatment as the control); the third factor was storage period at three levels (no storage, three months storage and six months storage). The study

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revealed that seeds of cassava stored for up to three months produced about 40% germination after undergoing the various pre-germination treatments. Seeds of the Aworowa-3 cultivar stored for six months produced the highest germination percentage of 61.0%. Seeds mechanically scarified with sand paper produced the highest germination percentage of 48.9% whereas seeds with no treatment recorded the least percentage of 34.8%. The study concluded that Aworowa-3 seeds without storage produced a higher germination percentage than Ahwengyanka-1 and Ahwengyanka-2 seeds without storage but all the seeds of the three varieties had the highest germination percentage when stored for six months.

Keywords: Dormancy; conductivity; scarification; breeding; clones.

1. INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is the most important tropical root crop in many parts of Africa because of its edible roots [1]. It is also cultivated for its leaves and tender shoots which are rich sources of proteins, vitamins A, B, C, and other minerals are consumed as vegetable [2,3]. In Africa, Ghana ranks third after Nigeria and the Democratic Republic of Congo as the largest cassava producing country [1]. Cassava in Ghana is grown across all the agro-ecological zones and contributes 22% to Ghana's Agricultural Gross Domestic Product (AGDP) [4].

However, a major problem with freshly harvested cassava seeds is its characteristic dormancy which is a well-documented occurrence in *Euphorbiaceae* genera [5-8]. The period of dormancy in cassava seeds could last for a minimum period of 6-9 months under ambient temperatures [9] with adverse consequences on breeding programmes. Dormancy in seeds, therefore is known to inhibit the germination of intact viable seeds under favorable conditions [10-12]. Under cold storage conditions (4°C and 70–80% relative humidity) cassava seeds can remain dormant for up to 7 years with no loss of germination.

To overcome this problem so that cassava seed breeding programmes can be undertaken anytime without the time-related dormancy limitation, development of suitable dormancy-breaking techniques are of paramount importance. Generally, treatments used to break seed dormancy may include mechanical scarification, chemical scarification (especially sulfuric acid), cold-wet, hot water, electrasonic waves and stratification [13,14]. Moreover, germination of cassava seeds can be favored by dry heat and complete darkness [15]. Genetically, cassava clones are highly heterozygous and sexual propagation (propagation through seeds) results in a wide diversity of phenotypes, which is of interest to breeders [16]. This discovery has endeared to breeders who have started to use cassava seeds as the starting material in their breeding programmes. There is however scanty information on how pre-germination treatments and storage duration affect seed quality.

This study sought to determine the most suitable pre-germination treatment for high germination in cassava seeds stored for breeding programmes.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at the CSIR-Crops Research Institute (CRI), Fumesua, near Kumasi from June, 2015 to January, 2016. Specific tests and analyses were carried out in laboratories at the CRI, Faculty of Agriculture, KNUST, Kumasi.

2.2 Source of Cassava Seeds

Cassava seeds were obtained from cassava trial fields at the CSIR-Crops Research Institute (CRI), at Fumesua, near Kumasi. The seeds were harvested from growing cassava plants. The cultivars collected were Ahwengyanka-1, Ahwengyanka-2 and Aworowa-3. The seeds were cleaned, dried and put in paper bags. Seeds were stored under ambient temperature conditions in the cassava seed storage room for periods of three and six months. The storage environment had a temperature range of 25°C – 30°C. Daily monitoring and recording of temperature and relative humidity were done for the entire storage period.

2.3 Experimental Design

A 3x3x7 factorial arrangement in Completely Randomized Design was used. The experiment

was replicated three times. The first factor was variety at three levels (Ahwengyanka-1, Ahwengyanka-2 and Aworowa-3). The second factor was storage period at three levels (0 month, 3 months and 6 months). The third factor was pre-germination treatment at seven levels (Hot water soaking (HW), Cold water soaking (CW), Acid scarification for 5 minutes (AS5), Acid scarification for 10 minutes (AS10), Acid scarification for 30 minutes (AS30), Mechanical scarification (MS), and No treatment as Control). The details of the pre-germination treatments (PGT) were as follows:

2.3.1 Hot water bath (HW)

Thirty seeds of cassava were placed in conical flasks containing 200 ml of water and put into a water bath at a temperature of 100°C for 30 mins. The seeds were allowed to cool after 30 minutes and they were placed into Petri dishes containing wetted paper towels for the germination test.

