Effect of seed size of *Berchemia discolor* (Klotcsch) Hemsl. on germination and seedling growth.

BY

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ABSTRACT

Berchemia discolor is a semi-deciduous tree of Africa that is a valuable for producing timber. A study was conducted to evaluate the influence of seed size on seed germination and seedling quality of *Berchemia discolor* mature seeds of *B. discolor* numbering 100 were collected from healthy trees in Buhera, Zimbabwe and the seeds were grouped into three groups in regard to their length, small (<1.5 cm), medium (1.5-2.5 cm) and large (>2.5 cm). The average width and thickness of the *B. discolor* seeds was calculated as <0.21 g for small seeds, 0.22-0.30 g for medium seeds and >0.31 g for large seeds. The treatments were completely randomized into four replicates. Germination was conducted in germination chambers (incubators) until complete, and the seeds were transplanted into black polythene bags with a mixture of topsoil and cow dug in a ratio of 3:1. Germination percentage was not significantly ($P > 0.05$) different between the treatments, although large seeds had the highest germination percentage of 94.9%. There were significant ($P < 0.05$) differences in seedling height and root collar diameter among the different seed sizes, with large seeds having the highest seedlings height and largest root collar diameter. This was attributed to differences in the food reserves. Survival of the transplants from shoot dieback was significantly ($P < 0.05$) different such that seedlings from large seeds attained the highest survival of 92%. It is therefore recommended that, for production of high quality transplants in the nursery, large sees should be used.

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DEDICATION

This project is dedicated to God the almighty.

CHAPTER ONE: INTRODUCTION

1.1 <u>BACKGROUND OF THE STUDY</u>

Africa has a wide range of valuable tree species. The genus *Berchemia* belongs to the family Rhamnaceaae, which is one of the major groups in Angiosperms. *Berchemia* consists of approximately 71 species (The Plant List 2010), distributed mostly in Africa, Madagascar and Yemen. *Berchemia discolor* (Klotzsch) Hemsl. is commonly known as Bird plum, Munyii in Shona and Umnyii in Ndebele. It is wide spread from the Sudan to South Africa and growing in dry open woodland, semi-arid bush land and along riverbanks (Lowore, 2006).

Berchemia discolor is a semi-deciduous tree reaching 10 to 18 m with erect spreading branches making a heavy rounded crown. The bark is greyish-brown, reticulately fissured. Leaves are shiny dark green, sticky at early stage and oval with the widest part towards the apex. The flowers are small yellow-green, with 5 floral parts (Abideen *et al*, 2009). The tree flowers in March. The wood is used to produce wheels, carts, boats, posts, agricultural implements, boxes and carvings. *Berchemia discolor* is considered a promising source of pulp for high quality paper (Chiroro, 2004). It is common in dry and moist kola agro climatic zones 0 - 1,600m above sea level. The tree is widespread and scattered in open woodlands or at lower altitudes, along river valleys, and in sandy soil in woodlands (Westoby *et al*, 1996). It also grows on termite mounds. *Berchemia discolor* is found natively throughout Zimbabwe including Hurungwe, Chipinge, and Masvingo, but not in mountain forests.

Berchemia discolor is an attractive tree, and is also planted as an ornamental, shade-bearing tree in many sub-tropical areas (Langdon, 2016). It is a very useful species for the rehabilitation of degraded fallow lands because of nitrogen fixing ability (association with *Rhizobium* spp.) and tolerance of moderately alkaline and saline soils (Langdon, 2016). The fruits are brown and yellow with seeds that are averagely about 2 cm long.

The fruit is found in small drupes about 1 to 2 cm long, that turn yellowish in colour when ripe. The fleshy pulp surrounds a kernel with 2 hard seeds (Kueh and Voon, 2000). Ripe fruits are collected from the ground or picked from the tree. Other parts of this tree, such as root, leaves, and bark, are used as traditional medicine to treat diff erent ailments, or instance, chest pain. The seeds of this species have combinational dorman**cy** (based on other species in the same genus), as they have impermeable seed coats (physical dormancy) and physiologically dormant embryos. It is also not known if there are other factors that affects its germination and seedling growth (e.g. seed size and weight).

Despite its importance, *Berchemia discolor* is threatened by an increasing rate of exploitation. Hence, to ensure the continuity in the benefit supply of *Berchemia discolor* tree species, nursery operations are done in various forestry activities to raise seedlings. However, *Berchemia discolor* seeds collected from the natural population are of different sizes, ranging from 1.0 cm to 4 cm long and 0.5 cm to 1.2 cm wide and the weight ranges from 0.15g to [0.4–0.5g]. Choe *et al* (2008) reported that seed size influenced germination and early seedling growth of *Syzygium cumini Miombo* tree species. Due to the importance of *Berchemia discolor*, knowledge of grading seed of *Berchemia discolor* to raise quality seedlings in the nursery is essential in order to obtain high germination and quality transplants and to grow this species all over the country. However, due to irregular seed sizes and weight of the species it restricts the plantation programs (Msanga and Maghembe, 1986). Thus, the current study was carried out to determine the influence of different seed size on seed germination and early seedling development.

1.2 **<u>PROBLEM STATEMENT</u>**

Berchemia discolor is a tree of great value economically (provides fruits and medicines), environmentally, and ecologically. However, *Berchemia discolor's* biggest drawback lies on the combinational dormant nature of the seeds. Even if the dormancy is broken, the *Berchemia discolor* seeds collected from the natural population are of different sizes, ranging from 1 cm to 3 cm long and 0.5 cm to 1.2 cm wide and the weight ranges from 0.15.g to [0.4–0.5g]. Due to new arising diseases, interest in indigenous plants has increased resulting in an increasing rate of exploitation of the trees. Zimbabwe has seen an increase in housing projects (from 2010-present) this has resulted in an increase in deforestation by 5% (Langdon, 2016). Zimbabwe has been experiencing shortages in electrical power supply, and being a developing country this has resulted in rural people cutting down trees for firewood (Azad *et al* 2011). The rapid change in climatic conditions has affected the world globally and this has affected the growth of indigenous trees such as *B. discolor.*

1.3 **JUSTIFICATION**

It is important to produce high quality transplants for *B. discolor* given its role economically, environmentally and ecologically. The roots of the tree have medicinal values and the tree itself is used as an ornamental in gardens and parks. The bark and leaves are used medicinally for various ailments, such as treating wounds, headaches and many more.

