



## EFFECT OF FOREST UNDERSTOREY SHADE ON SEED GERMINATION AND GROWTH OF SEEDLINGS OF THREE TROPICAL PIONEER TREES

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**ABSTRACT:** The impact of forest understorey shade on seed germination and initial growth of seedlings of three tropical pioneer trees (*Tamarindus indica*, *Parkia biglobosa* and *Terminalia ivorensis*) was investigated in University of Benin, Benin city, Nigeria. The variables evaluated in the six-treatment study – zero shade control (85% illumination level), canopy gap (13%), shade with side light (8.4%), Intermediate shade (6.5%), low shade (3.1%) and heavy shade (2.0%) – conducted in an open nursery / arboretum were: “days to plumule emergence; germination type & position of cotyledons relative to ground level and count of germinant” as well as “height and number of leaves”. Germination data were analysed using descriptive statistics, while seedling growth data were subjected to one-way Analysis of Variance (ANOVA) with means separated using LSD ( $p=0.05$ ) in a Completely Randomized Design (CRD). Results revealed 100% germination for all three species in the ‘Control and ‘Canopy gap’ plots. But *T. indica* (epigeal; phanerocotylar) and *P. biglobosa* (semi hypogeal; phanerocotylar) recorded 100% germination in ‘shade with side light’ and ‘low shade’ respectively. While *T. ivorensis* (hypogeal; cryptocotylar) recorded 50% germination in ‘intermediate shade’ which was the species best, no seed germinated in ‘deep shade’. Germination ‘lag time’ (time interval between beginning and cessation of plumule emergence) for *T. indica* was 5 days; *T. ivorensis* (9 days) and *P. biglobosa* (12 days). *T. indicia* grew best in height while *P. biglobosa* recorded most abundant leaves and were significant ( $p>0.05$ ). The study established the three species responded differently to the varied shade conditions but *T. indica* appeared most amenable to, and resilient under, the treatments, except ‘heavy shade’ which recorded nil germination.

**Keywords:** Forest understorey, illumination level, plumule emergence, seedling, pioneer trees.

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### 1. INTRODUCTION

Germination is the sprouting of seeds, a sprout, a spore, or additional reproductive body, regularly done after a period of dormancy (Carlson 2015). Germination of typical seeds begins with the process of imbibition (the passive uptake of water) by the seed, continues with resumption of cellular metabolism and ends with the emergence of the radicle (root tip) and plumule (shoot tip) from the seed coat (Miller and Donald 2010). The normal pattern of germination starts with radicle protrusion, followed by elongation of the part of the embryonic axis that develops into the main stem (Bentsen 2002). It is at that stage where the plant ‘bets its life’ by

marking the end of the latent period (dormancy) and becoming unable to return to a quiescent stage (Jurado 1997).

The cotyledons store food for the body plant inside the seed and provide nutrients till the seed coat ruptures and the plant is capable of drawing nutrients from the soil and the surroundings (Farjon and Styles 1997). Germination begins with water uptake by seeds and terminates with the initial elongation of the embryonic axis (Bewley 1997). Seed germination is a critical step in the plant life cycle and it is usually divided into 3 phases: imbibition (phase I); germination *sensu stricto* which means the true germination process (phase II) and growth (phase III) (Bewley 1997a). At the time of commencement of

germination all the essential structures are present in the embryo, and during the initial stage of germination, development is largely a further growth of these structures by cell expansion and divisions (Bentsen 2002). The process of germination is a critically important step in the life of a seed plant, because if it occurs during unfavorable conditions, the seedlings are unlikely to survive (Antipova *et al.* 2003).

Most forest/savanna tree species have been classified based on light requirements (illumination and irradiance) for their germination and establishment (Whitmore 1996). Shade-tolerant species can germinate, grow and survive in low light condition whereas light demanding species need a high light environment for establishment (Fletcher 1984). Knowledge on the ecology of germination and seedling growth is vital, not only for understanding the community processes of plant recruitment and succession, but also for developing strategies for the conservation of biodiversity and restoration of tropical forests (Khurana and Singh 2001).