2.3.2 Cold water (CW)

Thirty seeds were soaked in tap water for 24 hours after which they were placed on the paper towels in the Petri dishes and observed for occurrence of germination.

2.3.3 Acid scarification (AS)

Thirty seeds were soaked in 50 mls of concentrated sulfuric acid for periods of (i) 5 minutes, (ii) 10 minutes and (iii) 30 minutes. After each period, the seeds were thoroughly washed with tap water to remove any acid residue and a litmus paper was used to test for the presence or absence of acid. The seeds were placed in the Petri dishes when the absence of acid was confirmed.

2.3.4 Mechanical scarification (MS)

The seed coat of thirty seeds was scraped with sand paper to remove some part of the seed coat for easy imbibition of water. The seeds were placed on the paper towels in the Petri dishes and germination was observed.

2.4 Data Collected

2.4.1 1000 seed weight

The weight of 1000 seeds was determined as recommended by the International Seed Testing Association [17].

2.4.2 Temperature and relative humidity of storage room

The temperature and relative humidity readings of the storage room (ambient) were taken at specific times during the day. An Acurite manufactured indoor digital temperature and humidity monitor (00325) was used in taking the various readings.

2.4.3 Germination percentage

Germination percentage of seeds was determined using procedures recommended by [17].

2.4.4 Determination of seed vigour

Seed vigour was determined using the conductivity test as prescribed by [17].

2.5 Analysis of Data

Data collected were subjected to Analysis of Variance (ANOVA) using STATISTIX version 10. Data on germination were square root transformed before analysis. Tukeys Honest Significant Difference (HSD) was used for the separation of treatment means. The probability of declaring significant differences between treatments was set at P=.01.

3. RESULTS

3.1 Ambient Temperature and Relative Humidity of Storage Environment

The storage temperature ranged from 26°C to 32°C whereas the relative humidity ranged from 84% to 91%. The minimum temperature was recorded in September, 2015 while the maximum was recorded in November, 2015. The minimum relative humidity was recorded in July, 2015 while the maximum was recorded in August, 2015 (Table 1).

3.2 Effects of Cultivar and Storage Period on Percentage Germination (%) of Cassava Seeds

Significant variety x storage period interactions were observed in the percent germination of cassava seeds (Table 2). Seeds of all three cultivars stored for six months produced significantly the highest percent germination, while seeds of Ahwengyanka-1 and

Ahwengyanka-2 without storage produced the least germination percentages.

Among the cultivars, Aworowa-3 seeds produced significantly higher germination percentages than Ahwengyanka-1 and Ahwengyanka-2 which produced the least yet similar germination percentages.

Among the storage periods, seeds stored for six months produced significantly the highest germination percentage, 1.94 times greater than the least obtained from seeds without storage (Table 2).

3.2.1 Effects of cultivar and pre-germination treatments on the percent germination of cassava seeds

Significant cultivar x pre-germination treatments interactions were observed for percent germination (Table 3). Aworowa-3 seeds treated by mechanical scarification with sand paper produced significantly the highest percent germination although similar to Aworowa-3 seeds treated with hot water and Aworowa-3 seeds soaked in cold water. The least percent germination was recorded for Ahwengyanka-2 seeds without any pre-germination treatment.

Among the cultivars, Aworowa-3 seeds produced significantly higher percent germination than Ahwengyanka-1 and Ahwengyanka-2 which produced the least yet similar germination percentages.

