Evaluation of pre-sowing treatments for seed germination enhancement of *Chrysophyllum albidum* g. Don

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ABSTRACT

Indigenous fruits are important for the many ecosystem benefits they provide. *Chrysophyllum albidum* G. Don is a fruit tree which provides many services including food, and also used as shade tree in cocoa farms. Unfortunately most farmers find it difficult to germinate the seeds. Various pre-sowing treatments were explored to find the best for the germination of seeds of *C. albidum*. Pre-sowing treatments employed were immersion of seed in sulphuric acid for different time periods ranging from 5 to 30 min, fleshly sown, oven drying of seeds at 35 ^{o}C, 40 ^{o}C and 70 ^{o}C for 6 and 24 h, cold treatment in a refrigerator at 16 ^{o}C and 20 ^{o}C and mechanical scarification. Results of the study showed that mechanical scarification had the highest germination percentage of 73.3 per cent, and this was significantly higher than the other treatments ($P < 0.001$). It also showed the earliest germination time of 6 days with a significant mean germination time (MGT) of 10.2 ($P = 0.003$). Germination percentages in the other treatments were less than 20 per cent indicating dormancy in most of the seeds of *C. albidum*. Mechanical scarification with its high and uniform germination was the best method for adoption by farmers.

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Introduction

Chrysophyllum albidum G. Don is a tree used by some farmers in the Suhum-Kraboa-Coaltar District of Eastern Region of Ghana as shade trees in their cocoa farms. It is a tree which can grow to a height of 30 m or more (Irvine, 1961) and is found in the forest regions of Ghana. In Africa it is distributed from Sierra Leone to Kenya (Taylor, 1960, Irvine, 1961). It bears an ovoid berry of fruits and embedded in its pulp which could be white or brown-red are five brown glossy seeds with hard seed coats (Taylor, 1960). The tree is of economic importance to the farmers as it provides shade to the cocoa trees and the fruits are sold to generate additional income for the farmers. In a survey, most farmers indicated that they needed technical advice on the germination of *C. albidum* seeds (Boateng, 2015).

Most of the seeds of tropical fruit trees have hard seed coats which make it difficult for the seeds to exchange gases or imbibe water (Schmidt, 2000; Dirr & Heuser, 1987). Apart from the basic requirements of water, oxygen and suitable temperature, some seeds may respond positively to other stimulatory conditions such as light, potassium nitrate (KNO_3) and gibberillic acid (GA_3) (Hartmann et al., 2002; Rao et al., 2006). When all the requirements for germination are present, the

seed imbibes water followed by embryo expansion. This is followed by further elongation to break through the outer seed coat to result in germination (Manz et al., 2005). Cell elongation leading to radicle emergence is generally accepted as germination (Bewley, 1997; Kucera, Cohn & Leubner, 2005). Some seeds germinate easily while others possess a range of dormancy conditions.

Seed dormancy has been defined as the temporarily failure of a viable seed to germinate in the presence of favourable environmental conditions (Simpson, 1990). The seeds of most indigenous tropical fruit trees tend to experience seed dormancy as the trees mostly shed their fruits in the dry season when conditions for germination are not favourable (Atwater & Vivrette, 1987; Vivrette & Meyr, 2002).

There are two types of dormancy; exogenous dormancy (seed coat dormancy) and endogenous dormancy (embryo dormancy). Exogenous dormancy may be due to physical or chemical conditions which make it difficult for the uptake of moisture by the seed. Endogenous dormancy (embryo dormancy) occurs when inhibiting substances within or surrounding the tissues of the embryo obstructs germination (Rao *et al*., 2006). This type of dormancy could also be due to immature embryos at the time of shedding of fruits or seeds (Vivrette, 1993; Rao et al., 2006). Dormancy can also be caused by a combination of both endogenous and exogenous factors. Poor germination when a hard seed coat is removed from a seed might be due to embryo dormancy or unsuitable environmental conditions (Rao *et al*., 2006).