The rapid increase in the number of people who are engaged in the selling of *Berchemia discolor* fruits to provide a source of income has resulted in fewer seed germination and seedling growth thus resulting in critical shortages of the *B. discolor*. In Zimbabwe, companies like Forestry Commission Center, which are involved in selling and germinating of seeds, require specific values for which seeds have a higher chance to survive germination and seedling growth, thus it is necessary to identify if size and length affect the quality of the transplants.

Indigenization of plants is also necessary as it helps in reducing the critical shortage of trees and thus counteracting the effects of deforestation. This also results in diversity of the environment. In addition, the availability of *B. discolor* can result in higher consumption of the healthy fruits and increase their availability in urban areas (Azad *et al*, 2011).

The Venda people use the fruit and the bark *B. discolor* to treat infertility. The wood, which is yellow-brown, hard and attractive, is suitable for furniture and walking sticks. It also makes good firewood. The fruit is edible, very sweet in taste and is used to make beer or pleasantly flavored porridge. In traditional medicine, the juice from the fruit is used to treat bleeding gums (Azad *et al*, 2006).

The majority of the research (Anthony, 2011) for *Berchemia discolor* has focused on breaking the dormancy of the seeds but the area for seedling growth and survival is still neglected. Thus, it becomes of paramount importance to come up with means of improving the germination capability of its seed and produce high quality transplants.

1.4 **OBJECTIVES**

1.4.1 Main Objective:

- To investigate the effect of seed size of *Berchemia discolor* on germination and seedling growth

1.4.2 Specific Objectives:

- To assess the effect of seed weight in the germination of *B. discolor*
- To assess the effect of seed length in the germination of *B. discolor*
- To assess the early field performance of *B. discolor* in terms of survival, total height and root collar diameter.

CHAPTER TWO: LITERATURE REVIEW

2.1 History of *Berchemia discolour*

Berchemia is named after M. Berchem, a French botanist, and *discolor* means with two or more colours, referring to the fact that the upper and the lower surfaces are different colours. 'Dis' is a Latin prefix meaning two.

Scientific Classification

Kingdom	Plantae
Phylum	Angiosperms
Class	Eudicots
Order	Rosales
Family	Rhamnaceae

Genus Berchemia

Sited Anthony, 2011

2.2 **BOTANIC DESCRIPTION**

Berchemia discolor is a tree 3-20 m high; with a straight bole; with a rough, dark grey bark that flakes longitudinally. It is also characterized by having dense, rounded crown young branches that are slash yellow and conspicuously lenticellate branchlets that are glabrous to densely pubescent with short, spreading, whitish hairs (Anthony, 2011). The leaves of the tree alternate or sub-opposite, entirely or obscurely crenate, shiny above, dull and glaucous below, broadly elliptic, ovate or obovate-ellipticlanceolate, 2-9 x 2-5 cm, obtuse or acute at the apex, rounded or cuneate at the base; leaf stalks glabrous or pubescent, 1-1.8 cm long (Azad *et al*, 2011).

Fig 2.2.1 showing the *Berchemia discolor* tree

2.3 **BIOLOGY**

It takes about 4-5 months from flower fertilization to fruit ripening. Flowering starts at the onset of rains, while fruit ripening occurs towards the end of the long rains. In Zimbabwe, for example, flowering occurs from October to January and fruiting from January to July.

2.4 **ECOLOGY**

Berchemia discolor grows naturally in various climates, from semi-arid areas to areas receiving rainfall in 4 years out of 5 years. It is found scattered in semi-desert grassland, open woodland or at lower altitudes along river valleys, especially on termite mounds. It is common in riverine forests, *Acacia-Commiphora-Balanites* woodland and wooded grassland, *Acacia* woodland and bushland. *Berchemia discolor* tolerates drought but is not resistant to frost or cold wind.

2.5 **BIOPHYSICAL LIMITS**

The altitude for optimum growth of *Berchemia discolor* is 300-1900 m. Mean annual temperature is 14-30 ℃. Mean annual rainfall is 250-500 to 760-1200 mm. *Berchemia discolor* grows naturally on a variety of soils of various origins. Performs best on well-drained soils in woodlands and along drainage lines.

2.6 SEED SCARIFICATION

Seed coat (external dormancy) results from a seed's hard seed coat that is impervious to water and gases. The seed will not germinate until the seed coat is altered physically. Any process of breaking, scratching, or mechanically altering the seed coat to make it permeable to water and gases are known as scarification (Baraloto and Forget, 2007). In nature, this often occurs by fall seeding. Freezing temperatures or microbial activities modify the seed coat during the winter. Scarification can also occur as seeds pass through the digestive tract of various animals (Bekele-Tesemma *et al*, 2013). Scarification also can be forced, rather than waiting for nature to alter the seed coats. Commercial growers scarify seeds by soaking them in concentrated sulphuric acid. Scarification also can be forced, rather than waiting for nature to alter the seed coats.

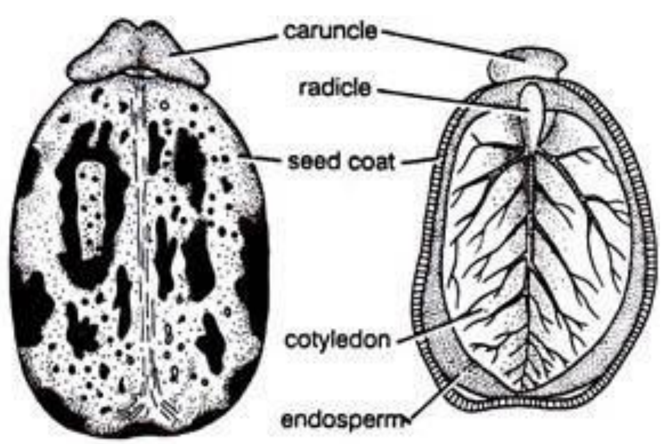

Fig 3.5.1.1 showing the hard seed coat of *Berchemia discolor*

2.7 FACTORS THAT AFFECT SEEDLING GROWTH

2.7.1 RAINFALL AND WATER

Rainfall is the most common form of precipitation. It is the falling of water in droplets on the surface of the Earth from clouds. Other forms of precipitation are freezing rain, sleet or ice pellets, snowfall, and hail (Bhat and Chauhan, 2005). The amount and regularity of rainfall vary with location and climate types and affect the dominance of certain types of vegetation as well as seedling growth.