Among the pre-germination treatments, seeds treated with mechanical scarification with sand paper (MS) produced significantly the highest percent germination, 40.4% greater than the least obtained from seeds without treatment any pre-germination treatments (Control) (Table 3). The other pre-germination treatment methods also produced germination percentages which were 28.7% (Hot and cold water) and 23.4% (acid scarifications 5, 10 and 30 mins) greater than the control.

3.3 Effect of Storage Periods on Vigour of Cassava Seeds

Significant differences were obtained in the storage periods for the electrical conductivity of the seeds. Seeds without storage produced significantly the highest electrical conductivity value (1.28 $\mu S/cm^{-1}g^{-1}$) whereas the least conductivity value was obtained from seeds stored for six months (1.04 $\mu S/cm^{-1}g^{-1}$) (Fig. 1).

Table 1. Minimum and maximum temperature and relative humidity of storage environment

Month	Minimum temperature (ºC)	Minimum relative humidity (%)	Minimum temperature (ºC)	Maximum relative humidity (%)
June	29	88	24	88
July	27	84	23	89
August	28	86	22	91
September	26	89	21	87
October	30	86	24	88
November	32	84	25	86
December	30	85	24	86

Table 2. Effects of cultivar and storage duration on the germination percentage of cassava seeds

Storage duration	Germination percentage (%)			
	Cultivars			
	Ahwengyanka-1	Ahwengyanka-2	Aworowa-3	Mean
No storage	28.1	27.6	36.2	30.6
Three months	38.6	38.6	41.4	39.5
Six months	58.6	58.6	60.9	59.4
Mean	41.8	41.6	46.2	

HSD (0.01): Cultivar =2.54; Storage =2.54; Cultivar x Storage = 5.40

Table 3. Effects of cultivar and pre-germination treatments on percent germination of cassava seeds

Pre-germination treatments	Germination Percentage (%)			
	Cultivars			Mean
	Ahwengyanka-1	Ahwengyanka-2	Aworowa-3	
Mechanical scarification	45.6	44.4	56.7	48.9
Control	30.0	30.0	44.4	34.8
Cold water	43.3	43.3	47.8	44.8
Hot water	43.3	43.3	47.8	44.8
Acid scarification-5mins	43.3	43.3	42.2	42.9
Acid scarification-10mins	43.3	43.3	42.2	42.9
Acid scarification -30mins	43.3	43.3	42.2	42.9
Mean	41.8	41.6	46.2	

HSD (0.01): Cultivar =2.54; PGT =4.59; Cultivar x PGT = 9.18

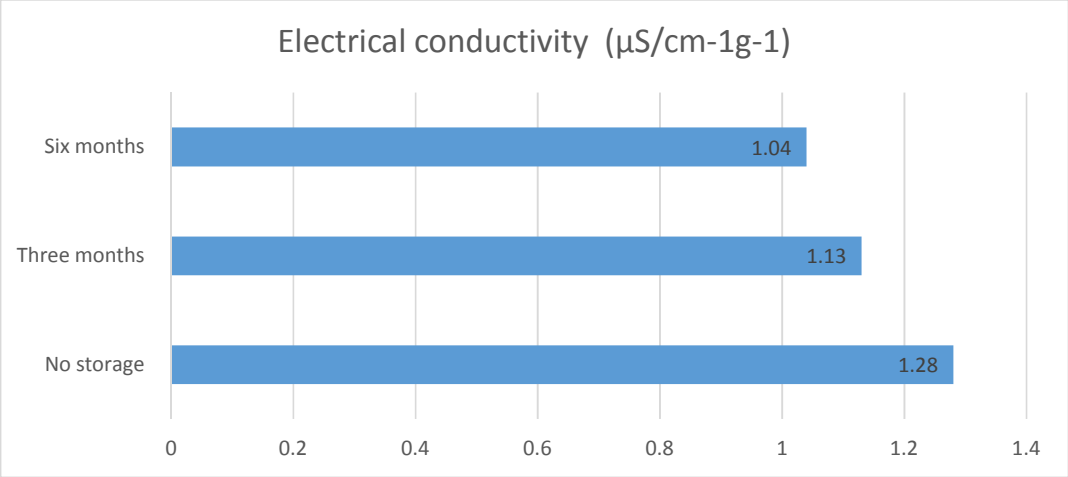

Fig. 1. Effect of storage period on electrical conductivity (vigour) of cassava seeds

