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Assessment of pre-germination treatment methods for reducing G*arcinia kola* (Heckel) seed dormancy and its germination characteristics dynamics

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ABSTRACT

G. kola seeds are recalcitrant losing viability in storage. The seed dormancy has been described as both physical and physiological otherwise known as combinational dormancy. This study assessed some pre-germination treatment methods for reducing *G. kola* seed dormancy and its germination characteristics dynamics. Twelve (12) seed pre-germination treatment methods were laid out in Completely Randomized Design (CRD) arrangement. Data collected include: number of days before inception of germination, germination days and germination count. Germination characteristics evaluated were dormancy period, germination capacity (%), germination speed, mean daily germination and mean germination time. Data were analysed using regression and analysis of variance (ANOVA) at $p < 0.05$. The results showed that dormancy period and mean germination time correlated negatively with, germination capacity (%), germination speed, and mean daily germination. DP (Seeds de-coated and pricked with a needle), $DP24_hW$ (Seeds de-coated and pricked with a needle and water soaked for 24 hours at room temperature (26^oC)), and $DP7_{ds}48_hW$ (Seeds stored 7 days at room temperature (26^oC), de-coated, pricked, and water soaked for 48 hours) were the pre-germination treatment methods that recorded the lowest dormancy period and mean germination time and therefore, the highest germination capacity (%), mean daily germination, and mean germination speed. DP and $DP24_hW$ did not correlate significantly ($p>0.05$) with the Control, I_s (Intact seeds sprinkled with water) while the remaining pre-germination treatments methods correlated significantly with the control. DP and $DP24_hW$ reduced dormancy and improved germination more than the other pre-germination treatment methods and are therefore recommended for reducing *G. kola* seed dormancy.

Keywords: Dormancy, pricking, de-coating, soaking, germination.

INTRODUCTION

Garcinia kola is an indigenous fruit tree in Nigeria that thrives in the rainforests of the south (Dadjo *et al.*, 2019). The species is found both in the dry rainforests and the wet/humid rainforests. Recent studies have shown that, there is genetic structuring and diversity between and within the ecotypes in the southwest and southeast (Ashiru *et al.*, 2018; Olawuyi and Azeez, 2019). There is therefore a reservoir of germplasm and genetic diversity within the species to be explored for the domestication and improvement of the species in the country (e.g. seed germination improvement). Moreover this is also important to the adaptation of the species to changing local growing conditions resulting from global climate change.

G. kola seed is by far the most popular and traded product of the tree. *G. kola* is locally used in the treatment of cough, anti-bacterial and other medicinal purposes

(Ashiru *et al.*, 2018). *G. kola* seed trade value chain is such that provides supplementary incomes and diversified livelihood activities. Nevertheless, *G. kola* is vulnerable in the wild due to high rate of deforestation and low cultivation (Cheek, 2004). There is therefore the need to improve the cultivation of the species and possibly develop early fruiting cultivars that will encourage farmers to incorporate the tree into local farming systems. Improved cultivation of *G. kola* will ensure the conservation of the species, increased on-farm biodiversity, climate change mitigation through on-farm carbon sequestration and improved rural livelihoods.

For a long time the idea was that *G. kola* seed was difficult to germinate (Anegbe*et al.*, 2006; Eyo-Matig, 2007; Oboho and Ogana, 2011; Yakubu *et al.*, 2014). However, it is clear that the major challenge to *G. kola* seed germination is its sensitivity to desiccation as the seeds capacity to germinate reduces with reduction in seed moisture content. The seed like a typical recalcitrant seed loses viability and ability to germinate with reducing seed moisture content (Finch-savage, 2003; Hartmann*et al.*, 2004). *G. kola* is best propagated from fresh seeds (Gyimah, 2000; Asomaning*et al.*, 2011; Okonkwo*et al.*, 2014) and germination capacity begins to reduce as seed moisture content begins to drop (Asomaning *et al.*, 2011).

G. kola seed dormancy has however been reported by several authors (Anegbe*et al.*, 2006; Eyo-Matig, 2007; Oboho and Ogana, 2011; Yakubu*et al.*, 2014). Okonkwo*et al.* (2014) and Yakubu*et al.*, (2014) described *G. kola* seed dormancy as both physical (seed-coat dormancy) and physiological (endospermic dormancy) otherwise known as combinational dormancy. Germination of fresh *G. kola* seed can however be enhanced when given the appropriate pre-germination treatment. For example, Gyimah (2000) reported that, soaking in water and hydrogen peroxide induces early start of germination while, warm stratification enhances germination by 40-45 %. Improved germination of *G. kola* seed is important to nursery propagation of the species and availability of seedlings. A study was therefore designed to investigate the effect of different seed pre-germination treatment methods on the germination of *G. kola* seed.

