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Desiccation Sensitivity and Germination of Recalcitrant *Garcinia kola* Heckel Seeds

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ABSTRACT

Investigations were undertaking on the desiccation sensitivity as well as on seed germination of recalcitrant *Garcinia kola* Heckel. Matured fruits were harvested from a moist semi-deciduous forest at Amantia in the Ashanti Region of Ghana. Depulped seeds were mixed with moistened sawdust and placed in white cotton sacks and quickly transported by air to the Seed Conversation Department of the Royal Botanic Gardens in the United Kingdom. Seed equilibrium relative humidity at 20°C and moisture contents on arrival in the U.K were 96.9 and 58.0%, respectively. As whole seeds and proximal parts/sections of the seeds dried in silica gel at 20°C and under shade at room temperature (26-30°C) moisture content, germination and electrical conductivity were measured. Germination percentages of whole seed and proximal parts reduced gradually as they were dried and at moisture contents below 30.0% germination was drastically reduced. The critical moisture content in seeds and seed pieces of *G. kola* was therefore around 30.0%. Electrical conductivity of leachate from seed increased as seed moisture contents was lowered. When whole seed, proximal sections, half of proximal sections, proximal end cut and distal end cut pieces were incubated, normal seedlings of the species were produced. Conversely, distal and half of distal sections of the seed produced only roots, while middle and half of middle sections of the seeds produced neither roots nor shoots. Germination characteristics of seeds of *G. kola* demonstrated the existence of polarity.

Key words: *Garcinia kola*, seed sections, desiccation sensitivity, electrical conductivity, critical moisture content, polarity

INTRODUCTION

Genus *Garcinia* L. belongs to the family Clusiaceae (Guttiferrae). It is composed of approximately 400-600 species, including dioecious, evergreen trees growing in the tropical parts of the world (Steentoft, 1988; Richards, 1990). Only 16 of these species occur in West Africa (Steentoft,1988).

Garcinia kola Heckel occurs in the wet and moist semi-deciduous forest zone in Western and Central African regions. *Garcinia kola's* interest is proved as one of the many non-timber forest products that are of high socio-economic importance (Adebisi, 2004), It most important use is probably as a source of chew-sticks in West Africa (Adu-Tutu *et al.*, 1979), offering natural dental care. The trees are often felled to facilitate both removal of bark and harvest of chew-sticks, contributing to the increasing scarcity of the species in West Africa. *Garcinia kola* which is also known as bitter cola is highly used for its medicinal purposes because of its anti-viral, anti-inflammatory, anti-diabetic, bronchio-dilator and anti-hepotoxic attributes. Fruit extracts from *G. kola* have proven effective at stopping Ebola virus replication in laboratory test (Wikipedia Contributors, 2006). The sap from *Garcinia kola* is used for the treatment of parasitic skin diseases while the latex is orally ingested for the treatment of gonorrhea. It is also useful in the eradication of guinea worm infestation (Ofakansi *et al.*, 2008).

Because of its high interest resulting in its overexploitation, *Garcinia kola* is extinction-threatened in several West African and Central African countries such as the Ivory Coast, Togo, Congo and Cameroon (Eyog-Matig *et al.*, 2007). Another reason threatening the survival of the species is that its natural regeneration is poor and seedlings are slow growing and uncommon (Abbiw, 1990; Gyimah, 2000).

Most species of the genus *Garcinia*, are shed at high moisture content levels, exhibit low viability and are short-lived and are described as being recalcitrant and therefore bieng desiccation sensitive (Morton, 1987; Chacko and Pillai, 1997).

Seed desiccation sensitivity may limit the ex-situ conservation of plant species and therefore, the first challenge for seed conservation is to determine seed response to desiccation (Gold and Hay, 2007). Knowledge of the critical and lethal moisture levels of a species is indispensable for planning and execution of seed drying and storage (Martins *et al.*, 2003).

The objective of this study was to determine the effects of seed dehydration on germination and vigour of *Garcinia kola* seedlings.