3.4 Effects of Storage Periods on 1000 Seed Weight of Cassava Seeds

Seeds stored for six and three months were significantly heavier than those without storage. Seeds without storage had the least 1000 seed weight, 9.56% and 7.78% less in weight than those stored for six months and three months, respectively (Fig. 2).

4. DISCUSSION

In the present study, cassava seeds stored for six months produced the highest 1000 seed weight. Interestingly, increasing seed weight was observed to be directly proportional to the lengthening of the storage period. This observation could be attributed to the high relative humidity recorded during the time of storage which resulted in the imbibition of moisture by the seeds during the period of storage. The 1000 seed weight obtained for the three cultivars of cassava seeds used in this study agrees with the findings of [18] that on the average, the 1000 seed weight of cassava seeds was 100 g.

The pre-germination treatment accorded seeds of a cultivar may have an effect on their germination response [19]. This finding was evident in the present study where Aworowa-3 seeds recorded profound differences in germination percentage depending on the pre-germination treatment. When Aworowa-3 seeds were mechanically scarified with sand paper they produced a germination percentage of 56.7% as against when similar Aworowa-3 seeds were acid-treated (42.2%). The seeds that were treated by mechanical scarification using sand paper produced the highest germination rate while the seeds with no treatment produced the least. This observation agrees with [20] who

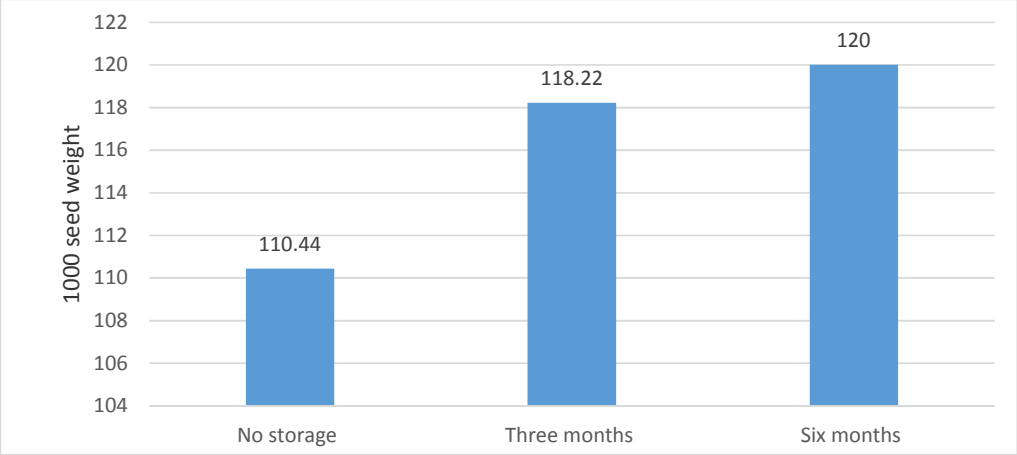

Fig. 2. Effect of storage period on 1000 seed weight of cassava seeds

reported that pre-treatment of seeds by mechanical scarification had significant effects on the probability of water imbibition leading to increase in germination by seeds. Mechanical scarification of dormant seeds has also been found to be an efficient method in increasing the rate of germination over time in *Acacia* spp. seeds [21], seeds of *Adesmia* spp. [22] and cassava seeds [23]. Cassava seeds exhibit the exogenous type of dormancy due to the hardness of the seed coat and mechanical scarification is one of the best methods used in breaking physical or exogenous dormancy in cassava seeds. Moreover, [24] indicated that mechanical scarification was an effective method used in breaking physical, mechanical and chemical dormancy in seeds since the impermeability of hard seed coat to water and gases had been found to be part of the many causes of poor germination in seeds [25].