MATERIALS AND METHODS

Seed Collection and Propagation

G. kola seeds used were collected fresh from 27 years old plantation of the Swamp Forest Research Station, Onne, Rivers State, Nigeria and the experiment was conducted in the nursery section of the station. The area is located on Latitude 4^{o} 50$^{'}$ N and Longitude 7^{o} 03$^{'}$ E. Annual rainfall is 2500 mm with a mean value of 75 % relative humidity in February and 80 % in July and the mean minimum temperature is 25^{o}C (Okonkwo*et al.*, 2019) and fall within the humid tropical rainforest ecological zone.

Fruits were collected under the mother tree from a population of thirteen (13) trees based on availability and mixed together to mute effects due to genetic variation. Seed extraction was undertaken after the decay of fruit pulp. A total of 900 seeds were allocated disproportionately to twelve (12) pre-germination treatment methods (Table 1) in a Completely Randomized Design arrangement and there were on the average 75 seeds per pre-germination treatment method. Seeds were propagated in clear heavy duty polythene bags 0.1 mm thick and 100 mm x 150 mm dimension at 26^{o} C room temperature (Okonkwo*et al.*, 2014; Yakubu*et al.*, 2014).

Table 1: Seed pre-germination treatment methods and description

Treatment	Description
DP	Seeds de-coated and pricked with a needle.
I_s	Intact seeds sprinkled with water (control).
C_s24_h	Seeds at 5° C cold stratification for 24 hours.
C_s72_h	Seeds at 5° C cold stratification for 72 hours.
$DP24_hW$	Seeds de-coated and pricked with a needle and water soaked for 24 hours at room temperature (26° C).
$LGA72_h$	Seeds lacerated with a knife and then soaked in 2500 ppm gibberellic acid for 72 hours.
$LS72_hH_s$	Seeds sorted into soft and hard seeds and the soft seed lacerated, and subsequently warmed under hot sun (30° C) for 72 hours.
$LH72_hH_s$	Hard seed from the sorting in treatment 7 above lacerated and warmed under hot sun (30° C) for 72 hours.
$I_s72_hH_s$	Intact seeds warmed 72 hour under hot sun (30° C).
$L1_hH_s$	Seeds lacerated and warmed under hot sun (30° C) for one hour.
$DP30_{ds}$	Seed stored for 30 days at room temperature (26° C) was de-coated and pricked.
$DP7_{ds}48_hW$	Seeds stored 7 days at room temperature (26° C) de-coated, pricked, and water soaked for 48 hours.

Data Collection

Propagation was done in transparent plastic bags and seeds were inspected for germination individually visually. Emergence of the undifferentiated mass of pinkish cells bump on one of the tips of the oval-shaped seed indicated germination. The seeds were monitored daily for germination and sprinkled with water when they were observed to dry. Data collected were number of days before inception of germination, germination days and germination count. Other germination parameters calculated include:

(1) Mean germination speed: This was calculated using the formula of Gairola*et al.* (2011); Kebede and Yidinekachew, (2014):
Mean germination speed = $n_1/d_1+n_2/d_2+n_3/d_3+\ldots./N$ -----1
Where, n = number of germinated seed, N = number of observations, d = number of days.

(2) Mean germination time: This was calculated as:
$MGT= d_1+d_2+d_3+\ldots /N$----2
Where, d = germination days, n = number of observations.

(3) Mean daily germination: This is calculated using the method of Czabator (1962); Kebede and Yidinekachew (2014):
MDG = Total number of germinated seed/Total number of days ----------3

(4) Number of days before first germination (dormancy period). This was the number of days from the sowing date to the first germination.

(5) Germination capacity: This was calculated as:
Germination percentage (%) = Number of germinated seed/total number of seed x100
----------4

Data Analysis

Data were analysed using analysis of variance (ANOVA), linear regression and

descritive statistics on excel. Variation relative to mean germination characteristics (coefficient of variation) was calculated as standard deviation/mean x100) and percentile was used to group data into four groups of lowest, low, high, and highest. Percentile was calculated as K^{th} percentile multiplied by the number of values in the order of the smallest to the greatest.