## 1.2 Botanical Description

### 1.2.1 *Tamarindus indica*

*Tamarindus indica* (Linn) – a multipurpose, leguminous, tropical evergreen fruit tree species of *Caesalpiniaceae* subfamily – is indigenous to Africa (Madagascar, Zimbabwe, Chad, Sudan, Nigeria, Uganda, and Kenya) and Southern Asia (Das and Alam 2001; Fandohan *et al.* 2010; Sidibé *et al.* 2012; Azad *et al.* 2013). It is one of the comparatively few tropical plant species which has been subjected to thorough studies concerning its biology and utilization (Sina and Traoré 2002). Tamarind trees are widely used in India and Sri Lanka as ornamentals and shade trees; they are planted in boulevards, roadsides, parks and along river banks (Meghwal 1997) and have become popular in the United States as a tree for indoor ornamentation (NAS 1979). It has been cultivated for so long on the Indian sub-continent that it is sometimes also reported to be indigenous tree (Wiley 1994). In some parts of India, it is planted around forest margins to act as a firebreak (Troup 1921; Salim *et al.* 1998).

It grows wild in the Sudano-sahelian region of West Africa. It is up to 30 m tall, bole usually 1-2 m, up to 2 m diameter; crown dense, widely spreading, rounded; bark rough, fissured, greyish-brown (Orwa *et al.* 2009). Leaves are alternate and even pinnate, in length (5-) 7-12 (-15) cm, shortly petiolated (up to 1.5 cm long) and petiole glabrous or puberulent as is the leaf rachis; leaflets are in (6-)10-18(-20) pairs / leaf, each narrowly oblong, rounded at the apex and slightly notched and asymmetric with a tuft of yellow hairs; at the base

obliquely obtuse or subtruncate (El-Siddig *et al.* 2006). Leaflets fold after dark due to the presence of leucoleptin synthesised when light and degraded in the dark (Ali *et al.* 1998).

The fruits are pods 5-10 (-16) cm long × 2 cm broad, oblong, curved or straight, with rounded ends, somewhat compressed and indehiscent although brittle; they have light grey or brown and scaly outer epicarp (El-Siddig *et al.* 2006). Fruit are leathery, nutritive pods that do not dehisce until they have fallen from the tree, while the seeds are hard and smooth and therefore hard to chew (Orwa *et al.* 2009). The ripened fruit is considered the more palatable, as it becomes sweeter and less sour (acidic) as it matures (Lewis 2005). It is used in desserts as jam; blended into juices or sweetened drinks, sorbets, ice cream, and other snacks (Rao *et al.* 1999) as well as traditional medicine in India, Sudan, Nigeria, Bangladesh, and most of the tropical countries (Bhadoriya *et al.* 2011). Sapwood is light yellow, heartwood is dark purplish brown; very hard, durable and strong (specific gravity 0.8-0.9 g/m<sup>3</sup>) and takes a fine polish (Orwa *et al.* 2009).

### 1.2.2 *Parkia biglobosa*

*Parkia biglobosa* (Jacq.) R.Br. ex G.Don popularly known as “African Locust Bean” is a multi-utility tropical deciduous tree which belongs to the family: Fabaceae. It grows commonly in wooded savanna and regions with annual rainfall of 500–800 mm in the Sahel but occurs in regions with much higher rainfall as well (e.g. 2200 mm in Guinea Bissau), and it has even been recorded in regions with over 3500 mm in Sierra Leone and 4500 mm in Guinea (Sina and Traoré 2002). The tree is widely distributed on the sandy loam soils of Sudan and Guinea savannah areas of Nigeria and known to spread across the semi-arid zone of sub-saharan Africa from Senegal to Sudan. (Aliero *et al.* 2001; Sacande and Clethero 2007). It is a multi-utility tree that has played a vital role in poverty alleviation and food security in Nigeria and with a wide range of value whose main product as seeds extracted from the pods for condiments in stews and soups and as sweetener; various parts of the tree are used as fodder for livestock, medicine, dye, fuelwood, timber for construction, and for soil improvement in agroforestry practices (Aliero *et al.* 2001; Ntui *et al.* 2012).

*P. biglobosa* provides investment opportunities as small item of finance for a large population of the rural poor, particularly women in local communities and serves as shelter belts for combating extreme climate events globally (Nair 1993). It is a deciduous perennial that grows to between 7 and 20 meters tall, in some cases up to 30 meters (Uyoh 2012). Its cultivation can be seen as

an important economic activity for many in Africa because of its favourable economic activity, indigenous healers in Africa use different parts of the locust bean tree for health benefits (Janick 2008). It multiplies primarily by way of sowing; the weakness of the natural regeneration of this species could be due to limiting factors related to abuse by pasture and bush fires (Sambe *et al.* 2010).