In the present study, seeds treated with sulfuric acid recorded lower germination rates but this contradicts an earlier study by [26], who reported that treating *Peltophorum pterocarpum* seeds with sulfuric acid yielded no germination. He explained that, the acid acted mainly on the micropylar and hilar regions of seeds and higher acid concentrations and long soaking periods not only damaged the soft tissues, but it created cracks on the testa, which allowed the acid to gain access into the embryonic tissue causing the death of the seed. In the present study, the rate of germination of seeds treated with sulfuric acid was about 42%, an indication that sulfuric acid had a positive effect on the germination of cassava seeds, an observation also found by [27]. Both short (5 minutes) and long (30 minutes) periods of immersion recorded germination. In other studies, the dormancy in *Cassia fistula* seeds was released when the seeds were soaked in concentrated sulfuric acid for 15 minutes [28]. Similarly, [29] obtained significantly higher germination rate of *Peltophorum pterocarpum* seeds treated by soaking in sulfuric acid for 5 – 75 minutes, washed and soaked in distilled water for 8-24 hours. These results however contradict those of [30,31] who indicated that prolonged immersion of seeds in sulfuric acid (H_2SO_4) injured the seeds and also destroyed some vital parts of the embryo leading to low or no germination. The occurrence of germination in the seeds pretreated with hot water but not stored could be due to the ability of the hot water to cause rupture of the hard seed coat which allows water imbibition leading to seed germination and further rapid emergence [32,33]. In the present study, the germination percentages recorded for cassava seeds were higher than the10-40% previously reported [34].

Among all three varieties, Aworowa-3 had the highest mean germination percentage. This could be attributed to several factors such as varietal differences, the oil and protein contents, weight of seed, moisture content, among others. The Aworowa-3 seeds stored for six months produced the highest germination. It proved to be the best of the varieties used in this study since germination even occurred without storage whereas the remaining two varieties failed to germinate. From the present study, percentage vigour increased as storage increased implying that vigour of cassava seeds increases over time; this could be due to the chemical processes

that take place in the seeds during storage such as the release of dormancy which occurs as storage increases. The increase rate of vigour could ascertain the reason why germination rates increased with increasing storage. However, even though the seeds without storage had a significantly high leachate rate which indicates low percentage vigour [17], they still produced an appreciable rate of germination (about 40%). The pattern of vigour of cassava seeds does not agree with the findings of [35] that vigour declines in storage as a result of deterioration of seed quality which precedes loss in standard germination and this could be attributed to the inherent dormancy exhibited by seeds of cassava.

The increasing rate of germination with increasing storage confirms reports of [36] that the length of storage caused the release of dormancy in seeds of *Peltophorum pterocarpum*. [37] also observed that an increase in the rate of germination occurred with an increasing storage period, especially in *Manihot glaziovii* and *Manihot pseudoglaziovii* seeds. Similarly, [38] reported that there was an increase in the rate of germination of stored seeds of different plant species and explained that the room temperature adequately attenuated the intensity of dormancy and caused acceleration in the germination and emergence of seedlings.

Conditions such as the temperature and relative humidity of the storage environment also play major roles in seed quality maintenance or deterioration. High temperature and relative humidity (25°C/75%) in storage environments cause seeds to deteriorate at a faster rate thereby leading to lower seed vigour and germination percentages than storage environments with low temperature and relative humidity (12°C/60%) [39,40].