RESULTS

Number of Days before First Germination (Dormancy Period)

$DP24_hW$ recorded the lowest dormancy period of 5 days, while, $DP30_{ds}$ recorded the highest dormancy period of 86 days (Figure 1) and the difference between the lowest and highest dormancy period was 81 days (Table 2). Mean dormancy period (MDP) among the pre-treatment methods was 24 days while, the variability relative to the mean (CV %) was 95 % (Table 2). Regression analysis (Table 2) showed that pre-germination treatment methods significantly influenced dormancy period. Percentile grouping showed that pre-germination treatment methods with the lowest dormancy period were those that included de-coating and pricking (DP, $DP24_hW$ and $DP7_{ds}48_hW$) of seed, while, pre-germination treatment methods with the highest dormancy period were those stored for 30 days or cold stratified at 5° C (C_s24_h, C_s72_h, and $DP30_{ds}$) (Figure 1) and (Table 5). Dormancy period was however negatively correlated with germination capacity, mean germination speed and mean daily germination but positively correlated with mean germination time (Table 3).

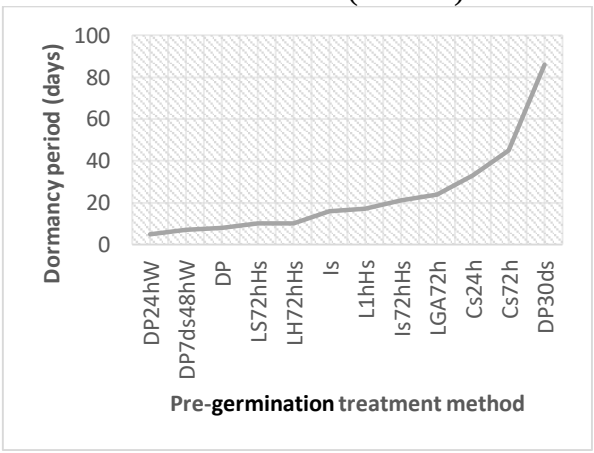

Fig. 1. Effect of pre-germination treatment methods on *G. kola* seed dormancy period

Table 2: Regression analysis of pre-germination treatment methods effect on germination characteristics

Germination Characteristics	Mean	Min.	Max.	CV %	p-value	R	R^2	Adj. R
Dormancy period, (Dp) (days)	24	5	86	95	0.00*	0.96	0.96	0.92
Germination capacity (GC %)	78	8	100	33	0.00*	0.95	0.90	0.89
Mean germination speed (MGS)	2	0.1	6	1	0.00*	0.98	0.96	0.93
Mean germination time (MGT)	43	14	86	60	0.00*	0.99	0.98	0.97
Mean daily germination(MDG)	2	1	5	1	0.01*	0.87	0.80	0.69

Significant (*) $p < 0.05$, Not significant (ns) $p > 0.05$.

Table 3: Regression analysis of germination characteristics dynamics

	Dp		GC (%)		MGS		MGT		MDG	
	p-value	Rc	p-value	Rc	p-value	Rc	p-value	Rc	p-value	Rc
Dp			0.00*	-0.93	0.06ns	-6.5	0.00*	0.72	0.76ns	-8.23
GC (%)					0.04*	8.10	0.03*	-0.64	0.06ns	9.99
MGS							0.00*	-0.06	0.00*	1.04
MGT									0.00*	-13.92
MDG										

Significant (*) $p < 0.05$, not significant (ns) $p > 0.05$, positive correlation (+), negative correlation (-), Regression coefficient (Rc).

Germination Capacity

Mean germination capacity among the pre-germination treatment methods was 78 % (Table 2). Highest germination capacity was 100 % in $DP24_hW$ while the lowest was $DP30_{ds}$ 8 % (Figure 2). The difference between the highest and lowest mean germination capacity was 92 %, while, variability relative to the mean germination capacity CV was 33 % (Table 2). Regression analysis (Table 2) showed that the pre-germination treatment methods significantly ($p < 0.05$) influenced germination capacity (%). Percentile grouping showed that pre-germination treatment methods with the lowest germination capacity (%) were $LH72_hH_s$, C_s24_h, and $DP30_{ds}$, while, those with the highest germination capacity (%) were DP, $DP24_hW$ and $DP7_{ds}48_hW$ (Table 5). However, germination capacity (%) was positively correlated with mean germination speed and mean daily germination but negatively correlated with mean germination time (Table 3).