### 1.2.3 *Terminalia ivorensis*

*Terminalia ivorensis* A. Chev. (also called black afara or idigbo, framire, emeri in various other languages) is a tree species of tree in the family Combretaceae (Lincoln 1986). It is found in Cameroon, Ivory Coast, Ghana, Guinea, Liberia, Nigeria and Sierra Leone (Hawthorne, 1998). *T. ivorensis* grows in evergreen forest but can also be found in forest transition (Okoh *et al.* 2014). It is a Class 1 commercial rainforest timber species commonly called 'Black Afara' (Redhead 1971). Known in Yoruba as Idigbo and Benin as Eghoin-nebi, it is deciduous in habit and endemic to the rainforest region of Nigerian (Isikhuemen and Ekhomu 2011). The wood is pale yellow-brown in colour while slash is yellowish, often turning tarnishing on exposure; it has a density of about 560 kg/cubic meter (Isikhuemen and Ekhomu 2011; Cragg 2002; Hawthorne 1998). *T. ivorensis* is a large forest tree ranging in height from 15 to 46m, branchless for up to 30m; dbh 2 – 4.75m (Taylor 1989).

Bole is clean, very straight with small buttresses and sometimes fluted (Voorhoeve 1965). Bark smooth and light grey to dark brown when young and on branchlets in mature tree often blackish, with deep longitudinal fissures, the bark flakes off in long thin strips (Willan 1985). *T. ivorensis* produces bunched fruits which are borne on terminal tufts (Isikhuemen and Ekhomu 2011). Leaves are whorled, simple (Lincoln 1986). It has winged fruit which is elongated and narrow; emarginated and slightly decurrent, finely tomentose with very short reddish or orange-brown hairs (FAO 1980). *T. ivorensis* is common in rainforest, derived savanna and regrowth forest. It is a pioneer and usually colonizes farm fallows. It is very vulnerable to fire (Hawthorne 1998). The tree has been successfully used for regenerating forest through the taungya system in Nigeria.

There is paucity of information on seed and seedling ecology of most pioneer tree species, particularly on seed germination and growth of seedling *in situ* (under the mother tree) as well as under varied canopy or understorey shade conditions. This study evaluated the impact of illumination (photosynthetically active radiation) on seed germination and early growth response of seedlings of three tropical multi-utility tree pioneers – *Tamarindus indica* L, *Parkia biglobosa* (Jacq.) R. Br. ex

*G. don* and *Terminalia ivorensis* (A. Chev.) under diverse understorey shade conditions.

## 2.0 MATERIALS AND METHODS

### 2.1 Study Site

The experiment was carried out in the Department of Forest Resources and Wildlife Management nursery / arboretum in the University of Benin, Benin City, Nigeria. University of Benin (Latitude 06° 24' 61'' N and Longitude 005° 37' 43'' E) is located in the rainforest zone of Nigeria. It has mean annual rainfall 2800 mm; relative humidity is 70% at noon and 95% at 6am while maximum and minimum temperatures are 35°C and 23°C respectively (Isikhuemen and Edore 2016).

### 2.2 Sources of Seeds, Data Collection and Analysis

The seeds of *Tamarindus indica* and *Parkia biglobosa* were obtained from Forestry Research Institute of Nigeria (FRIN), Ibadan, while those of *Terminalia ivorensis* were collected freshly under mother trees in a 48-year old stand in Sakpoba Forest Reserve, Edo State, Nigeria (Lat. 06° 04' 031'' N and Long. 005° 58' 59'' E). Although *T. indica* and *P. biglobosa* seeds were certified viable at point/time of procurement, three hundred seeds (100 per species) were tested for viability using simple flotation method and 296 passed the test. To further validate the outcome of the germination test, 144 seeds (48 per species) were sown directly into polythene pots under zero shade condition in a pilot study and 141 seeds (*ca.* 98%) germinated.

Subsequently, six treatment plots were established – one in the open nursery (control) and five in the arboretum. A Lux Meter was used to measure the level of illumination / photosynthetic active radiation (PAR) in the different treatment plots at 10am, 12 noon, 2.00 pm and 4.00 pm four times in four weeks. Though the Lux Meter is uncalibrated and somewhat inexact (*e.g.* Kent, 2000; Allen and Brown, 1965), it nevertheless provided invaluable clue on PAR levels in treatment plots, in the absence of a digital data logger (*cf.* Isikhuemen and Uwuba (2014); Isikhuemen and Bamawo (2013). PAR data were pooled, harmonized and relativized using 1000 as common denominator; thus the average illumination (PAR) level in Control plot was *ca.* 85%; Canopy gap: 13%; Shade with side light: 8%; Intermediate shade: 7%; Low shade: 3% and Deep shade: 2%.