MATERIALS AND METHODS

Collection and processing of seed samples: Fully matured fruits of *Garcinia kola* were obtained from trees at Amantia in the Ashanti Region of Ghana. Fleshy fruits of the species were processed by depulping soon after collection to avoid fermentation and heating as recommended by Willan (1985). Seeds were then packed in cotton bags filled with moistened sawdust to prevent loss of seed moisture. In order to establish the exact shedding moisture contents of fruits, seeds and seed parts of the species, samples to be used for the initial moisture contents tests were depulped without fruits/seeds being soaked in water. Seed samples were immediately sent by air to the Seed Conservation Department of the Royal Botanic Gardens, Kew, in the United Kingdom where part of the experiment was carried out. The second season's collection was used for the second part of the work at the Forestry Research Institute (FORIG), in Ghana.

Equilibrium Relative Humidity (eRH) of seed samples: The equilibrium relative humidity (eRH) of *G. kola* seeds was measured soon after their arrival in the United Kingdom and also after 30 days of desiccation in silica gel at 20°C using a Rotronic AWVC-DIO sensor manufactured by Rotronic Ltd. of the United Kingdom. The control samples were mixed with moistened vermiculite and also held at 20°C.

Seed and seed components moisture content determination: Moisture contents were determined using 10 whole fruits in four replications; mesocarp extracted from 10 fruits in three replications; 10 whole seeds in three replications and testa extracted from 10 seeds in three replications.

Moisture contents were determined gravimetrically by weighing fruits, seeds or seed components before and after drying in an oven at 103°C for 17 h (ISTA, 1993). Moisture Content (MC) was calculated using the formula:

$$MC\ \% = \frac{(FW\text{-}DW)}{FW \times 100}$$

where, FW is (fresh) weight of sample before drying and DW is (dry) weight of sample after drying. The mean moisture content was then calculated for fruit, seed or seed components.

Seed desiccation, viability and vigour assessment: Whole seeds and proximal sections/parts of *Garcinia kola* with initial moisture content of 58% were placed in separate plain polythene bags and desiccated by mixing them with silica gel (1 kg of seeds for 1 kg of silica gel) to various moisture contents. Seed samples were drawn every 2 days for seed moisture contents and seed viability and vigour assessment.

Assessment of seed viability and seed vigour: Electrical conductivity measurement of leachates from desiccated proximal sections of *G. kola* seeds was used to assess the vigour levels of samples as adopted by Steere *et al.* (1981). The Multiple Cell (C100) Conductivity Meter 2.18 manufactured by Reid and Associate of South Africa was the conductivity meter used. The device has three main components:

- A plastic soaking tray that contains 100 compartments or cells each with about capacity
- A multi-electrode head with 100 pairs of specially designed electrodes connected to an electrical system and
- A seed analyzer computer program that analysis the measurements of the current or resistance across each electrode pair

When the electrode head system is placed on the tray, one pair of electrode is submerged in each cell. An applied voltage exerts a uniform electrical potential across electrode pair and the computer translates the amperage into conductivities.

Seeds pieces drawn from desiccating proximal samples were cut into the weights of 0.16, 0.31, 0.37, 0.46, 0.59 and 0.66 g and dropped into cells 1, 2, 3, 4 and 5 of the conductivity meter tray. Prior to dropping the seed pieces, each tray was filled with 3 mL of deionized water to receive the leachate. The soaking tray was washed and rinsed with double-distilled water prior to each test run to remove ionic impurities. Measurement voltage applied during the experiment was 6.00 V with a reference temperature of 25°C and a measurement interval of 10 sec.