Scarification can be used to break dormancy due to a hard seed coat. If the seed is scarified it allows imbibitions of water, in addition, if the seed coat contains inhibitors, they are leaked away during imbibitions (McDonald & Khan, 1983).

In a recent study, Guma *et al*. (2010) reported using mechanical scarification and immersion of seeds in sulphuric acid for 120 min to break the dormancy of *Cicer canariense*. Cold treatment has been found to relieve embryo of oxygen stress to help in breaking seed dormancy (Corbineau & Come, 1995). In another recent study, Zammouri & Neffati (2010) reported that temperature range of 25–35 °C was found to be optimal in the germination of seeds of *Ziziphus lotus*. Choudhury, Khan & Das (2009) observed that the use of boiling water (100 °C) treatment of seeds of *Glymnocladus assamicus* for 2 min significantly released dormancy. In a work on germination of seeds of *C. albidum*, Aduradola, Adeola & Adedine (2005) reported that hot water (100 °C) treatment gave the highest germination percentage of 86.1, followed by mechanical scarification with 70 per cent.

Pre-sowing treatment of seeds using sulphuric acid is the principal means of chemical scarification used to break dormancy imposed by seed coat (Argel & Paton, 1999). The treatment causes degradation of the seed coat leading to imbibitions of water (Nagaveni & Srimathi, 1980; Baskin & Baskin, 1998). The period of treatment with sulphuric acid can range from a few seconds to several hours but is normally between 1 and 20 min (Ellis, Hong & Roberts, 1985).

Results of a survey (Boateng, 2015) showed that most farmers find it difficult to germinate seeds of *C. albidum*. Since the tree is of economic importance to the farmers through the sale of its fruits, it is, therefore, important to undertake a study which can lead to increased germination of the seeds. The study investigated, therefore, whether pre-sowing treatments of *C. albidum* seeds can significantly influence germination positively. The specific objective of the study was to determine the best pre-sowing treatment for the germination of *C. albidum* seeds.

Materials and methods

Three experiments were performed to ensure repeatability of results.

Experiment 1

The seeds of *Chrysophyllum albidum* were collected from a single fruit tree in the fruit orchard on-station at Plant Genetic Resources

Research Institute at Bunso in Ghana in January 2009. After 2–3 days the seeds were de-pulped, washed and surface sterilised with alcohol for 1 min and washed with three changes of distilled water. The seeds were then dried at room temperature of 25 ° C for 10 h after which they were subjected to the following pre-sowing treatments:

Sulphuric acid (95%) immersion of seeds for 5 min; Sulphuric acid (95%) immersion of seeds for 10 min; Sulphuric acid (95%) immersion of seeds for 15 min; Sulphuric acid (95%) immersion of seeds for 20 min; Sulphuric acid (95%) immersion of seeds for 30 min; Boiling water (100 ° C) treatment of seeds for 2 min; Boiling water (100 °C) treatment of seeds for 5 min; Oven drying at 40 °C for 24 h;

Oven drying at 3 5 °C for 24 h; Freshly sown (Control); Mechanical scarification using a sterilised scalpel to cut open part of the seed coat.

Each treatment consisted of three replicates each of 30 seeds of *C. albidum*. Each replicate of seeds was arranged on two layers of paper towels. A third paper towel was then used to cover the seeds and the paper towels were folded over the seeds. The seeds were then wetted with distilled water and put in glass beakers containing water to a height just below the first line of seeds in the paper towels.