2.7.2 LIGHT

Three properties of this climatic factor that affect plant growth and development are light quality, light intensity, and day-length or photoperiod. Light quality refers to the specific wavelengths of light; light intensity is the degree of brightness that a plant receives; and day-length is the duration of the day with respect to the night period (Chauham and Raina2012).

2.7.3 TEMPERATURE

The degree of hotness or coldness of a substance is called temperature (Chauham and Raina, 2012). It is commonly expressed in degree Celsius (℃) or centigrade (C) and degree Fahrenheit (F). This climatic factor influences all plant growth processes such as photosynthesis, respiration, transpiration, breaking of seed dormancy, seed germination, protein synthesis, and translocation. At high temperatures the translocation of photosynthate is faster so that plants tend to mature earlier (Chiroro, 2004).

In general, plants survive within a temperature range of 0 to 50℃ (Choe *et al*, 2008). The favorable or optimal day and night temperature range for plant growth and maximum yields varies among crop species.

Enzyme activity and the rate of most chemical reactions generally increase with rise in temperature. Up to a certain point, there is doubling of enzymatic reaction with every 10℃ temperature increase (Close and Wilson, 2002). But at excessively high temperatures, denaturation of enzymes and other proteins occur.

Excessively low temperatures can also cause limiting effects on plant growth and development. For example, water absorption is inhibited when the soil temperature is low because water is more viscuous at low temperatures and less mobile, and the protoplasm is less permeable. At temperatures below the freezing point of water, there is change in the form of water from liquid to solid. The expansion of water as it solidifies in living cells causes the rupture of the cell walls (Dunlap and Barnett, 2013).

2.7.4 **AIR**

The air is a mixture of gases in the atmosphere. According to Edwards (2010), about 75% of this air is found in the troposphere, the innermost layer of the atmosphere which extends about 17 km above sea level at the equator and about 8 km over the poles.

In addition, about 99% of the clean, dry air in the troposphere consists of 78% nitrogen and 21% oxygen. The remainder consists of argon (slightly less than 1%), carbon dioxide (0.036%), and traces of other gases.

The oxygen and carbon dioxide in the air are of particular importance to the physiology of plants. Oxygen is essential in respiration for the production of energy that is utilized in various growth and development processes. Carbon dioxide is a raw material in photosynthesis (Dusan *et al*, 2007).

The air also consists of suspended particles of dust and chemical air pollutants such as carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), sulfur trioxide (SO_3), nitrogen oxides, methane (CH_4), propane, chlorofluorocarbons (CFCs), solid particles of dust, soot, asbestos and lead, ozone and many more.

However, the composition of this climatic factor is susceptible of variation. Recently, there has been a heightened alarm about the increase of carbon dioxide in the atmosphere.

2.7.5 **RELATIVE HUMIDITY**

The amount of water vapor that the air can hold depends on its temperature; warm air has the capacity to hold more water vapor than cold air. According to Foster (2013), there is almost one-half reduction in the amount of water vapor that the air can hold for every 10℃ drop in temperature.

The amount of water vapor in the air ranges from 0.01% by volume at the frigid poles to 5% in the humid tropics. In relation to each other, high RH means that the air is moist while air with minimal content of moisture is described as dry air. Compared to dry air, moist air has a higher relative humidity with relatively large amounts of water vapor per unit volume of air (Fowels, 2000).

The relative humidity affects the opening and closing of the stomata which regulates loss of water from the plant through transpiration as well as photosynthesis. A substantial understanding of this climatic factor is likewise important in plant propagation. Newly collected plant cuttings and bare-root seedlings are protected against desiccation by enclosing them in a sealed plastic bag. The propagation chamber and plastic tent are also commonly used in propagating stem and leaf cuttings to ensure a condition with high relative humidity.

2.7.6 WIND AS CLIMATIC FACTOR

Air movement or wind is due to the existence of pressure gradient on a global or local scale caused by differences in heating. On a global scale it consists of the jet stream flow and movement of large air masses. On the local scale only a smaller quantity of air moves. Surface winds are lower and less turbulent at night due to the absence of solar heating (Gonzalez, 1992).

When air that is close to the ground cools, it contracts and the pressure rises; when it warms, it expands and loses pressure. Where both cold and warm air occur in proximity, as over a lake and its adjacent shore, the cold flows to the direction of the warm air or from high to low pressure area to correct the pressure imbalance. This also happens in tropical Asia but in a larger and more complex way, as the monsoon winds (Hidayati *et al*, 2011).

This climatic factor serves as a vector of pollen from one flower to another thus aiding in the process of pollination. It is therefore essential in the development of fruit and seed from wind-pollinated flowers as in many grasses.

Moderate winds favor gas exchanges, but strong winds can cause excessive water loss through transpiration as well as lodging or toppling of plants. When transpiration rate exceeds that of water absorption, partial or complete closure of the stomata may ensue which will restrict the diffusion of carbon dioxide into the leaves. As a result, there will be a decrease in the rate of photosynthesis, growth and yield (Joker and Msanga, 2000).

2.8 **IMPORTANCE OF *Berchemia discolour***

2.8.1 **NUTRITIONAL VALUE**

The nutritional value is found in food products of *Berchemia discolor*. Humans find the sweet, taste of the fruit quite pleasant (Kandya, 2008). The sugar content of the pulp is as high as 30%, and seeds taste like walnuts. The vitamin C content of the fruit is 65 mg/100 g. The fruit may be eaten boiled with sorghum. This is essential in reducing malnutrition among people in rural areas who cannot afford other alternative nutrient sources (Kueh and Voon, 2000). A beverage similar to tea is made from the leaves. Large quantities of the fruit are collected, dried and stored and later used by people in the low veld areas of Zimbabwe.

Fig 8.1.1 showing the seeds of *Berchemia discolor*

2.8.2 **INCOME GENERATION**

Zimbabwe is known as a farming country which acquires money mainly through farming. *Berchemia discolor* is important for income generation especially among women and orphaned youths in rural areas, because the fruits can be sold in super markets and street markets. In Zimbabwe most people involved in selling the fruits are women's co-operative groups and orphans and they are located in both urban and rural areas (Chiroro, 2004). Therefore, the tree is playing a pivotal role in alleviating poverty most importantly for families with about 0.4 million people involved in street market selling (Chiroro, 2004). Cattle are a major part of Zimbabwe's economy, and due to changes in climatic conditions pastures are becoming scarce. This has led to a market of fodder production. Thus the fruit and leaves of *B. discolor* can be used as fodder.