Germination of seed and seed portions of *G. kola*: Whole seeds of *G. kola* as well as seed sections/parts with moisture content 55% were placed on 1% water agar in plastic sandwich boxes (measuring 17.3×11.3×6.0 cm) and incubated at constant temperatures of 5, 10, 15, 20, 25, 30 and 35°C in order to make a comprehensive study on the germination of the species. The seed sections//parts used were:

- Distal Section (DS) (50% of the seed)
- Half of Distal Section (HDS) (25% of the seed)

- Proximal Section (PS) (50% of the seed)
- Half of Proximal Section (HPS) (25% of the seed)
- Distal End Chipped off (DEC) (80% of the seed)
- Proximal end chipped off (PEC) (80% off the seed)
- Middle Section (MS) (50% of the seed)
- Half of Middle Section (HMS) (25% of the seed)

Seed or seed sections were counted as germinated when radical or plumule attained at least 1 cm and were free from visual infection or deformation (Rawat, 2005).

Data on desiccation and germination of whole seeds and seed parts as well as electrical conductivity was subjected to Analysis of Variance (ANOVA) using the Genstat statistical package to determine significance.

RESULTS AND DISCUSSION

Seed eRH and moisture content: The eRH measured at 20°C and moisture content of *Garcinia kola* seeds when they were received fresh at the laboratory in the United Kingdom were 96.9 and 58.0%, respectively. The eRH and moisture content of the seed samples after 30 days of desiccation in silica gel were 57.7 and 20.0%, respectively. Seeds maintained in moistened vermiculite as control for 30 days had eRH and moisture content of 96.4 and 56.0%, respectively (Table 1). The initial mean fruit, mesocarp and seed coat moisture contents obtained for seeds was 86.6, 93.2 and 79.4%, respectively (Table 2).

Desiccation and germination trials: Results of the desiccation and germination trials carried on the species are presented in Fig. 1. Whole seeds of *Garcinia kola* with initial moisture content

Table 1: Equilibrium Relative Humidity (eRH) of fresh *Garcinia kola* seeds measured with a Rotronic AWVC-DIO at 20°C on receipt at the laboratory and after desiccation in silica gel

Parameters	Description
Seed	Garcinia kola
Period of desiccation in silica gel (days)	30
eRH of seed dried in silica gel (%)	57.7
	*96.9
Moisture content of seed dried in silica gel (%)	20
	*58.0
Period at which seeds were held in moistened vermiculite (control) (days)	30
eRH of seed dried held in moistened vermiculite (Control) (%)	96.4
	*96.9
Moisture content of seed held in moistened vermiculite (Control) (%)	56
	*58.0

Values initial eRH and moisture contents of seeds

Table 2: Initial moisture content of fruit, seed and seed components of *G. kola*

	Initial moisture content (%) of fruit, seed and seed components			
Species	Fruit	Seed	Mesocarp	Seed coat
Garcinia kola	86.8±1.8	58.0±1.1	93.2±2.4	79.4±1.6