For the sulphuric acid treatments, a flat-bottomed flask, which contained 100 ml of 95 per cent sulphuric acid, was utilised for each replicate of a treatment. The flask was regularly shaken to ensure uniform acid action on the seeds. After the end of the specified period for the acid treatment, the seeds were washed with tap water and then rinsed with distilled water before being put in the paper towels. Mechanical scarification involved the use of sterilised scalpel to cut open the pointed end of the seed coat to expose part of the endosperm of the seed. Oven treated seeds had seeds put in 9 cm glass petri dishes and put in an oven set at the required treatment temperature and removed after the time period for that treatment. The paper towels containing the seeds of the various treatments were then randomly placed in a Sanyo MIR incubator (Sanyo Electric Co. Ltd., Japan) with light for 12 hours and darkness for 12 h. Temperature was set at 25 °C ± 5 °C with relative humidity of 100 per cent. The light was provided by 'cool' white fluorescent tubes of at a light flux density of 40 µmol m^{-2} s^{-1}, 400-700 nm. The seeds were left for 6 days when the first assessment of germination was made. Thereafter, observations were made every 6 days for germination. Seeds were scored as being germinated when the length of the radicle emerged was 2 mm or more. The study period lasted 24 days.

At the end of the experimental period, the cumulative number of germinated seeds was determined. Mean germination time was also calculated from the germination data as follows; $\sum nd/N$, where n = numbers of germinated seeds on each day, d = number of days from the onset of the test and N = Total number of germinated seeds. Five seeds which had not germinated were randomly collected from each treatment replicate, and the seeds were dissected to determine whether the seeds were alive or dead.

Experiment 2 on germination of *C. albidum* seeds

In a second experiment, treatments and conditions for germination included combinations of treatments that showed promising results in Experiment 1, and extreme temperature treatments to break dormancy of *C. albidum* seeds. Seeds were collected as in Experiment 1 before pre-sowing treatments were applied. The treatments applied were as follows:

Cold treatment at 16 °C in a refrigerator for 24 h; Oven drying at 70 °C for 24 h; Cold treatment at 16 °C for 24 hours +

heat treatment in oven at 70 °C for 24 h; Freshly sown (Control); Mechanical scarification in which scalpel was used to cut open part of the seed coat.

Each treatment was replicated three times with 30 seeds in each replicate. A modified germination test was applied in experiment 2 following the methods of AOSA, (2000). Two layers of Whatman No. 1 paper were laid in 9 cm glass Petri dishes. The papers were wetted with 10 ml of distilled water. Then 30 seeds of a particular treatment were placed in each Petri dish. The Petri dishes were then randomly placed in a Sanyo MIR incubator with conditions set to provide 6 h of light and 18 h of darkness, temperature of 22 °C ± 5 °C and relative humidity of 100 per cent. The light used were cool white fluorescent tubes of 40 μmoles $m^{-2} s^{-1}$ at 400-700 nm.

Petri dishes containing the seeds were observed after 6 days and, thereafter, observed after every 6 days. As in experiment 1, the final observation and final count of germinated seeds were carried out 24 days after germination (prior to day 24 there were no further germination for 6 days in most treatments). Other experimental procedures were as for experimental 1.

Experiment 3

The seeds were collected from a single *C. albidum* fruit tree at the Plant Genetic Resources Research Institute, Bunso in Ghana. The location of the site is N 06° 16', W 00° 27' and the area experiences an average annual rainfall of 1410 mm. The mean minimum and maximum temperatures are 22.7 and 32.6 °C with a mean relative humidity of 87 per cent.

After 2 - 3 days after the collection of the fruits, seeds were depulped, washed and surface- sterilised with alcohol for 1 min and washed with three changes of distilled water. The seeds were dried at room temperature of 25 °C for 10 h after which they were subjected to pre-sowing treatments. Before being subjected to the pre-sowing treatments, the seeds were placed in water and those that floated were deemed not to be viable and were not included in the experiment.

Pre-sowing treatments. The following pre-sowing treatments were applied and consisted of the most promising treatments of the previous two experiments:-

Oven drying at 35 °C for 24 h; Oven drying 40 °C for 24 h;

Oven drying 40 °C for 6 h; Freshly sown (Control); Soaking for 48 h; Cold storage at 20 °C in a refrigerator for 24 h; Oven drying at 40 °C for 24 h followed by cold storage at 20 °C for 24 h.