Top soil sample was collected from 0 – 15cm depth in the arboretum; sieved to free it of roots / debris and thereafter analyzed using Standard Laboratory Methods of IITA (1979). The soil (pH: 5.3; N: 0.19 mg/kg; P: 6.82mg/kg; K: 0.22mg/kg; sand: 92.3%; Clay: 5.2%; Silt: 2.5%) was

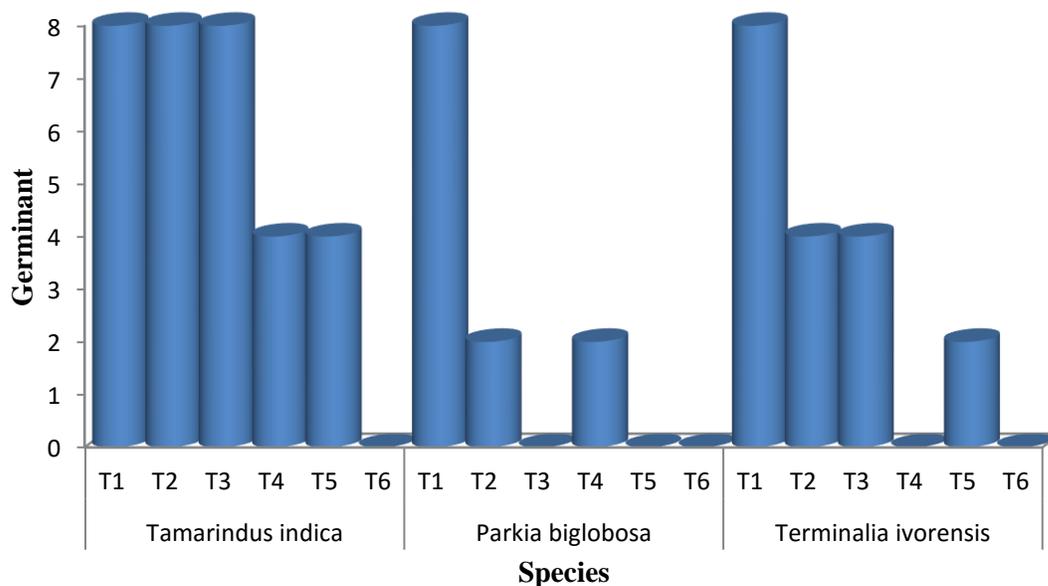
filled into 144 polythene pots and each given a uniform weight of 5kg. On March 24, 2015, 144 viable seeds (48 per species) were sown – each in a pot and four pots per treatment in three replicates. Watering and weeding were carried out regularly until the experiment was terminated.

The variables assessed / observed during the germination phase which spanned 41 days (24/03/15 – 03/05/15) were “days to plumule emergence, count of germinants, and germination type / cotyledonal position relative to ground level” while those for seedling growth were seedling height and number of leaves. Germination data were analysed using descriptive statistics, while seedling growth data were subjected to one-way Analysis of Variance (ANOVA) and means separated with LSD ( $p=0.05\%$ ) in Completely Randomized Design (CRD) using GENSTAT (Version 8.1), 2005.

### 3. RESULTS

#### 3.1 Seed Germination

Plumule emergence for *Tamarindus indica* commenced 9 days after sowing (DAS) and terminated 13 DAS. It recorded 100% germination in three plots – Control / zero shade; Canopy gap and Shade with side light, which translates to 67% overall average across all treatment plots. For *Parkia biglobosa*, plumule emergence was first noticed 11 DAS and terminated 22 DAS; it recorded 100% germination only in ‘control plot’ and overall germination success of 25%. *P. biglobosa* had nil germination in ‘Shade with side light’ and ‘Low shade’. While plumule emergence for *Terminalia ivorensis* started 18 DAS and terminated 24 DAS; it recorded 100% germination in ‘control plot’ and had overall germination success of 37.5%. Generally, none of the seeds of the three pioneers germinated in ‘Deep shade’ (Figure 1).