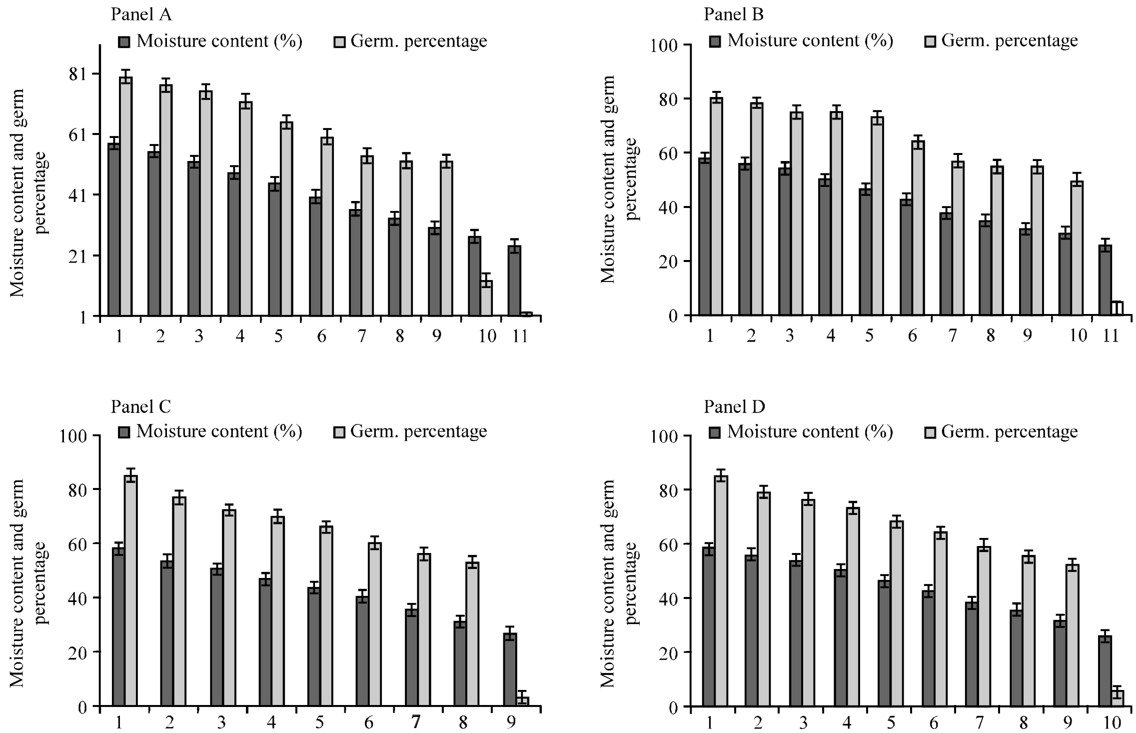

Fig. 1: Panel A (top L), desiccation of whole seeds of *G. kola* in silica gel at room temperature (27-30°C) and germination. Panel B (top R), desiccation of whole seeds of *G. kola* under shade at room temperature (27-30°C) and germination. Panel C (bottom L), desiccation of proximal sections of *G. kola* in silica gel at room temperature and germination. Panel D (bottom R), desiccation of proximal sections of *G. kola* under shade at room temperature (27-30°C) and germination. Error bars represent two standard error of the difference

of 58.0% had a germination percentage 80.0%. When seeds were desiccated in Silica Gel (SG) or under shade (SD), seed viability declined gradually with decreasing moisture content. At moisture contents of 52.1 and 40.3% (SG) germination significantly ($p<0.001$) reduced to 75 and 60%, respectively. Seed germination at moisture content of 30.2% was 52% and this drastically reduced to 13% at a moisture content of 27.5%. After 20 days of drying in silica gel, the moisture content had reduced to 24.3%, germination recorded was 0%. For seed dried under shade (SD), seed germination at moisture contents of 50.1 and 43.0% significantly reduced to 75 and 64%, respectively. Germination at moisture content of 30.8% was 50% which significantly reduced to 3% at seed moisture level of 26.1% after 20 days of drying (Fig. 1, Panels A and B). Proximal sections of *G. kola* with initial moisture content of 58.0% had 85.0 % germination. When the seed portions were desiccated in silica gel or under shade, seed viability declined gradually with decreasing moisture content. At moisture contents of 50.4 and 40.2% (SG) germination significantly ($p<0.001$) reduced to 72 and 60%, respectively. Seed germination at moisture content of 31.0% was 53% and this drastically declined to 10% at a moisture content of 26.6%. For Shade Drying (SD), seed germination at moisture contents of 53.9 and 42.4% significantly ($p<0.001$) reduced to 76% and 64% respectively. Germination at moisture content of 31.3% was 52% and this reduced to 10% at seed moisture level of 25.5% after 18 days of drying (Fig. 1, Panels C and D).