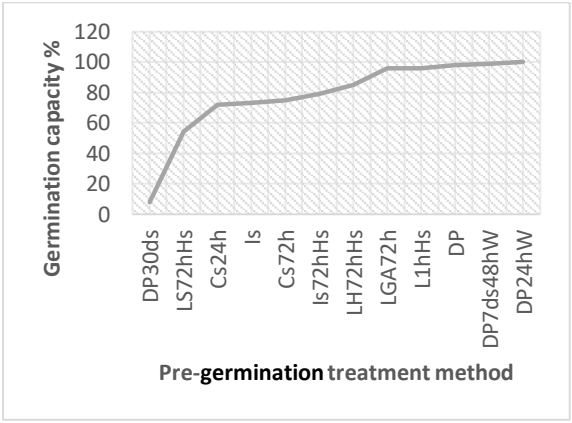

Fig. 2. Effect of pre-germination treatment methods on the germination capacity % of *G. kola* seed.

Mean Germination Speed

Mean germination speed among the pre-treatment methods was 2 seed per day (Table 2). The highest germination speed was recorded in DP 6 seed/day, while, the lowest speed was recorded in $DP30_{ds}$ 0.09 seed equivalent to 9 seed in 100 days (Figure 3). Standard deviation from the mean germination speed was 1.9, while, the difference between the highest and the

lowest germination speed was 5.9 and variability relative to the mean was 1 % (Table 2). Regression analysis (Table 2) showed that the influence of pre-germination treatment methods on germination speed was significant. Percentile grouping showed that pre-treatment methods with the lowest germination speed were I_s, C_s24_h, and $DP30_{ds}$ while, those with the highest germination speed were; DP, $DP24_hW$ and $DP7_{ds}48_hW$ (Table 5). Germination speed was however positively correlated with mean daily germination but negatively correlated with mean germination time (Table 3).

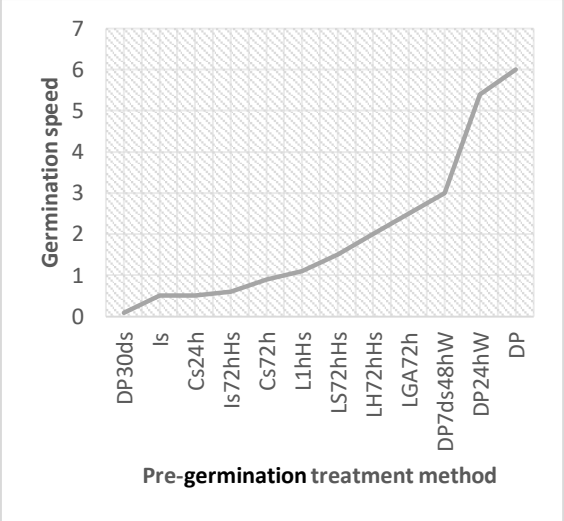

Fig. 3. Effect of pre-germination treatment method on germination speed of *G. kola* seed

Mean Germination Time

Mean germination time was 43 days (Table 2). The longest was 86 days recorded in $DP30_{ds}$ and the shortest was 14 days recorded in DP (Figure 4). Variability relative to the mean CV % was 60 % (Table 2). Regression analysis (Table 2) showed that the influence of pre-germination treatment methods on the seed mean germination time was significant. Percentile grouping show that pre-treatment methods with the lowest germination time were DP, $DP24_hW$ and $LS72_hH_s$, while those with the highest germination time were C_s24_h, C_s72_h, and $DP30_{ds}$ (Table 5). Mean germination time was however negatively correlated with mean daily germination (Table 3).

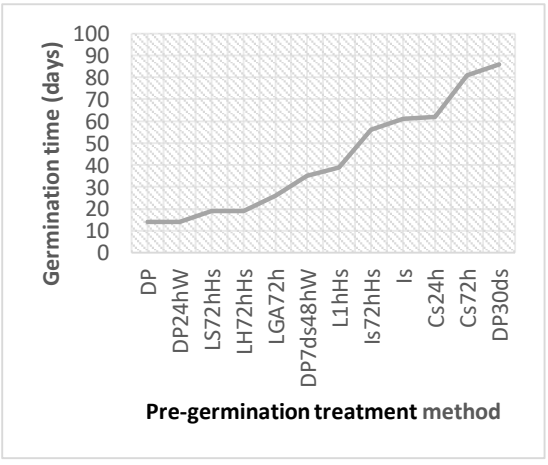

Fig. 4. Effect of pre-germination treatment method on germination time in *G. kola* seed

Mean Daily Germination

Mean daily germination was 2 seeds. The highest daily germination was recorded in DP and the lowest was 0.09 recorded in $DP30_{ds}$ (Figure 5). Variability relative to the mean daily germination CV % was 1 % (Table 2). Regression analysis (Table 2) showed that the influence of pre-germination treatment methods on the mean daily germination was significant. Percentile grouping showed that pre-germination treatment methods with the lowest mean daily germination were I_s, C_s24_h, and $DP30_{ds}$, while, those with the highest mean daily germination were DP, $LH72_hH_s$, and $LGA72_h$ (Table 5).