Due to an increase in honey demand, there has seen an increase in beekeeping business. Thus *B. discolor* is also important for apiculture, as bees are attracted to the small yellow-green flowers found in loose clusters on the tree. An important timber species of southern Africa. The sapwood is pale brown, heartwood hard, heavy (air-dry 992 kg/m^3) and fine grained, yellow-brown with a reddish tinge. The wood is excellent for making furniture such as tables, chairs and benches and is also used in making poles, pestles and hair combs. Black dye, popular with basket makers, is produced from powdered heartwood and roots. The heartwood also produces a resin which is important in industries that use polymers to produce materials such as plastic dishes. A strong alcoholic drink is distilled from the fruit. Other products include the whitewash produced from the ash which is used for painting houses.

The spreading branches and heavy, rounded crown make *Berchemia discolor* an effective shade tree; it can also act as a windbreak. *Berchemia discolor* is planted as an ornamental, it is one of the best indigenous trees for this form of art.

2.8.3 **MEDICINAL VALUE**

The Venda people use the fruit and the bark to treat infertility. In traditional medicine, the juice from the fruit is used to treat bleeding gums (Langdon, 2016).

CHAPTER THREE: MATERIALS AND METHODS

3.1. **STUDY SITE**

The study was carried out at the Forestry Commission (F.C) nursery in Highlands, Harare Zimbabwe. The geographical coordinates are 17° 48'/27°S, 31° 5'/17°E. The area is dominated by deep red soils of high nutrient value. The Forestry Commission is an area of relatively cold climatic conditions. It is characterized by savanna climate, experiencing the wet summer season from October to mid-April and the winter season from mid-April to July (Langdon, 2016). The mean annual rainfall is above 1000mm, whilst the average minimum temperature is 17℃ and average maximum is 24℃. Temperatures are highest in October and lowest in June. The average day and night temperatures are 27℃ and 16℃ respectively. The average daily relative humidity is 71% and wind speed is 11kph/7mph (Lowore, 2006).

Fig 3.1.1; The location of Harare: area under study

PARAMETERS THAT WERE ASSESSED

- Height was measured monthly intervals using a slide micrometer.
- Root collar diameter was measured at monthly intervals using a slide micrometer.
- Survival was assessed at monthly intervals by physically counting the number of surviving seedlings
- The rate of growth of the seed

3.2. SOURCES OF MATERIAL

3.2.1 SEED COLLECTION

Sun dried fruits of *Berchemia discolor* were collected fresh in March 2015 from various trees in Buhera and they were stored at 5℃ until provided for this study at Forestry commission in Highland Harare.

3.3 MATERIAL SELECTION

Materials were carefully selected based on potential dormancy effects. Forest Research Center annually evaluates all inbred lines comparing relative maturity. Six lines with the longest maturities over the last three years were used in this study. Three of them are characterized as high oleic materials, which are also known to exhibit dormancy. To determine a baseline and identify if seeds were dormant, a germination test was performed in the laboratory under controlled conditions. A warm germination test was compared to a cold germination test to evaluate possible dormancy effects. In the warm germination test, seeds were placed in a germ towel and sprayed with water. The towel was folded to assure contact between seeds and then placed in a growth chamber at 25°C for seven days. The percentages of normal, dormant and dead seed were calculated. The cold germination test was the same as the warm test, but required a pre-chill of seven days at 10°C prior to the seven days at 25°C. Exposure to the pre-chill technique greatly improved the germination rate in the seeds.

3.4 SEED VIABILITY TESTING

Seed viability testing was done according to standard procedures. The viability of the seeds was assessed using the flotation technique and staining with triphenyl tetrazolium chloride (TTC) salt. The extent of predation was assessed visually. The collected seeds were checked to remove stained, discolored and damaged seeds. Healthy dried seeds were then used in the experiment.

3.4.1 FLOTATION TEST

Excess water was added to the seeds and left for a period of 24 hours. Seeds which were found floating were considered to be empty and dead and those which sank were considered full and viable. This method was adapted from Matin *et al* (2006), ISTA (1993) and Missanjo *et al* (2013). The proportion of seeds which sank was taken as a measure of seed viability.

3.5.1 METHODS FOR BREAKING DORMANCY

Surface sterilization was done by dipping the fruits in 90% ethanol. A secateur was dipped in 90% ethanol and flamed until it was red hot. The secateur was allowed to cool before it was used to nick the seeds. Using the secateurs, the seeds were nicked lengthwise and a small portion was removed using a sterilized scapel. In order to improve the germination of the seeds, they were then soaked in cold water for 24 hours. Thereafter seeds were put on a moist paper towel which was rolled four times in their respective plastic petri-dishes and then monitored for germination on daily bases. The treatment was done on all the seeds with a hard coat.

Fig 3.5.1.1 showing the hard seed coat of *Berchemia discolor* seeds

3.5.2 <u>THE CONTROL</u>

This consisted of untreated seeds, thus they were not nicked and soaked.

<u>GERMINATION AND TREATMENTS</u>

3.6.1 <u>PREPARATION OF SEEDS</u>

Seeds were categorized into small, medium, and large in terms of weight and length (Table 1). The seeds were soaked in large plastic dishes separately for 24 hours. For all the seeds that were under study, 100 seeds were measured using a balancing scale and mixed with water (Oei, 2005). After preparing the seeds all the jars were loaded into the autoclave and subjected to sterilization at 22 lbp p.s.i pressure at 126^{o}C for 90 minutes.

TABLE 1: Seed size categories in terms of weight and length.

Seed size categories	Range of seed weight (g)	Average weight (g) of 100 seeds	Range of length (cm)	Average length (cm)
Small	<0.21	0.15	<1.5	0.9
Medium	0.22-0.30	0.27	1.5-2.5	2.0
Large	>0.31	0.49	>2.5	3.2

3.6.2 SEED CONTAINERS

Petri dishes were used in this study and they were soaked for three hours in 5% household bleach solution. To allow gaseous exchange four holes were drilled on each lid of the covers. Filter paper was placed inside each cover to filter gas exchange. The petri dishes were subjected to sterilization at 37^{o}C for 30 minutes.