Table 3: Seed moisture content and soaking time effect on electrolyte leakage (µS) from seeds of *Garcinia kola* desiccated to various moisture contents

Seed moisture content (%)	Soaking time (h) 1	2	3	4	5	6	7	8
27	131.77	158.31	181.61	202.98	230.02	252.22	256.85	285.54
30	99.73	115.07	123.89	133.84	154.03	167.98	177.41	185.95
35	66.15	72.45	75.97	78.56	83.43	86.89	90.81	93.48
38	58.15	62.98	64.97	66.92	69.18	71.49	73.76	75.57
41	17.13	22.98	29.85	35.62	38.94	43.14	46.23	49.57
45	13.94	21.24	25.88	32.45	37.38	42.84	45.57	47.92
50	8.59	13.33	18.68	25.51	29.92	34.15	38.84	42.68

Replications = 18 df = 672 SED = 0.08144 CV = 0.3%

Table 4: Seed weight and soaking time effect on electrolyte (µS) leakage from seeds of *Garcinia kola* desiccated to various moisture contents

Seed weight (g)	Soaking time (h) 1	2	3	4	5	6	7	8
0.16	44.92	54.84	61.44	68.06	74.49	80.62	85.35	89.73
0.31	48.62	57.33	63.76	70.41	78.57	86.70	92.75	98.47
0.37	52.56	60.51	67.29	73.83	81.89	90.74	95.88	103.86
0.46	56.23	66.71	74.32	80.88	90.79	99.61	97.59	112.21
0.59	64.34	74.63	84.21	93.59	107.34	114.84	121.26	127.07
0.66	72.67	85.72	95.42	106.83	117.96	126.37	132.40	137.85

SED = 0.02666; Probability (P)<0.001, df = 672

Electrical conductivity measurement of desiccated *Garcinia kola* seeds: The electrical conductivity measurement of proximal sections of *G. kola* seeds desiccated from 50 to 27% moisture content are shown in Table 3 and 4. There were significant differences between electrical conductivity measurement at different seed moisture contents and soaking times ($p<0.001$). Electrical conductivity increased with the reduction in seed moisture content and longer soaking time. Electrical conductivity was highest (285.54 µS) at the moisture content of 27% after 8 h of soaking desiccated seeds in deionized water. The lowest electrical conductivity (8.59 µS) was recorded at the moisture content of 50% after an hour of soaking seeds in deionized water.

Germination pattern observed in *Garcinia kola* seed and seed sections/parts: Germination in whole seed as well as seed sections of the species occurred only from 20 to 35°C. Germination in whole seed of *G. kola* began with the emergence of the Primary Root (PR) at the distal end of the seed followed by the appearance of a shoot from the proximal end. Subsequently, prior to leaf differentiation, an Adventitious Root (AR) originated from the base of the shoot. The Primary Root (PR) disintegrated later and eventually the adventitious root took over as the main root system of the plant (Fig. 2: Panel A).

The Half of Proximal Section (HPS) and Proximal Section (PS) of *G.kola* had similar germination pattern. There was the appearance of a shoots from the proximal ends of the sections followed by the appearance of Adventitious Roots (AR) from the bases of the shoots. No root emerged from the cut ends of the seed sections. Like the whole seed, the Half of Proximal Section (HPS) and Proximal Sections (PS) developed normal seedlings (Fig. 2: Panels B and C).

Fig. 2: Panel A, germinated whole seed of *G. kala* showing a Primary Root (PR) at the distal end and a shoot with an Adventitious Root (AR) at the proximal end. Panel B, proximal sections of *G. kola* seed showing shoots with adventitious roots. Panel C, half proximal sections of *G. kola* seed showing a shoot with an adventitious root. Panel D, half distal sections of *G. kola* showing

Germination of Distal Section (DS) and Half of Distal Section (HDS) of *G. kola* started with the primary root emerging at the distal end of the seed section. No emergence of shoot was observed from any part of the seed sections. Subsequently, the primary root degenerated later leading to the termination of any further development (Fig. 2: Panel D and Fig. 3: Panel A).

No emergence of root or shoot was observed when the Middle Section (MS) and Half Middle Section (HMS) of *G. kola* were set for germination. Germination of Distal End Cut (DEC) fragments of *G. kola* started with the appearance of a shoot from the proximal end. Subsequently, a strong adventitious root emerged from the base of the shoot. In very few cases a Primary Root (PR) emerged from the distal end of the seed section which had been severed. Like the primary roots which appeared in the other seed fragments of the species, this soon degenerated and eventually the adventitious root took over as the main root system of the young seedling (Fig. 3: Panel A right). Germination of the Proximal End Cut (PEC) fragment of *G. kola* also started with the appearance of a Primary Root (PR) from the intact distal end followed by the emergence of a shoot at the cut proximal end. There was a subsequent appearance of a robust adventitious root from the base of the developing shoot and soon there was the degeneration of the primary root and eventually the adventitious root took over as the main root system of the plant (Fig. 3: Panel A left).