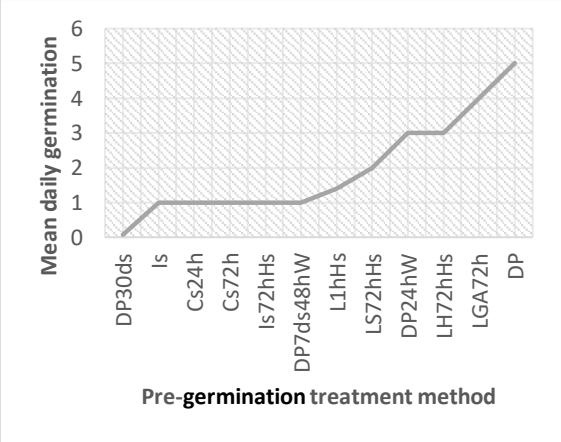

Fig. 5. Effect of pre-germination treatment method on daily germination in *G. kola* seed.

Table 4: Regression analysis to determine similarity between the control effect and other pre-germination treatment method

Other methods	DP	C_s24_h	C_s72_h	$DP24_hW$	$LGA72_h$	$LS72_hH_s$	$LH72_hH_s$	$I_s72_hH_s$	$L1_hH_s$	$DP30_{ds}$	$DP7_{ds}48_hW$
Control	p-value										
I_s	0.09^{ns}	0.00*	0.00*	0.09^{ns}	0.26^{ns}	0.00*	0.03*	0.00*	0.00*	0.36^{ns}	0.01*
Rc	0.63	0.97	0.80	0.60	0.41	1.48	0.86	0.98	0.83	0.31	0.78

Significant (*), $p < 0.05$, Not significant (ns), $p > 0.05$. Regression coefficient, Rc.

The effect of seven (C_s24_h,C_s72_h, $LS72_hH_s$,$LH72_hH_s$,$I_s72_hH_s$,$L1_hH_s$,and $DP7_{ds}48_hW$) out of the twelve pre-germination treatment methods was significantly positively correlated with that of the control treatment (I_s). While, the positive correlation of four (DP, $DP24_hW$, $LGA72_h$,$DP30_{ds}$) with the control (I_s) was not significant (Table 4). Percentile grouping of the pre-germination treatment methods showed that the control pre-germination treatment method (I_s) frequency of occurrence in the 25th, 50th, 75th and 100th percentiles was in the ratio 1:2:1:0 (Table 5). However, the four pre-germination treatment methods (DP, $DP24_hW$, $LGA72_h$,$DP30_{ds}$) occurred in the ratio: DP 3:0:0:3, $DP24_hW$ 3:0:1:2, $LGA72_h$ 1:1:2:1, and $DP30_{ds}$ 2:0:0:2. This shows that the reason that the four pre-germination treatment methods (DP, $DP24_hW$, $LGA72_h$,$DP30_{ds}$) correlation was not significant ($p < 0.05$) was because their effect exceeded the control (I_s) treatment method.

Table 5: Percentile grouping of pre-germination treatment method effect on germination characteristics

Germination characteristics	25^{th} =lowest	50^{th} =low	75^{th} =high	100^{th} = highest
Dormancy period (days)	$DP24_hW$	$LS72_hH_s$	$L1_hH_s$	C_s24_h
	$DP7_{ds}48_hW$	$LH72_hH_s$	$I_s72_hH_s$	C_s72_h
	DP	I_s	$LGA72_h$	$DP30_{ds}$
Germination capacity %	$DP30_{ds}$	I_s	$LH72_hH_s$	DP
	$LS72_hH_s$	C_s72_h	$LGA72_h$	$DP7_{ds}48_hW$
	C_s24_h	$I_s72_hH_s$	$L1_hH_s$	$DP24_hW$
Mean germination speed	$DP30_{ds}$	$I_s72_hH_s$	$LS72_hH_s$	$DP7_{ds}48_hW$
	I_s	C_s72_h	$LH72_hH_s$	$DP24_hW$
	C_s24_h	$L1_hH_s$	$LGA72_h$	DP
Mean germination time	DP	$LH72_hH_s$	$L1_hH_s$	C_s24_h
	$DP24_hW$	$LGA72_h$	$I_s72_hH_s$	C_s72_h
	$LS72_hH_s$	$DP7_{ds}48_hW$	I_s	$DP30_{ds}$
Mean daily germination	DP	C_s72_h	$L1_hH_s$	$LH72_hH_s$
	$DP24_hW$	$I_s72_hH_s$	$LS72_hH_s$	$LGA72_h$
	$LGA72_h$	$DP7_{ds}48_hW$	$DP24_hW$	DP