3.6.3 MEDIA PREPARATION

Paper and cloth media were used, this was available as large A4 papers and small round white napkins. They were firstly cut into small and round pieces such that they could fit into the petri dishes. The papers were then labelled A, B, C, and D respectively. Finally, the media was transferred to petri dishes and autoclaved at 121^{o}C for 1 hour. The same procedure was repeated for all petri dishes containing the media.

3.6.4 INCUBATION

Each treatment had a total of 100 seeds which were replicated four times with 25 seeds each. After the seeds were placed in the sterilised petri dishes, the petri dishes were placed in the incubation room for 28 days. Over this period the petri dishes were checked for germination growth on a 24-hour interval. Any changes were noted and recorded. All the contaminated jars were removed from the incubation room to avoid contaminating other jars. All the contaminated glass bottles were discarded. The dishes were labelled according to the replicates and treatments assigned. Water was added twice a day to maintain adequate moisture. The days taken for complete germination were recorded.

3.7 **SOWING**

The seeds were sown on December 27, 2017, in black polythene bags. The media in the poly-bags was a mixture of topsoil and cow dung in a ratio of 3:1. The media was first autoclaved before it was used. One seed was sown per tube at a depth of 2 cm, as recommended by Mosseler (*et al,* 2000). The poly-bags were then labeled and the plants watered twice a day to maintain adequate moisture necessary for germination and seedling growth.

3.8 **DETERMINATION OF SEED GERMINATION**

Germination was recorded daily for 30 days until germination stopped. The seeds were considered germinated by a visible protrusion of split seed coat with the cotyledons, hypocotyls, and epicotyl on the surface of the paper media. Daily germination percentages were summed up to obtain cumulative germination for each treatment. After the completion of seed germination, the growth performance of the seedlings was monitored for 8 weeks, to assess the seed size treatment effect on growth. All the seedlings were measured for total shoot height and collar diameter at 37 days, 65 days and 86 days after sowing during which all seeds were considered germinated. Survival of the seedlings was also assessed at the same intervals. Total shoot height was measured by using a 30cm ruler and collar diameter by using a microcaliper to the nearest 0.01mm. The measurements were taken just below the cotyledons. The number of seedlings that survived was also counted in each and every treatment. The germination percentage and rate of germination (Munthali, 1999) were calculated using the following equations:

$$G_p = \frac{Ng}{Nt} \times 100$$

$$G_r = \sum \frac{Ng}{Days\ of\ count} \Longrightarrow \sum \frac{Ng}{Day\ of\ first\ count} + \ldots + \sum \frac{Ng}{Day\ of\ last\ count}$$

G_p is the germination percentage

N_g is the number of germinated seeds

N_t is the total number of seeds planted

G_r is the rate of germination

Fig 3.8.1 showing the germinating seeds of *Berchemia discolor*

3.9 **DATA ANALYSIS**

Analysis of variance was conducted using two-way ANOVA in SPSS. There were two predictor variables that is seed weight and seed length. A two-way ANOVA was conducted that examined the effect of seed size on germination percentage and seedling growth. Tukey's test was also used to determine the relationship that existed between seed size, germination percentage, seedling height, root collar diameter, and survival percentage.

CHAPTER FOUR: RESULTS

4.1 **SEED GERMINATION PERCENTAGE RATE**

Germination percentages for small, medium and large seeds of *B. discolor*, 30 days after sowing are presented in Figure 2. Germination started a little earlier in small seeds than in other seeds. Germination took longer to complete in larger seeds than in the other two treatments. An average of 26 days was taken for all the seeds to germinate in all treatments. Statistically there were no significant differences ($P > 0.05$) between germination of all the three treatments, although large seeds had a higher cumulative germination percentage than the other treatments.

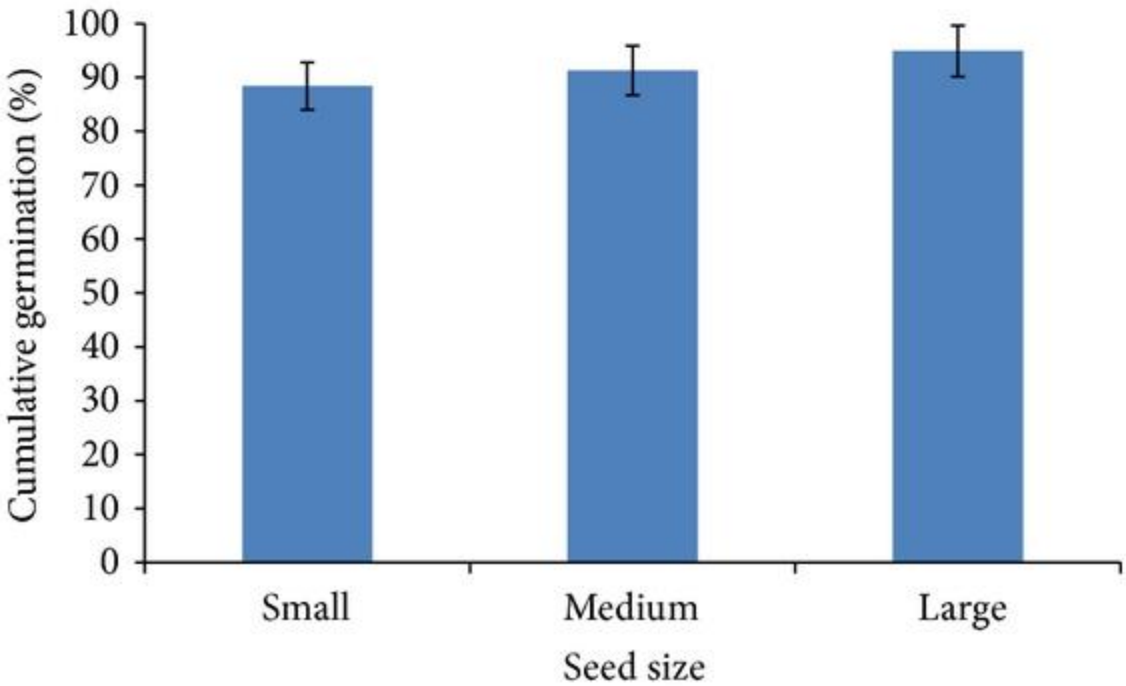

Figure 4.1.1: Cumulative germination percentage for small, medium, and large seeds of *Berchemia discolor* at 30 days after sowing.