5. CONCLUSION

A rate of 40% germination was obtained from cassava seeds stored up to three months. This is appreciable since seeds stored up to three months are known to exhibit dormancy which is usually released after a period of time. Aworowa-3 seeds without storage produced a higher germination rate than Ahwengyanka-1 and Ahwengyanka-2 seeds without storage but all the seeds of the three varieties had the highest germination percentage when stored for six months. Mechanical scarification with sand paper proved to be the best method in breaking dormancy of cassava seeds especially seeds stored up to three months.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO. FAOSTAT database. Rome: Food and Agriculture Organization of the United Nations; 2009.
   Available:http://faostat.fao.org
2. Fregene M, Bernal A, Doque M, Dixon A, Tohme J. AFLP analysis of African cassava (*Manihot esculenta* Crantz) germplasm resistant to Cassava Mosaic Disease (CMD). Theor. Applied Genet. 2000;100:678-685.
3. IITA. International Institute of Tropical Agriculture Research Guide 55. Physiol Cassava. Cassava Plant. 2001;2. (03.11.15)
   Available:http//www.iita.org/info/tmmat/irgss/irg553.html
4. Parkes EY. Using molecular markers to identify new sources of CMD resistant genes for cassava improvement. 2nd GSS Workshop, CIAT, Cali. Colom; 2009.
5. Keleny GP, Van Haaren AJH. Progress report on rubber seed investigation. Papaua New Guinea Agriculture Journal. 1967;19:72-87.
6. Eakle TW, Garcia AS. Hastening the germination of lumbang (*Aleurites moluccana* (L.) Willd.) seeds. Sylvatrop. 1977;2:291-295.
7. Lago AA, Zink E, Razera LF, Banzatto NV, Savy-Filho A. Seed dormancy of three castor bean cultivars. Bragantia. 1978;38: 41-44.
8. Nassar NMA, Teixeira RP. A quebrada dorme´ncia da semente das espe´cies selvagens damandioca. Manihot spp. Cie´ncia e Cultura. 1983;35:630–632.
9. Ellis RH, Hong TD, Roberts EH. An investigation of the influence of constant and alternating temperature on the germination of cassava seed using a two-dimensional temperature gradient plate. Annals of Botany. 1982;49:241–246.
10. Bagheri R, Asadi F. Collection and conservation of forest tree seeds. Roosta Shaghayegh Publications. 2003;1:96.
11. Robert L. Geneve. Hortscience. 2003; 38(3):336-341.