Equilibrium Relative Humidity (eRH) is the value of relative humidity into which a hygroscopic product can be placed where no net exchange of moisture between the product and the surrounding environment can take place. In the seed industry, knowing seed eRH at harvest can inform post-harvest handling (MSBP, 2002). The Equilibrium Relative Humidity (eRH) and Moisture

Fig. 3: Panel A Half distal sections of *G. kola* seed showing a primary root. Panel B (left): a proximal end cut (PEC) section of *G. kola* showing a primary root(PR) at the intact distal end and a shoot with an adventitious root(AR) at the cut proximal end. Panel B (right): a distal end cut (DEC) section of *G. kola* showing a shoot and an adventitious root at the intact proximal end

Content (MC) values of 96.9 and 58.0%, respectively recorded for the fully matured fresh seeds of *Garcinia kola* when they were received at the laboratory were very high (Table 1). According to MSBP (2002), very high eRH close to 100% indicates that seeds are potentially immature or probably seeds are in post-abscission phase. This is however applicable to orthodox seeds which go through the process of maturation drying. Desiccation sensitive (recalcitrant) seeds like *Garcinia kola* do not undergo maturation drying and even after shedding from the mother plant they have high moisture content, ranging from 30 to 70% (Roberts, 1973; Chin *et al*., 1984), leading to their "wetness" and high eRH values (MSBP, 2005). This is an important characteristic of the Genus *Garcina* (family Clusiaceae) as reported by Morton (1987). *Garcinia kola* desiccated in silica gel for 30 days still had relatively high eRH and MC of 57.7 and 20.0%, respectively. This observation may be attributed to the large seed sizes of the species which resulted in the slow drying rate. Troftgruben (1977), observed that small fruits/seeds dry faster than thick and large ones.

In carrying out a seed desiccation study, it is important to know whole seed moisture as well as individual seed components moisture content. This helps in determining the variation in moisture content within the seed (IPGRI/DFSC, 1999). The initial test indicated that mesocarp of *Garcinia kola* had a higher moisture content compared to the whole fruit, whole seed and seed coat. Since the fruits of the species are fleshy (Thomsen, 2000; Geeta *et al*., 2006) their mesocarps were expected to contain a lot of water. The whole fruit of *G. kola* had a higher moisture content compared to the whole seed and seed coat. These observations might have come about as a result of overwhelming high moisture level of the fruits' mesocarp which greatly enhanced the fruit moisture content. The testa of the seed, though, was observed to be thin and leather-like as was earlier reported by Gyimah (2000), had significantly higher moisture contents than the whole seed (Table 2).

The relationship between seed moisture content and germination capacity revealed that fresh *Garcinia kola* seeds and seed parts with moisture content 58.0% will germinate to 80% (whole seed), 85% (proximal section). Seed and seed parts gradually lost their viability as seed moisture reduced. Desiccation to relatively high moisture content (approx. 25-27%) almost reduced seed viability to about 10% or less. *Garcinia kola* can therefore be categorized as desiccation sensitive seed. Geeta *et al.* (2006) reported that the Genus *Garcina* are recalcitrant in storage behavior. The seed exhibit most of the characteristics of recalcitrance such as having large seeds and trees growing in the humid forest environment (Chin, 1989, fruits/ seeds being fleshy (Thomsen, 2000). Drying of seed or seed parts in silica gel (SGD) or under shade (SD) at ambient temperature (27-30°C) did not significantly affect the Critical Moisture content (CMC) which is the lowest-safe moisture content of the species and this was recorded to be between 30 and 32%. When fresh recalcitrant seed begin to dry, viability is first slightly reduced as moisture is lost, but begins to decline considerably at a certain moisture content termed the critical moisture ontent (King and Roberts, 1980) or lowest safe moisture content. (Tompsett, 1984). If drying continues further, viability is eventually reduced to zero (Hong *et al.*, 1996). Critical levels of moisture content vary greatly among species (Chin, 1988) and even among cultivars and seed lots (King and Roberts, 1979).