DISCUSSION

The highest variability (CV %) of germination characteristic was recorded in dormancy period (95 %), followed by mean germination time (60 %), germination capacity, (33 %) and the lowest variability (1 %) was recorded in germination speed and mean daily germination. This implies that dormancy period was the most sensitive germination characteristic to the pre-germination treatment methods. Moreover, since increase in dormancy period reduces germination capacity (%), mean germination speed and mean daily germination due to negative correlation but increases mean germination time due to positive correlation. It is clear that dormancy period is the critical germination characteristic in *G. kola* seed germination due to the dynamics among the germination characteristics. Therefore, pre-germination treatment methods that effectively minimize dormancy period automatically improve the seed germination. This is in agreement with the findings of Anegbe*et al.* (2006); Yakubu*et al.* (2014); Okonkwo*et al.* (2014); Dadjo*et al.* (2019) who found that pre-germination treatment methods that reduced dormancy period invariably improved germination capacity, germination speed, and germination rate.

Pre-germination treatment methods that recorded the highest seed dormancy period were C_s24_h, C_s72_h, and $DP30_{ds}$. These same pre-germination treatment methods (C_s24_h, C_s72_h, and $DP30_{ds}$) recorded the highest mean germination time due to a positive correlation with dormancy period. However, C_s24_h, C_s72_h, and $DP30_{ds}$ recorded between low to lowest germination capacity (%), mean germination speed, and mean daily germination due to a negative correlation between dormancy and these three germination characteristic. Pre-germination treatment methods C_s24_h and C_s72_h were seeds cold stratified at 5° C for 24 hours and 72 hours respectively while $DP30_{ds}$ were seeds stored 30 days, de-coated and pricked. Cold stratification and long duration of storage therefore increase

dormancy period and limits germination in *G. kola* seed. This is in agreement with Asomaning*et al.* (2011) who reported that *G. kola* seed is desiccation sensitive, lose viability in storage and are therefore recalcitrant. While Dadjo*et al.* (2019) reported lowered seed germination of *G. kola* seeds that were cold stratified at 4^{o} C for two (2) months. Furthermore, Pammenter and Berjak, (1999); Berjak and Pammenter, (2008); Oubruchev*aet al.* (2016) reported that recalcitrant seeds unlike their orthodox counterparts are sensitive to cold stratification.

Lowest dormancy period was recorded in DP, DP24$_{h}$W and DP7$_{ds}$48$_{h}$W (Table 5). As expected these group of pre-germination treatment methods recorded the highest germination capacity, mean germination speed, and mean daily germination due to the negative correlation between dormancy and the three germination characteristics. While a positive correlation between dormancy and mean germination time put DP, DP24$_{h}$W and DP7$_{ds}$48$_{h}$W in the low to lowest mean germination time percentile group. Pre-germination treatment method DP, were seeds de-coated and pricked, DP24$_{h}$W were seeds de-coated, pricked, and soaked 24 hours in water at room temperature (26^{o} C) while DP7$_{ds}$48$_{h}$W were seeds de-coated, pricked, stored for 7 days and soaked in water at room temperature (26^{o} C) for 48 hours. Therefore DP, DP24$_{h}$W and DP7$_{ds}$48$_{h}$W reduced dormancy and improved germination the most among the 12 pre-germination treatment methods. This implies that de-coating, pricking, 24-48 hour water soaking at room temperature (26^{o} C), and 7 days storage were seed pre-germination treatment combinations that effectively improved *G. kola* seed germination. Several authors have reported similar findings. For example, Anegbe*et al.* (2006) comparing the effects of varying degrees of soaking and nicking on the germination of *G. kola* seed found that nicked seeds recorded lowest period of dormancy, highest germination capacity and rate. Okonkwo*et al.* (2014) corroborated the findings of Anegbe*et al.* (2006) when in a study investigating the effect of different degrees of pricking on *G. kola* seed germination confirmed that all de-coated and pricked pre-germination treatment methods reduced dormancy and increased germination significantly compared to the intact seed used as the control. Investigating the effect of varying degrees of seed soaking and de-coating on *G. kola* seed germination,Yakubu*et al.* (2014) reported that dormancy period increased with increasing period of soaking and therefore negatively affected germination capacity and rate. Meanwhile, Asomaning*et al.* (2011) who studied the desiccation sensitivity of *G. kola* seeds concluded that the seed can only retain viability during short storage periods but lose viability in a long period of storage.