Mechanical scarification

For the mechanical scarification treatment, a small slit was made at the pointed end of the seed coat near the embryo using a new and sterilised scalpel. For the Control treatment, the seeds were sown fresh. The seeds were first sprayed with Top Cop (Tribasic Copper Sulphate with sulphur as base element) a fungicide, using 50 ml/kg of seeds before the seeds were put in the incubator. Thereafter, spraying of the seeds was at 10–day intervals using the same chemical. Seed germination was as described for experiment 1. There were four replicates of 30 seeds each for each treatment. The germination treatments were arranged in a completely randomised design in a Sanyo MIR-553 incubator (Sanyo Electric Co. Ltd., Japan) under conditions described for experiment 1. Paper towels were changed when they became weak to contain the seeds.

The first observation was made 3 days after beginning the germination treatments. Another observation was made on day 6 and, thereafter, observations were made on every 6 days. On each occasion germinated seeds were counted and removed. Seeds were scored as being germinated when the length of the radicle emerged was 2 mm or more (Mackay , Davies & Sankhla, 1995). The experiment was terminated after 60 days

when there had been no further germination in most treatments for at least 6 days. As in experiment 1 and 2, cumulative number of germinated seeds, mean germination time, germination index and coefficient of velocity were calculated.

At the end of the experiment, ungerminated seeds were subjected to a tetrazolium test. Here, seeds of each treatment were placed in a dilute solution (0.1%) of 2,3,5-triphenyltetrazolium chloride for 17 h. The solution was then discarded and the seeds were rinsed in distilled water. Viable embryos undergo respiration in which hydrogen is produced which reacts with the solution and changes it to red (reduction reaction) (Moore, 1976). A hand lens was used to observe the embryo of the seeds. Those seeds that stained red or pink were considered viable and those not stained were considered dead. At the end of the test all the seeds that did not germinate were found to be non-viable.

Results

Mean germination time (MGT) was calculated using the formula by Bewley & Black (1994): $\sum nd/N$, where n = numbers of germinated seeds on each day, d = number of days from the onset of the test and N = Total number of germinated seeds. Rate of Germination is the reciprocal of MGT, i.e. 1/MGT.

Germination Index (GI) is a measure of speed of germination (AOSA, 1983), and was calculated using the formula: $GI = \sum T_i N_i / S$, where T_i is the number of days after sowing, N_i is the number of seeds germinated on day i and S is the total number of seeds sown (Scott, Jones & Williams, 1984). Coefficient of velocity (CV) is a measure of number of seeds germinated and the velocity of germination and was calculated using the formula: $CV = 100[\sum Ni / \sum N_i T_i]$, where N is the number of seeds germinated on day i and T is the number of days from sowing (Scott *et al*., 1984).

Data on germination on Experiments 1, 2 and 3 and germination performance variables of Coefficient of velocity (CV), Mean Germination Time (GMT) and Germination Index (GI) were subjected to ANOVA test in Genstat. Least significance difference (LSD) at 0.05 was used to estimate the differences between the treatment means. All statistical analyses were done in Genstat 10th edition statistical package.

Experiment 1

The following treatments showed no germination after an incubation period of 24 days: Freshly sown (Control), sulphuric acid for 5 min, Sulphuric acid for 15 min, Sulphuric acid for 20 min, Sulphuric acid for 30 mins, Boiling water for 2 min and boiling water for 5 minutes. In addition, three treatments showed limited germination at the end of the experiment (Table 1). These were sulphuric acid for 10 min, 4.4 per cent, oven-drying at 35 °C, 3.3 per cent and Oven-drying at 40 °C, 2.2 per cent. The treatment which showed significantly higher percentage germination than the other treat-ments was mechanical scarification at 88.9 per cent.

When a sample of non-germinated seeds were cut open for observation at the end of the experiment, seeds of the following treatments were found to be alive: Control, oven dried at 35 °C, Oven-dried at 40 °C and mechanical scarification.

TABLE 1

Pre-sowing treatments giving limited or significant germination of C. albidum seeds for 24 days. Each value is a mean of three replicates of 30 seeds.