4.3 **PLANT HEIGHT AND ROOT COLLAR DIAMETER**

The mean height and root collar growth of the seedlings at 38, 66, and 87 days after sowing are presented in Table 2. The results indicate that there were significant ($P < 0.05$) differences in seedling height and root collar diameter among the different seed sizes, with large seeds having the tallest seedlings height and largest root collar diameter than the other two treatments. Small seeds had the lowest seedling height and root collar diameter. However, there were no significant ($P > 0.05$) differences between small seeds and medium seeds for root collar diameter at 66 days after sowing.

Table 2: **Mean seedling height and root collar diameter growth with standard errors at 38, 66, and 87 days after sowing.**

Treatment	38 days after sowing		66 days after sowing		87 days after sowing	
	Height (cm)	Root collar diameter (mm)	Height (cm)	Root collar diameter (mm)	Height (cm)	Root collar diameter (mm)
Small seeds	13.15	0.3	13.85	0.5	14.53	0.5
Medium seeds	15.22	0.4	16.75	0.5	17.30	0.6
Large seeds	16.77	0.5	19.38	0.6	22.95	0.8

4.4 SEEDLING SURVIVAL

Seedling mortality caused by shoot dieback was first noticed 40 days after sowing the seed. The survival percentages of the seedlings after 87 days of sowing are shown in Figure 3. There were significant ($P > 0.05$) differences in survival percentage between the seed sizes, with the highest (92%) attained by seedlings from large seed and the lowest (68%) by those from small seed.

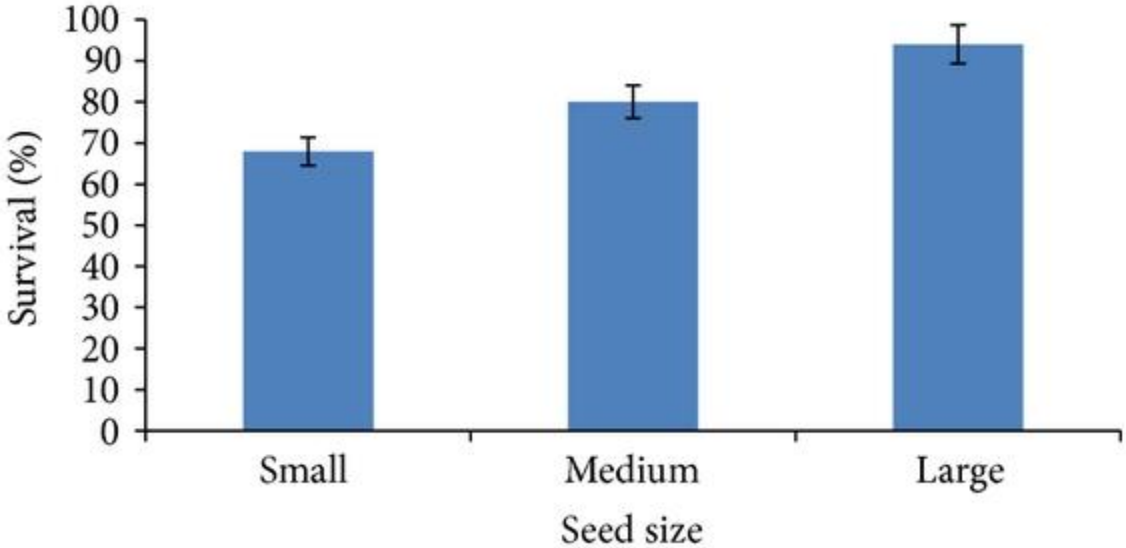

Figure 3: Seedling survival for small, medium, and large seeds of *Berchemia Discolor* at 30 days after sowing.

4.4 **INTERACTION BETWEEN PARAMETERS**

Weak correlation between seed size and germination could imply that as long as seed is of high physiological quality it will germinate irrespective of size. However, in the current study there was a strong relationship between seed size, seedling height, and root collar diameter and survival percentage. This could imply that seed size could be used as a parameter for predicting seedling growth rates in the nursery. The results of the present study are in line with Azad *et al* (2010) which reported strong relationships between seed weight and growth factors such as height and root collar diameter growth of *Pinus oocarpa*.

CHAPTER FIVE

DISCUSION

Seed problems related to seed dormancy often limit the use of particular species in nurseries for the production of seedlings. Seed dormancy can vary from species to species, stage of maturity of seed and the climatic conditions faced by the seed. Several investigators including Azad *et al* (2010) have discussed different methods of germination and have all concluded that in the case of *B. discolor* physical scarification of the seed coat either by piercing, flaming, clipping, nicking, or filling with the aid of abrasion paper is highly effective to enhance the rate of germination and speed up the germination process.

5.1 **GERMINATION PERFORMANCE**

Seed traits, namely seed length, width, weight, and germination parameters vary significantly among the seed sources. Germination is an event which denotes transition from seed being dependent on food sources from the mother plant to an independent plant capable of taking up nutrients and growing independently. Larger seeds germinate faster and more completed than smaller one probably due to more endosperm nutrient pool (Munthali, 1999). There were inconsiderable differences in germination percentages between large and medium, medium and small and large and small seeds (2%, 3.5% and 6.5%) respectively. Differences observed for germination percent could be genetic in nature because environmental deviations are negligible for experimental conditions and seeds of all states were stored in similar conditions. This is supported by the reports of Mwase and Mvula, 2011) and Vakshasya *et al.* (1992) for *Dalbergia sissoo* and Orwa *et al.* (2009) for *Prosopis cineraria*. Since the seeds were germinated under similar conditions, the small variations among the seed sources may be attributed to genetic differences. Such variations in nursery performances have been reported in *Acacia albida* (Pauley *et al*, 2011), *Acer rubrum* (Payne *et al*, 2010) and *Prosopis cineraria* (Roy *et al*, 2010).