Mean daily germination was highest in LH72$_{h}$H$_{s}$, LGA72$_{h}$, and DP. Dormancy period and mean germination time among the three pre-germination treatment methods was in the percentile range lowest to high, while, germination capacity (%), and mean germination speed were in the percentile range high to highest. This means that while dormancy period and mean germination time reduced backwards, germination capacity (%) and mean germination speed increased forward. This is due to the negative correlation between dormancy period, mean germination time and mean daily germination on the one hand and the positive correlation between the mean daily germination, germination capacity (%) and mean germination speed on the other hand. LH72$_{h}$H$_{s}$, was the pre-germination treatment method where hard seeds were lacerated, heat stratified in water at 30^{o} C, LGA72$_{h}$ were seeds lacerated and soaked in 2500 ppm gibberellic acid solution for 72 hours, while DP were seeds de-coated and

pricked. Therefore, laceration, heat stratification and gibberellic acid are pre-germination treatment methods that also reduce dormancy period and increase germination. This is in agreement with Nzegbula and Mbakwe (2001); Kanmegne and Omokolo (2008); who reported that gibberellic acid improved germination of *G. kola* seeds although not significantly. The result is however contrary to Eyog-Matig*et al*. (2007) who reported that heat stratification for 24 hours in a cooling 70^{o}C water resulted in embryo mortality.

The effect of seven (C_s24_h,C_s72_h,$LS72_hH_s$,$LH72_hH_s$,$I_s72_hH_s$,$L1_hH_s$,and$DP7_{ds}48_hW$) out of the 12 pre-germination treatment methods correlated significantly with the control treatment I_s. This means that the seven pre-germination treatment methods did not differ significantly from the control in their effect on the germination characteristics. Therefore, they may not be considered when considering a significant improvement in germination of *G. kola* seeds. Four (DP, $DP24_hW$, $LGA72_h$,and $DP30_{ds}$) out of the 12 pre-treatment methods were not significantly ($p > 0.05$) correlated with the control. The four pre-germination treatment methods produced results different from the control. DP, and $DP24_hW$ reduced dormancy period and as such increased germination capacity (%), germination speed and mean daily germination more than the control, I_s. $LGA72_h$ though did not reduced dormancy period below the control (I_s), it however recorded higher germination capacity, speed and mean daily germination. While $DP30_{ds}$ recorded the highest dormancy period and mean germination time and as such the lowest germination capacity (%), mean germination speed, and mean daily germination than the control, I_s. Hence DP, and $DP24_hW$ were the pre-germination treatment methods that exceeded the control in dormancy reduction as well as in germination capacity (%), germination speed, and mean daily germination improvement. This is in agreement with Anegbe*et al.* (2006); Okonkwo*et al.*, (2014) who reported that de-coating and nicking of *G. kola* seeds reduced seed dormancy and improved germination better than the control treatment of intact seeds. Moreover Munjuga*et al.*, (2008) reported using seed de-coating to reduce dormancy period significantly in *Allanblackia floribunda.* Furthermore, Yakubu*et al.* (2014) reported that de-coated *G. kola* seeds soaked for 24 to 72 hours reduced dormancy significantly and improved germination above the control treatment where seeds were de-coated but not soaked.

C**ONCLUSION**

The germination characteristics dynamics investigated in the study was such that dormancy and mean germination time were negatively correlated with germination capacity (%), germination speed, and mean daily germination. This implies that dormancy and mean germination time were inversely related to germination capacity (%), germination speed and mean daily germination. Therefore, pre-germination treatment methods that reduced dormancy and mean germination time invariably improve germination. DP (seeds de-coated and pricked), $DP24_hW$ (seeds de-coated, pricked and soaked 24 hours at room temperature 26^{o}C) and $DP7_{ds}48_hW$ (Seeds stored 7 days at room temperature (26^{o}C) were de-coated, pricked, and water soaked for 48 hours) pre-germination treatment methods recorded the lowest dormancy period and improved germination the most due to the dynamics among the germination characteristics. DP and $DP24_hW$ did not correlate significantly with the control, I_s (Intact seeds sprinkled with water) while the remaining pre-germination treatments methods correlated significantly with the control. Therefore DP and $DP24_hW$ reduced dormancy and improved germination more than the other pre-germination treatment methods. The two

pre-germination treatment methods are therefore recommended for reducing *G. kola* seed dormancy.

REFERENCES

Anegbeh, P.O., Iruka, C. and Nkirika, C. 2006. Enhancing germination of bitter cola (*Garcinia kola*)Heckel: prospects for agroforestry farmers in the Niger Delta. *Scientiaafricana*, 5 (1), 1-8.