In all cases whether seed or seed parts were dried in silica gel or under shade, viability was drastically reduced below this critical moisture content (30-32% M.C.). In other words, the rate of drying (relatively faster by silica gel) and slower (under shade drying) did not affect the critical moisture content. Probably the seeds as well as the seed parts were still too large in sizes to ensure a very fast drying rate as it has been achieved with the excised embryos of some recalcitrant seeds since it is difficult to dry large seeds fast (Thomsen, 2000). King and Roberts (1980) suggested that seed death resulting from desiccation occurs at or below a critical moisture and is caused by membrane related physiological damages or an accumulation of by-products of biochemical enzymatic breakdown. Hanson (1984), postulated that in desiccation tolerant seeds, membrane permeability and structure remains intact during desiccation, while in the desiccation sensitive seeds some membrane dysfunction occur during desiccation.

Measurement of electrical conductivity of leak water from imbibing tree seeds can be used as a vigour test (Sorenson *et al.*, 1996). Seeds of many tropical and temperate plant species do not survive dehydration (Chin and Roberts, 1980). It is known that the germination of desiccation-sensitive seeds decline rapidly as seed moisture content is decreased (Becwar *et al.*, 1982). It has been suggested that water uptake by desiccation-tolerant seeds reinstates the original structure of the cellular membranes, whereas, membranes of desiccation-sensitive seeds that have been dehydrated are unable to reform completely (Mckersie and Stinson, 1980). If dehydration stress disrupts membrane integrity in desiccation sensitive seeds, then changes in the leakage rates and increases in the amount of solutes leaked may be detectable in response to dehydration and these changes should be associated with loss of viability (Becwar *et al.,* 1982). The results from the dehydration and electrical conductivity measurement on *Garcinia kola* as presented in (Table 3, 4) has indicated that as seeds of *Garcinia kola* dehydrated from the moisture content of 50% to lower moisture levels and were soaked in water, the seeds released more electrolytes into solutions and this reflected in the higher electrical conductivity measurements recorded with reduction in seed moisture. The rate of increase in leakage from hour to hour as seeds were soaked increased gradually from the initial moisture content of 50% till after 35% seed moisture content. At the moisture content of 30% (which has been established as the ‘ critical moisture content’ for the species from the present experiment) and below, hour to hour increases in solutes leakages as indicated by the electrical conductivity values were drastic (Table 3, 4). The results from this study has shown that cellular membranes of desiccation sensitive *Garcinia kola* seeds were damaged as seeds were dried further and for that matter increases in the levels of solute leakages observed. Excessive dehydration of the seeds beyond the critical content moisture severely disrupted the integrity of the cellular membranes of seed tissues resulting in the uncontrollable rate of solute losses from the seed. The results from the present study are complementary to findings made by Becwar *et al.* (1982) on desiccation sensitive silver maple (*Acer saccharinum* L.) and areca palm (*Chrysalidocarpus lutescens* [Bory] Wendl). The authors reported from their study that desiccating silver maple and areca palm seeds below their critical moisture contents of 40 and 55%, respectively resulted in massive solute leakage as membranes were no more effective barriers to solute leakage during imbibitions (Becwar *et al.*, 1982).