T1= Control/ Zero shade; T2 = Canopy gap; T3 = Shade with side light; T4 = Intermediate shade; T5 = Low shade; T6 = Deep shade.

Figure 1: Plumule emergence among seeds of three pioneer tree species in treatment plots

#### 3.2 Seed and Seedling Ecology

The results of the observed variables of *T. indica*, *P. biglobosa* and *T. ivorensis* with regards to longevity upon detachment from mother tree showed that the seeds exhibited increasing loss of viability after fruit/seed fall or in storage, implying that they have short shelf life. But the outcome of the study on germination type and position of cotyledons (seed leaves) relative to ground

level upon plumule emergence/germination reveal that *T. indica* displays fully exposed cotyledons (epigeal – phanerocotylar); *P. biglobosa* has semi-hypogeal (cotyledons/seed leaves are partly exposed or at ground level – phanerocotylar); while *T. ivorensis* has hypogeal (cotyledons below the ground – cryptocotylar). The seeds and seedlings of the three pioneer tree species are shown in Figure 2.



Figure 2: *Parkia biglobosa*; *Terminalia ivorensis* and *Tamarindus indica* seeds after floatation test (top row); seedlings of same species (bottom row).

### 3.3 Seedling Height

At 20 Weeks after Germination (WAG) all the three pioneer tree species recorded best average seedling height in 'Control plot' (Table 1) but *T. indica* had tallest seedling height and were significantly different from other species ( $P < 0.05$ ) with the exception of Heavy shade where none of the seeds germinated (Table 1).

Table 1: Average height of seedlings at 20 Week after Germination (WAG)

Treatment / Shade Level	Tree Species		
	<i>Tamarindus indica</i>	<i>Parkia biglobosa</i>	<i>Terminalia ivorensis</i>
Heavy shade	0.00	0.00	0.00
Low shade	6.93 <sup>d</sup>	2.73 <sup>b</sup>	0.00
Moderate shade	7.01 <sup>d</sup>	0.00	0.65 <sup>b</sup>
Canopy gap	14.35 <sup>b</sup>	0.91 <sup>b</sup>	0.44 <sup>c</sup>
Control	19.44 <sup>a</sup>	16.38 <sup>a</sup>	10.01 <sup>a</sup>
Shade with side light	10.60 <sup>c</sup>	0.00	1.56 <sup>b</sup>

Means with different alphabets (a,b,c,d) indicate significant difference between treatments ( $P < 0.05$ )

### Number of Leaves

The seedlings propagated in the 'Control plot' had the most abundant leaves at 20 Weeks after Germination (WAG). However, among species, *P. biglobosa* recorded the greatest number of leaves and was significantly different ( $P < 0.05$ ) from *T. indica* and *T. ivorensis* seedlings (Table 2).

Table 2: Average number of Leaves at 20 Weeks after Germination (WAG).

Treatment / shade level	Tree Species		
	<i>Tamarindus indica</i>	<i>Parkia biglobosa</i>	<i>Terminalia ivorensis</i>
Heavy shade	0.00	0.00	0.00
Light shade	4.10 <sup>b</sup>	3.00 <sup>b</sup>	0.00
Moderate shade	2.97 <sup>b</sup>	0.00	0.25 <sup>b</sup>
Canopy gap	3.83 <sup>b</sup>	1.27 <sup>b</sup>	0.15 <sup>b</sup>
Control	14.02 <sup>a</sup>	20.98 <sup>a</sup>	11.73 <sup>a</sup>
Shade with side light	2.80 <sup>b</sup>	0.00	1.25 <sup>b</sup>

Means with different alphabets (a,b,c) indicate significant difference between treatments ( $P < 0.05$ )

## 4. DISCUSSION

Entry of a species into the patchwork of light and shade is likely to depend on the species response to light, both at the stages of seed germination and seedling growth (Grace, 1992). The seeds germination of *T. indica* germinated first with the shortest lag time of 5 days (9 – 13DAS); followed by *P. biglobosa* which had a lag time of 12 days while *T. ivorensis* (9 days). The outcome of germination of *T. indica* did not differ significantly from results obtained in earlier studies which affirmed that "on average, tamarind seeds begin to germinate about 13 days after sowing but may take a month to complete (Padolina 1931; Galang 1955; Jøker 2000). The result of seed germination of *P. biglobosa* recorded in this study is in accord with Okunlola *et al.* (2011) who obtained 50% germination success at 14 days after sowing (DAS). But the result of germination of *T. ivorensis* recorded in this study (i.e.18DAS) is fairly different from the 14DAS reported for the same species raised under zero shade condition by Isikhuemen and Ekhomon (2011). The reasons for the observed difference might be attributed to environmental factors, particularly illumination (Photosynthetically Active Radiation).