Ashiru, M.O., Sifau, M.O., Gunkanmi, L.A., Dekoya, K.O. andOboh, B.O. 2018. Morphological characterization of *Garciniakola* Heckel (bitter kola) from Southern Nigeria. *Annals of west University of Timişoara, Series of Biology,* 21 (2), 199-206.

Asomaning, J.M., Olympio, N.S. and Sacande, M. 2011. Desiccation sensitivity and germination of recalcitrant *Garcinia kola* Heckel seeds. *Research Journal of Seed Science*, 4, 15-27.

Berjak, P. and Pammenter, N.W. 2008.From A*vicennia* to *Ziza nia*: seed recalcitrance in perspective. A*nnals of Botany*, 101,213–228.

Cheek, M. 2004. *Garcinia kola*. *The IUCN Red List of Threatened Species* 2004: e.T34715A9884648. https://dx.doi. org/10.2305/IUCN.UK.2004.RLTS .T34715A9884648.en. Retrieved 23 March 2020.

Czabator, F.J. 1962. Germination value: An index combining speed and completeness of pine seed germination. *Forest Science*, 8, 386-395.

Dadjo, C., Nyende, A.B., Kahia, J. and Assogbadjo, A.E. 2019. Effect of storage temperature and dormancy breaking pre-treatments on germination and early seedling growth of G*arcinia kola* (Heckel): A threatened medicinal fruit tree in Benin. *Forest Science and Technology*, 15(4), 173-179.

Eyog-Matig, O., Aoudji, A.K.N. and Linsoussi, C. 2007.G*arcinia kola* Heckel seeds dormancy-breaking. *Applied Ecology and Environmental Research*, 5 (1), 63-71.

Gairola, K.C., Nautiyal, A.R. and Dwivedi, A.K. 2011. Effect of temperatures and germination media on seed. Germination of *Jatrophacurcas* Linn. *Advances in Bioresearch*, 2 (2), 66–71.

Gyimah, A. 2000. Effect of pre-treatment methods on germination of G*arcinia kola* (Heckel). *Ghana Journal of Forestry*, 9, 39-44.

Kanmegn, G. and Omokolo, N.D. 2008. Germination of G*arcinia kola* (Heckel) seeds in response to different hormone treatments. *Fruits*, 63, 155–161.

Kebede, W. and Yidinekachew, H. 2014. Effect of seed storage period and condition on viability of *Jatrophacurcas* L. seed. *Research Journal of Forest*, 8 (2), 56–62.

Munjuga M., Ofori D., Sawe C., Asaah E., Anegbeh P., Peprah T., Mpanda M., Mwaura L., Mtui E., Sirito C., Atangana A., Henneh S., Tchoundjeu Z., Jamndaass R. and Simons A.J. 2008,Allanblackia Propagation Protocol. (Editor, Ian Dawson). World Agroforestry Center Publication. 1-44 pp.

Nzegbule, E. and Ubakwe, R. 2001.Effect of pre-sowing and incubation treatment on germination of *Garcinia kola* (Heckel) seeds.*Fruits*, 56, 437–442.

Oboho, E.G. and Ogana, F.N. 2011. Effects of varying water soaking duration on the germination of *Garcinia kola* (Heckel) seeds. *Nigerian Journal of Agriculture, Food and Environment*, 7 (2), 57-62.

Okonkwo, H. O., Koyejo, O. A., Osewa, S.O. and Babalola, O.T. 2014. Techniques for improvement of *Garcinia kola.* (Heckel) seeds germination. *International Journal of Applied Research and Technology,* 3 (8), 80 -86.

Olawuyi, O.J. and Azeez, A.A. 2019. Molecular evaluation of *Garcinia kola* (Heckel) accessions using rapid markers. *American Journal of Molecular Biology*, 9, 41-51.

Oubrucheva, N., Sinkevich, I. and Lityagina, S. 2016. Physiological aspects of seed recalcitrance: a case study on the tree *Aesculushippocastanum. Tree Physiology,* 36 (9), 1127-50.

Pammenter, N.W. and Berjak, P. 1999. A review of recalcitrant seed physiology in relation to desiccation-tolerance mechanisms. *Seed Science Research,* 9,13–3710.

Yakubu, F.B., Bolanle – Ojo, O.T., Ogunade, O.J.andYahaya, D.K. 2014. Effects of water soaking and light on the dormancy of *Garcinia kola* (heckel) seeds. *European Journal of Agriculture and Forestry Research,* 2 (2), 17-26.