Treatment	*Mean germination (%)*
Mechanical scarification	88.9
Sulphuric acid for 10 min	4.4
Oven drying at 40°C for 24 h	2.2
Oven drying at 35°C for 24 h	3.3
LSD (5%)	8.88
P	< 0.001

The endosperm and the embryo were white in colour and firm, similar to that of fresh seed from a ripened fruit. However, the seeds of the remaining treatments (sulphuric acid for 5 min, sulphuric acid for 10 minutes, sulphuric acid for 15 min, sulphuric acid for 20 min, sulphuric acid for 30 min, boiling water for 2 min and boiling water for 5 min) were dead. The endosperm and embryo of the dead seeds were brown, purple or black in colour and soft.

Experiment 2

Seeds of the following treatments did not germinate during the experimental period: Oven-drying at 70 °C for 24 h and cold treatment at 16 °C for 24 h followed by oven-drying at 70 °C. The remaining treatments had low percentage seed germination.

TABLE 2

Pre-sowing treatments giving limited or significant germination of C. albidum seeds for 24 days at 6/18 hours of light and darkness (remaining treatments gave no germination). Each value is a mean of three replicates of 30 seeds.

Treatment	*germination (%)*
Freshly sown (Control)	15.6
Cold storage at 16 °C	15.6
Mechanical scarification	7.8
LSD (5%)	15.38
P	0.415

Germination of the freshly sown and cold stored at 16 °C seed gave the highest germination of the three treatments (15.6%) (Table 2). This was followed by mechanical scarification which had a lower germination (7.8%). Analysis of variance showed that there were no significant differences between the means of the treatments ($P = 0.415$).

When a sample of the seeds was cut open 41 per cent of the seeds of the freshly sown (control) treatment, 32 per cent of the seeds of cold treatment at 16 °C and 30 per cent of the seeds of mechanical scarification treatment were found to be alive. Oven dried at 70 °C and cold storage at 16 °C followed by oven drying at 70 °C seeds were dead.

Experiment 3

Fig. 1 shows the effect of different pre-sowing treatments on seed germination of *Chrysophyllum albidum*. Mechanical scarification gave significantly higher germination than all the other treatments throughout the experimental period.

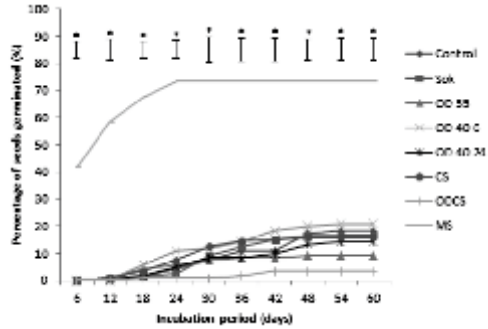

Fig. 1 Cumulative germination percentage of different pre-sowing treatments of *Chrysophyllum albidum* seeds. Each point represents the mean value of four replicates (n = 30 for each replicate). The bars with different lengths show value of LSD at 0.05 and * on LSD bar shows significant difference between treatments. Symbols: diamond, control; square, soaking in water; triangle, oven drying at 35 °C; two lines crossed, oven drying at 40 °C for 6 h; asterisk, oven drying at 40 °C for 24 h; circle, cold storage; vertical line, oven drying followed by cold storage; horizontal line, mechanical scarification.

Of the remaining treatments, the highest germination rate was recorded for oven dried seed at 40 °C for 6 h. However, this treatment did not show germination until day 18 when 5.8 per cent had germinated. Germination subsequently increased to 20 per cent on day 48 and reached its highest germination percentage of 20.8 on day 54 and did not show further germination by day 60 (Fig. 1).

The freshly sown (Control) treatment had the next highest germination percentage (18.3%) by day 60 followed by soaked seeds in water for 48 h (16.7%) and cold treated seeds at 20 °C for 24 h (15.8%). Other treatments were oven-dried seeds at 40 °C for 24 h which reached its highest germination on day 54 (14.2%) and oven dried seeds at 35 °C for 24 h which reached its highest germination on day 48 (9.2%).