Present findings were close to those of (Palgrave, 2002) who argued that only those seeds which germinate rapidly and vigorously under favourable conditions, are likely to be capable of producing vigorous seedlings in field conditions which is of immediate interest, whereas, week or delayed germination is often fatal. Schmidt, (2009) stated that populations with high germination rate are more vigorous in terminal and root growth. Shackleton and Dzerefos, (2000) also recommended the detection of fast growing provenances based on germination traits. The seeds of *B. discolor* did not influence the rate of germination between the three treatments. Thus, the seeds can germinate provided that the conditions are optimal for germination. However, Shivanna (2007) in his studies for *Pinus taeda* states that germination percentage shows a significant difference between small, medium and large seeds. In general, seed and germination traits are supposed to be inherited characters influenced by age, growth, micro and macro habitats of the parent tree (Van Wyk and Van Wyk, 2000).

The present results could be an indication that grading the seeds of *B.discolor* with the aim of enhancing the rate of germination is not important. On the other hand, the silvicultural practice that could be applicable in this species is to consider the use of high physiological quality seed for the enhancement of germination. According to Westoby *et al.* (1996) some of the desirable seed physiological qualities include plumpness, high purity, freedom from pests and diseases, and being dried to a right moisture content. Schimdt (2009) further reported that high physiological quality is necessary for obtaining high germination capacity and vigor, which subsequently could result in well-established, vigorous, and uniform transplants in the nursery. A previous study of white pine reported that percent germination under laboratory conditions was higher in larger seeds as compared with smaller seed (Willan, 1993). However, since only empty seed were removed in that study, it is possible that some of the smaller mass seed used may not have had fully mature female gametophytes and/or embryos. The presence of morphologically immature seed with reduced germinability could have depressed mean germination performance of this smaller mass (Wright, 2015). A higher percent germination in medium mass, as compared with small and large mass seedlots, was reported by Wright (2015), but the methods used are unclear and the seed was not pretreated. The absence of empty and immature seed and adequate pretreatment in the seeds tested in the present study should have minimized the potentially confounding influence of the above-mentioned factors on the results.

5.2 **HEIGHT AND ROOT COLLAR DIAMETER GROWTH**

Substantial height growth percentage difference (22%) between seedlings from large and small at 38 days could be attributed to differences in food reserves. This is supported by (Payne *et al* 2010) which reported that larger seed store greater amounts of carbohydrate in their endosperm than small seed. It could also be that large and medium seed had reserves that were not much different than with small seed resulting in lower differences of 9% compared to the latter. Large-seeded species are predicted to be better adapted to the catastrophic events encountered by seedlings because they can compensate for damage using seed reserves (Payne *et al* 2010).

The pattern of growth continued at 65 days with increased height growth difference (28%, 17%, and 13% between seedlings from large and small, medium and small, and large and medium, respectively). At this stage, this could indicate that plants were using the photosynthesized food for growth, as the food reserves were being invested in the tap root of the plants. This was also indicated by the plants that changed cotyledons colour from brown yellowish to right green in the nursery. Roy *et al* (2010) reported that, during early growth of a seedling, food reserves are transported to the growing axis such as root or photosynthetic tissue in order to maintain a positive net energy balance as seedling reaches higher light intensity.

The trend continued at 87 days for seedlings developed from large and medium seed, such that there was an increased height percentage difference in *B. discolor* transplants (36% and 25% between large and small, large and medium, respectively) with time. However, a slight decrease in height percentage difference (16%) between medium and small seeds with time could mean that seedlings from small seed could also achieve faster growth with time, since they fully use photosynthesized food for growth. Esen *et al.* (2007) support that, while the plant is growing and developing additional leaves, food reserves diminish with increased rate of photosynthesis. This could also imply that *B. discolor* seedlings from small seed may be slow starters, such that with time they can attain fast growth rate regardless of having initial small amount of seed reserves.

The present results of the height growth and root collar diameter growth are in agreement with the observation in the relative growth of *Bauhinia thonningii* (Chauham and Raina 2012), *Pinus elliotti* (Azad *et al* 2010), and *Pinus strobus* (Bekele-Tesemma *et al* 2013) where the height growth and root collar diameter growth at the end of first year were influenced by the weight of the seed. Present results have shown that, for production of better seedlings in terms of seedling vigor, large and medium seeds should be promoted in the nursery. On the other hand, seedling from small seeds should not be discarded as their growth improves following active photosynthesis and hence field study should assess their performance in the field.

5.3 **SEEDLING MORTALITY**

Seedling mortality in the nursery was largely attributed to the occurrence of shoot dieback (dying back to about 3 cm below the ground). Low mortality in seedlings developed from large seed could be due to its ability to develop a new shoot after dying back by drawing from the large amount of energy reserves contained in the tap root. Munthali (1999) reported that there is a positive correlation between shoot dieback and the sizes of the shoot and root in *Pterocarpus angolensis* seedlings.

The present results are in line with Shackleton and Dzerefos (2000) which reported that survival of a *Pterocarpus angolensis* seedling is dependent on the amount of the reserves at the time of regrowth, such that those with greater amount of food reserves were able to regenerate a new shoot. The present study has indicated that survival percentage difference between seedlings from large and medium (6%) was small in degree; however, it was considerable between large and small (15%). This implies that large and medium seeds of *B.discolor* should be promoted for sowing because of its low mortality rate.

5.4 **CORRELATION OF SEED SIZE WITH SEEDLING PARAMETERS**

Weak correlation between seed size and germination could imply that as long as seed is of high physiological quality it will germinate irrespective of size. However, in the current study there was a strong relationship between seed size, seedling height, and root collar diameter and survival percentage. This could imply that seed size could be used as a parameter for predicting seedling growth rates in the nursery. The results of the present study are in line with Kueh and Voon (2000) which reported strong relationships between seed weight and growth factors such as height and root collar diameter growth of *Pinus oocarpa*.

5.5 **DORMANCY**

Seed coat induced dormancy delays germination and emergence by impeding the expansion and water absorption of mega-gametophyte and embryo tissues, but can be overcome by different pretreatments for an appropriate period (Munthali 1999). In the present study, seed were pretreated by subjecting them to nicking. This pretreatment method and the relatively high seed viability (>95%) observed in the current study suggests that differential seed dormancy among families due to insufficient cold storage likely had little influence on speed of emergence. Stronger seed dormancy and delayed germination in some seeds is also related to a higher percentage of total seed mass contained in seed coat tissues Shackleton and Dzerefos (2000). However, variation among families in percent seed coat mass as a factor in the present study is also unlikely since this proportion apparently varies little with seed mass in this species Wright (2015).