While all the seeds of the three taxa performed differently under varied shade levels, the germination percentages recorded were significantly higher in plots that received substantial amounts of illumination (PAR). These results are in harmony with the outcome of germination experiment carried out on seven tree pioneers in the Amazon region by Aud and Ferraz (2012). According to Huang *et al.* (2015), "pioneer seeds have evolved to be highly efficient sensors and interpreters of not only the prevailing environment, but also their environmental history, in order to regulate physiological dormancy and the initiation of germination."

Grace (1992) described 'pioneers as species, which colonize gaps, have numerous small seeds that form seed banks in the soil, stimulated to germinate by light, grow fast, have high rates of photosynthesis and rapid turnover.' The fact that majority of the seeds raised in treatment plots with considerable canopy shade did not germinate might be attributed to the low light and/or temperature levels. Pearson *et al.* (2002) assert that temperature could be a more trigger than light for seed germination in the understorey. If temperature requirements are not met, seeds will not germinate even when other conditions, such as light, are favourable (Leverett *et al.* 2016). Seed germination and seedling pre-establishment growth are critical stages in life cycle, which determine plant population dynamics and ultimately community development, structure and sustainability in the recruitment of plant populations (Baeten *et al.* 2009; Chen and Xie 2007).

According to Masaka *et al.* (2011), understorey shade is an important factor influencing plant growth and survival in forest ecosystems – the light environment being largely determined by the degree of canopy cover. Though significant differences were recorded among the seeds during germination and seedling growth in treatment plots, the species that received substantial amounts of illumination recorded optimal performance in growth. Among the species, *T. indica* had best results in the growth variables in the Control, Canopy gap and Shade with side light plots, although there were no significant differences ( $P < 0.05$ ). These findings corroborate the affirmation by several authors (Okpala-Jose 1991; Valladares and Niinemets 2008; Isikhuemen and Bamawo 2013) 'that pioneer tree seedlings mobilize resources to support height growth for light capture when growing under a low light environment'. Arneberg *et al.* (1998) posited that "various plants require different variables for successful seed germination; these are largely dependent on the endogenous factors inherent in individual seeds that are closely linked to the ecological conditions of a plant's natural habitat."

Although *T. indica* has been implicated to exhibit poor *in situ* regeneration (e.g. Channal *et al.* 2002; Parvez *et al.* 2003), the best height growth recorded in control which received zero illumination confirms the assertion of these authors. The performance of *P. biglobosa* was generally poor in treatments located in the shaded understorey. Although Kennedy (1936) described the ability of *P. biglobosa* to regenerate *in situ* (i.e. under mother tree) as fair, Dalziel (1937) attributed the suppression of species' undergrowth under the mother tree to abundant leaf fall.' The poor results recorded for *T. ivorensis* corroborate Isikhuemen and Ekhomun (2011) who observed that "the species has low germination and poor regeneration capabilities *in situ* and /or under heavily shaded forest

understorey". Many authors (Whitmore 1996; Raven *et al.* 2005; Isikhuemen and Bamawo 2013; Isikhuemen and Uwuba 2014) have reported that most seeds produced by pioneer trees, including those adapted to the rainforest region, will not germinate until an opening in the forest canopy allows sufficient light to reach the forest floor to break physiological dormancy and trigger germination as well as growth of seedlings of pioneers.

## 5. CONCLUSION AND RECOMMENDATIONS

1. Seed germination and seedling initial growth patterns reported in this study suitably fits the pioneer species guilds generally; however, their responses to varied light levels in the forest understorey differed significantly.
2. The seeds and seedlings of the three pioneers: *Tamarindus indica*, *Parkia biglobosa*, and *Terminalia ivorensis* performed best in all the variables measured under Zero shade (Control treatment) plot.
3. *T. indica* had overall best results on aggregate – scoring  $\geq 50\%$  in seed germination and all the seedling growth variables measured, and
4. On account of increasing decline in viability under storage condition, the seeds of *Tamarindus indica*, *Parkia biglobosa*, and *Terminalia ivorensis* should not be stored for too long under air temperature or in open condition prior to propagation.

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