The lowest germination percentage was recorded on seeds heated to 40 °C for 24 h and immediately transferred to a refrigerator set at 20 °C for 24 h for cold treatment which reached a maximum germination at day 42 (3.3%). Results of ANOVA showed there were significant differences between the means of the treatments on each data collection day at $P < 0.001$.

Germination Performance variables on Experiment 3

TABLE 3

Germination characteristics of seeds of C. albidum *for an incubation period of 60 days. Values are means of four replicates with 30 seeds per replicate for each treatment.*

Treatment	***Coefficient of Velocity (no units)***	***Germination Index (no units)***	***Mean germination Time (days)***	***Rate of germination (day^{-1})***
Mechanical scarification	9.76	7.55	10.2	0.098
Cold storage	3.70	4.35	27.5	0.036
Oven dried @ 35 °C	3.51	2.89	25.2	0.040
Oven dried @ 40 °C for 6 h	3.38	6.40	31.4	0.032
Soaking for 48 h	3.33	5.10	33.6	0.030
Oven dried @ 40 °C for 24 h	3.35	4.85	32.4	0.031
Oven-dried @ 40 °C for 24 h + Cold storage	2.02	1.15	14.5	0.069
Freshly sown (Control)	2.82	6.70	37.2	0.026
LSD (5%)	1.850	2.724	13.18	
P	<0.001	0.001	0.003	

Table 3 shows that the mechanical scarification treatment had the lowest mean germination time of 10.2 days with the control having the highest. Coefficient of velocity was significantly higher ($P < 0.001$) in mechanical scarified seeds than freshly sown seeds (Control), and there were significant differences between the treatments (Table 3). Germination index showed a similar trend to percentage germination in terms of the ranking of the treatments. The mechanical scarification treatment gave the highest Germination Index (7.55) ($P = 0.001$), followed by Freshly sown seeds (Control) (6.70). Oven-drying at 35 °C for 24 h showed the lowest value of 2.89 (Table 3).

Discussion

In the case of the freshly sown (Control) treatment, in all the three experiments germination did not exceed 20 per cent indicating dormancy (Baskin & Baskin, 1998) in most of the seeds of *C. albidum*. The different pre-sowing treatments significantly affected germination percentage. Mechanical scarification led to the highest germination percentage of 73.33 per cent (Fig. 1) and the lowest mean germination time of 10.2 days (Table 3) and, therefore, was the treatment the seeds responded to most positively. This reflects the fact that the seeds of *C. albidum* have hard seed coats which will not allow easy imbibitions

of water for germination. Similar results in which mechanical scarification gave higher germination percentage were observed in *Lupinus varius* (Karaguzel et al., 2004), *Albizia lebbeck* (Mutha et al., 2004) and *Cicer canariense* (Guma *et al*., 2010). The physical scraping of part of the seed coat of *C. albidum* allowed imbibition of water and oxygen. Most tropical fruit trees have hard seed coats which could be broken by processes such as scarification, which could be physical or chemical (Dirr & Heuser, 1987).

It can be seen that in Experiments 1 and 3 (Table 1 and Fig. 1) in which there was 12 h of light and 12 h of darkness, mechanical scarification had very high germination percentage. These conditions mimic those found in the tree's natural environment in the tropics. The seeds are naturally used to this condition and so germination was higher with this condition than treatments with 18 h of darkness and 6 h of light in Experiment 2. Under the latter condition most of the treatments failed to respond and a number of treatments had no germination. This result agrees with an observation on *Ziziphus lotus* in which the optimal temperature range of 25-30 °C for germination was the temperature range experienced *in situ* by the plant (Zammouri & Neffati, 2010). The results indicate that *C. albidum* seeds could show both physical and physiological dormancy.