12. Finch-Savage WE, Leubner-Metzger G. Seed dormancy and the control of germination. New Phytologist. 2006;171: 501-523.
13. Isvand HR, Maddah Arefi H, Tavakkolafshari R. Genetic researches and improvement of rangelands and forest plants in Iran. 2004;13(1):68-83.
14. Dehghani SY. Seed and seedling of forest trees production. Jahad Keshavarzy Publications. 2005;115.
15. Ellis RH, Hong TD, Roberts EH. An investigation of the influence of constant and alternating temperature on the germination of cassava seed using a two-dimensional temperature gradient plate. Annals of Botany. 1982;49:241–246.
16. Ceballos H, Iglesias CA, Perez JC, Dixon GO. Cassava breeding: Opportunities and challenges. Plant Mol. Biol. 2004;56:503–516.
17. ISTA. International Rules for Seed Testing. International Seed Testing Association, Bassersdorf, Switzerland; 2007.
18. Rogers DJ. Some botanical and ethnological considerations of *Manihot esculenta*. Econ. Bot. 1965;19:369-377.
19. Bishaw Z, Van Gastel AJG. Components of seed quality. In Proceedings of a Train-The Trainers Workshop, 24 April - 9 May 1993 at Amman, Jordan. Van Gastel AJG, Pagnotta MA and Porceddu E (Eds). 1996;289-98.
20. Pujol B, Gigot G, Laurent G, Pinheiro-kluppel P, Elias M, McKey H, McKey D. Germination ecology of cassava (*Manihot esculenta* Crantz, Euphorbiaceae) in traditional agro ecosystems: Seed and seedling biology of a vegetatively propagated domesticated plant. Economic Botany. 2002;56(4):366-379
21. Mohammed SM. Ecological studies on germination and establishment of some Acacia. M.Sc. Thesis. Faculty of Agriculture, University of Khartoum; 1981.
22. Tedesco SB, Stefanello MO, Schifino MT, Battistin A, Dal M. Seeds break dormancy of Adesmia D.C. (Legumenosae) species. Revista Brasileira de Agrociencia. 2001;7(2):89-92.
23. Pujol B, Gigot G, Laurent G, Pinheiro-kluppel P, Elias M, McKey H, McKey D. Germination ecology of cassava (*Manihot esculenta* Crantz, Euphorbiaceae). In Traditional; 2002.
24. Hartmann HT, Kester DE. Plant propagation, principles and practices (Fourth edition). Prentice_Hall. Inc. New York; 1983.
25. Ibrahim NIE. The effect of pre-sowing treatments on germination of (*Peltophorum pterocarpum* (DC.) K. Heyne) seeds; 2004.
26. Gupta V, Sushil K, Hasan SA, Dwivedi S, Kukreja AK, Sharama A, Singh AK, Sharama S, Tewari R. Structural changes in seed coat morphology during dormancy breaking in some medicinal plants. Journal of Medicinal and Aromatic Plant Science. 2001;22(23):672-673.
27. Lefèvre F. Ressources génétiques et amélioration du manioc, *Manihot esculenta* Crantz, en Afrique. Paris, France, ORSTOM, Travaux et Documents Microédités. 1989;57:175.
28. Karaboon S, Riponaa S, Thanapornpoonponga S, Pawelzikb E, Vearasilp S. Breaking germination dormancy and optimum storage temperature of golden shower (*Cassia fistula*) seeds. Presented the Conference on International Agricultural Research for Development, Tropentag, Stuttgart-Hohenheim. 2005;1-4.
29. Zodape ST. The improvement of germination of some forest species by acid scarification. Indian Forester. 1991;117(1): 61-66.
30. Aliero BL. Effects of sulphuric acid, mechanical scarification and wet heat treatments on germination of seeds of African locust bean tree, *Parkia biglobosa.* African Journal of Biotechnology. 2004;3:179-181.
31. Adjata KD, Tchaniley L, Banla E, Tchansi KK, Gumedzoe YMD. Study of germination conditions of cassava (*Manihot esculenta* Crantz) seeds obtained by genetic selection. Scientific Research and Essays. 2013;8(43):2138-2143.
32. Travlos IS, Economou G, Karamanos AI. Germination and emergence of the hard seed coated *Tylosema esculentum* (Burch) A. Schreib in response to different pre-sowing seed treatments. J. Arid Environ. 2007;68:501-507.
33. Lebutswe T, Ramolemana GM, Machacha S, Tsopito CM. Effects of different dormancy-breaking treatments on the germination and emergence of morama bean (*Tylosema esculentum* Burch.), Botswana. UNISWA J. Agric; 2003.
34. Ekandem MJ. Techniques for cassava hybridization and production of seedlings.

Fed. Dept. Agric. Res. Nigeria Memo No. 105; 1970.
35. Pratt P, Bolin P, Godsey C. (Eds.) Soybean production guide. Oklahoma Cooperative Extension Service, Division of Agricultural Sciences and Natural Resources, Oklahoma State University. 2009;12-114.
36. Girase US, Jambhale ND, Suryawanshi YB. Germination and seed dormancy studies in Acacia species. Seed-Research. 2002;30(1):39-42.
37. Martins MTCS, Bruno RLA, Alves EU, Neto AP. Superação Da Dormência em sementes de maniçoba armazenadas. Caatinga. 2009;22(2):181-186.
38. Mezzalira I, Costa CJ, Viera EA, Fialho JDF, Silva MS, Denke ML, Silva KND. Pre-germination treatments and storage of cassava seeds and their correlation with emergence of seedlings. 2013;113–118.
39. Šimić B, Sudarić A, Liović I, Kalinović I, Rozman V, Ćosić J. Influence of storage conditions on seed quality of maize, soybean, and sunflower. In 9th International Working Conference on Stored Product Protection; 2006.
40. Al-Yahya SA. Effect of storage conditions on germination in wheat. Journal of Agronomy and Crop Science. 2001;186(4): 273-279.

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