Instead, more rapid emergence was likely due to higher germinative vigor associated with larger reserve tissues and embryos in heavier seeds.

CHAPTER SIX

6.1 **Conclusion**

The study has demonstrated that seed size does not affect germination, therefore use of only high physiological quality seeds could enhance germination of this species. Seedling vigour and survival were influenced by the length and weight of the seeds. Positive relationship between seed size and early seedling growth and survival percentage confirms merits of grading seed to enhance transplant quality. Therefore, in raising

Berchemia discolour, nursery managers, forests, and local communities are recommended to use large and medium seed for production of high quality transplants.

6.2 RECOMMENDATIONS

Further studies need to be carried out to promote the growth of indigenous trees of Africa to ensure diversification in the forestry industry. There is also need to support the production of high quality transplants in Zimbabwe through funding of the available seedling producers.

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CHAPTER 8: APPENDICES

APPENDIX 1: SPSS output for germination percentages

Dependent Variable: Germnation

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	10966.051[a]	25	438.642	7.258	.000
Intercept	33729.282	1	33729.282	558.100	.000
Seeds	**1329.282**	**1**	**1329.282**	**21.995**	**.000**
Media	**7591.051**	**12**	**632.588**	**10.467**	**.000**
seeds * Media	**2045.718**	**12**	**170.476**	**2.821**	**.005**
Error	3142.667	52	60.436		
Total	47838.000	78			
Corrected Total	14108.718	77			

a. R Squared = .777 (Adjusted R Squared = .670)

APPENDIX 2: SPSS output tests for survival rates

Dependent Variable: Days to complete germination

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	1219.485[a]	25	48.779	19.961	.000
Intercept	24913.282	1	24913.282	10194.827	.000
Seeds	**5.128**	**1**	**5.128**	**2.099**	**.153**
Media	**1164.765**	**12**	**97.064**	**39.720**	**.000**
Seeds * Media	**49.592**	**12**	**4.133**	**1.691**	**.096**
Error	127.073	52	2.444		
Total	26259.840	78			
Corrected Total	1346.558	77			

a. R Squared = .906 (Adjusted R Squared = .860)

APPENDIX 3:

Dependent Variable: Days to complete germination
Dunnett t (2-sided)[a]

(I) Seed type	(J) Seed type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Small	Small (control)	-4.067*	.9025	.000	-6.657	-1.477
Medium	Small (control)	2.933*	.9025	.019	.343	5.523
Large	Small (control)	4.083*	.9025	.000	1.493	6.673
Small-medium	Small (control)	-1.067	.9025	.866	-3.657	1.523
Small-large	Small (control)	-3.350*	.9025	.005	-5.940	-.760
Medium-small	Small (control)	2.767*	.9025	.030	.177	5.357
Medium-large	Small (control)	9.067*	.9025	.000	6.477	11.657
Large-Small	Small (control)	6.983*	.9025	.000	4.393	9.573

Based on observed means.
The error term is Mean Square(Error) = 2.444.
*. The mean difference is significant at the .05 level.
a. Dunnett t-tests treat one group as a control, and compare all other groups against it.
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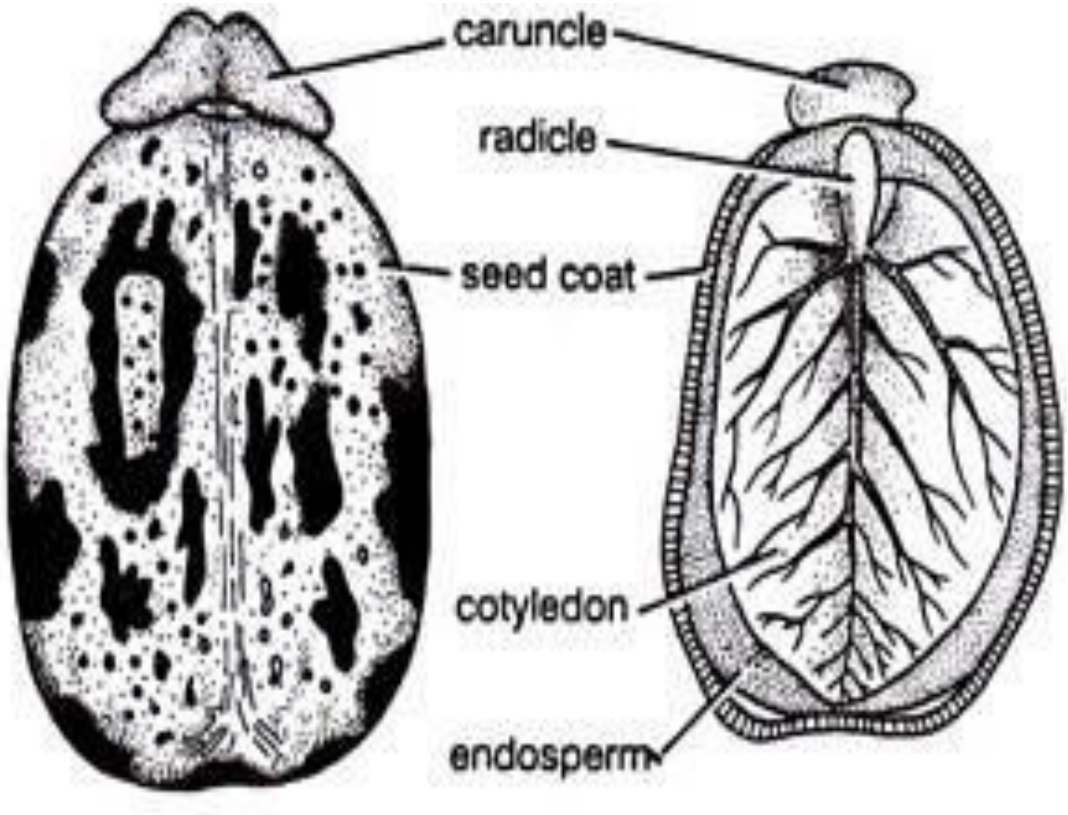
APPENDIX 4:
The *Berchemia discolor* tree

APPENDIX 5:

The seed dormancy associated with berchimia discolor seeds



APPENDIX 6:
The seeds of *Berchemia discolor*

APPENDIX 7:

The hard seed coat of *Berchemia discolor* seeds

APPENDIX 8:
The germinating seeds of *Berchemia discolor*