Most plant species have adaptive survival strategies to escape unfavourable environmental conditions and perpetuate their progeny when favourable conditions arrive (Atwater & Vivrette, 1987). *C. albidum* sheds its ripened fruit in the dry season from November to March in Ghana. In such conditions, when moisture is barely available, seeds will not be able to germinate. The seeds have hard seed coats which can be degraded gradually by abiotic factors such as different day and night temperatures and occasional rains during the dry season, and biotic factors like fungi, bacteria and some animals to facilitate germination in the rainy season which starts in April.

In experiments 1 and 3 it was found that, apart from the mechanical scarification treatment, all other treatments gave seed germination below 21 per cent, showing the difficulty of using other techniques to enhance seed germination in *C. albidum*. The chemical scarification (sulphuric acid) treatments were not strong enough to open up or break part or all the seed coat to facilitate imbibitions of water for germination. Although sulphuric acid is known to corrode the outer portions of the seed coat for easier permeability (Baskin & Baskin, 1998) and promote germination (Varela & Lizardo, 2010) the treatment failed to be effective in this study.

Results of the thee experiments show that high temperature seed treatments could damage the embryo, thus, preventing it from germinating. In Experiment 1 (Table 1), sulphuric acid was used as a chemical scarification treatment, however, the seeds put in the sulphuric acid might have been damaged by the heat generated which charred the outer part of the testa of the seeds. Another case of higher heat or temperature was the case of boiling water (100 °C) treatment of the seeds for 2 and 5 min. Although boiling water treatment has been used to achieve significant higher germination than mechanical scarification and sulphuric acid in *Gymnocladus assamicus* (Choudhury , Kan & Das, 2009), its effect on *C. albidum* seeds did not lead to germination. In all these treatments, with the exception of sulphuric acid for 10 min treatment, the seeds did not germinate showing the seeds might have been killed or damaged. These agree with a recent observation by Al-Absi (2010) that hot water (90 °C) and sulphuric acid failed to effect germination in *Prunus mahaled.*

In Experiment 2 (Table 3.2), seeds treated to a temperature of 70 °C in an oven did not germinate. Similarly seeds put in a refrigerator for 16 °C for 24 h followed immediately with oven treatment at 70 °C resulted in no germination. In contrast, when the seeds were only treated to a temperature of 16 °C for 24 h,

15.6 per cent germinated (Table 3.2). The tetrazolium tests in all the experiments confirm-ed that seeds in the high temperature treatments were all dead. This shows that the seeds of *C. albidum* have a limited tolerance to high temperature. Cold treatment in a refrigerator at 16 °C (15.6%), heat treatment at 35 °C (3.3%) and soaking for 48 h (16.7%) were not effective in germinating the seeds. In some cases the control treatment fared better than some of these treatments.

The mechanical scarification treatment was effective in breaking the dormancy of the seed when combined with conditions found in its natural environment, i.e. temperature of about 25 °C, Relative humidity of 80 per cent, 12 h of day and 12 h of darkness. It has been shown that the dormancy imposed is due to hard seed coat which restricts imbibitions, gaseous exchange and embryo growth. The removal of a small portion of the hard seed coat near the embryo allowed imbibitions of water, cell elongation of the embryo and radicle protrusion leading to germination.

Although mechanical scarification showed easy and high germination in Experiments 1 and 3, the treatment resulted in very low germination in the second condition of 18 h darkness and 6 h light. This may imply secondary dormancy where the primary dormancy may be broken but the environmental conditions may not be suitable for effective germination (Vivrette & Meyr, 2002). It also points in a way to a difference between dormancy and germination in the sense that when part of the seed coat was removed in which case dormancy had been broken, one of the conditions for germination which is appropriate length of daylight with its attendant increase in temperature was not available.

Conclusion

The study has shown that mechanical scarification can lead to a high percentage germination of seeds of *C. albidum* and this is, therefore, the best method for adoption by farmers for effective seed germination. Farme only have to make sure the scarification does not bruise the endosperm or the embryo as this could lead to fungal attack and death of the seed. Workshops could be organised to train farmers in this technique for increased germination of seeds.

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