Table 4 clearly indicated that seed weight significantly affected electrolyte leakage from desiccated *Garcinia kola* seeds as reported by Hepburn *et al.* (1984). Electrolyte leakage and for that matter electrical conductivity measurement increased as seed weight increased. This observation could only be possible if there is enough de-ionized water to ensure the full submission of the electrodes as well as to receive all the leachate from imbibing and leaking seeds. The fact is the larger the seed, the more potential electrolytes to be leaked into the water from imbibing seeds. Another factor which is possible to disprove this statement is when there are variations in the volume of de-ionized water in the various trays receiving the leachates from imbibing seeds. Cells that contain less amount of de-ionized water could reduce the potential of seeds to release electrolytes and also under-reading by the electrodes since they will not be fully submerged (Sorenson *et al.*, 1996). The results from the study on dehydration effect on imbibitional leakage in *Garcinia kola* seeds (Table 3) could also be used to draw a conclusion that there is a close correlation between increased leakage and loss of seed viability (Table 3, 4) and therefore seed quality (Becwar *et al.*, 1982; Sorenson *et al.*, 1996).

The pattern of germination described as garcinia-type of seed germination by De-Vogel (1980) in other *Garcinia species* including *Garcinia gummi-gutta* (Geeta *et al.*, 2006) and in *Garcinia indica* (Malik *et al.*, 2005) was observed in the present germination trials with *Garcinia kola*. The Primary Root (PR) emerged from the distal end of the seed whilst the shoot emerged from the opposite end called the proximal end (end towards the peduncle). The proximal extremity or end of the seed is slightly broader than the distal end (Agyili *et al.*, 2007). Subsequently, prior to leaf differentiation, an Adventitious Root (AR) originated from the base of the shoot. The Primary Root (PR) disintegrated later and eventually the adventitious root took over as the main root system of the plant. In the present germination studies, it was observed that whole *Garcinia kola* seeds (WS), Proximal Sections (PS), Half of Proximal Sections (HPS), proximal end cut-off sections (PEC), distal end cut-off sections (DEC) of the seed germinated and developed into complete seedlings. On the other hand Distal Sections (DS) and Half of Distal sections (HDS) of the seed developed only primary roots which soon degenerated to end the life of the potential seedlings. Middle Section (MS) and half of Middle Section (HMS) of the seed produced neither roots nor shoots. Malik *et al.* (2005) also reported that the middle segments of *Garcinia indica* failed to produce either shoots or roots but the proximal segments showed development of shoots and roots while the distal segments developed only roots. These observations from the germination patterns in *Garcinia kola* points to the fact that root-shoot polarity is exhibited by the embryo of the seed. Geeta *et al.* (2006), reported of root- shoot polarity in *Garcinia gummi-gutta* seeds. Kumar and Rangaswamy (1977), observed monopolar and bipolar pattern of seedling development in *Orabanche aegyptiaca* treated with certain growth substances.

It is appears that *Garcinia kola* seed exhibits bipolar as well as monopolar pattern of seedling development. The bipolar mode of seedling formation, means that a shoot originates from the plumular pole and roots from the radicular pole when the complete/whole seed is used. The monopolar mode of germination is when both roots (adventitious) and shoots originate from the morphological plumular pole of the embryo (the proximal end) when the proximal fragment/section of the seed is set for germination (Kumar and Rangaswamy, 1977).

One noticeable difference between the germination pattern observed in *Garcinia kola* in the present studies and that in *Garcinia* gummi-*gutta* as reported by Geeta et *al.* (2006) is that in *Garcina kola*, the Middle Section (MS) and Half of Middle Section (HMS) of the seed produced neither roots nor shoots but in *Garcinia gummi-gutta*, seedlings were produced from the middle sections of the seed. Malik *et al.* (2005), observed from their study on *Garcinia indica* that the middle fragment would not develop roots nor shoot, as observed in the current situation in *Garcinia kola*.

CONCLUSIONS

Seeds of *Garcinia kola* Heckel were found to be desiccation sensitive with critical moisture content around 30-32%. Whole seed, proximal sections, half of proximal sections, proximal end cut and distal end cut pieces germinated into normal seedlings. Distal and half of distal sections of the seed produced only roots, while middle and half of middle sections of the seed produced neither roots nor shoots. Germination characteristics of seeds of *G. kola* demonstrated the existence of polarity.

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