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Ecological environment effects on germination and seedling morphology in *Parkia biglobosa* in nursery (Côte d'Ivoire) and greenhouse (France)

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Abstract— *Néré* (*Parkia biglobosa*) is a wild species preferred and overexploited for its multiple uses by rural populations in Sub-Saharan Africa. The study of its germination and seedlings could constitute a prerequisite for its domestication, necessary for its conservation. This study aimed to assess the germination and morphology of seedlings taking into account distinct habitats from its natural environment. A total of 2160 seeds from different mother plants and 540 seedlings from germination were selected and evaluated. The trials were conducted on three sites (two nurseries in Côte d'Ivoire vs one greenhouse in France) with different microclimates. The results showed that the larger the mother trees are, the larger the seeds they produce, which in turn generate more vigorous seedlings. This study showed that the species grows better in a milder environment that is different from its region of origin (fertile soil with a stable or humid tropical climate: Montpellier greenhouse and Daloa nursery). Overall, parent trees did not statistically influence each germination and seedling development parameter for the three sites combined ($P > 0.05$). However, analysis of variance showed that germination and seedling development parameters differed between experimental sites ($P < 0.05$). These results are useful and could be used as decision support tools to guide conservation (domestication) and agroforestry programmes based on *Parkia biglobosa*. This study could be extended to other endangered species in order to preserve biodiversity.

Keywords— *Parkia biglobosa*, environments, seed germination, seedling morphology.

I. INTRODUCTION

The existence of many species is threatened by poverty combined with a galloping demography in most tropical countries (Chupezi et al. 2009; Houndonougbo et al. 2020). Indeed, phylogenetic resources, in particular native forest, fruit and agroforestry species constitute an important source of subsistence and income for rural populations. In Africa, studies have shown that around 55% of plant species are endangered in forests, of which 10% are already extinct in the wild (Aké 1999; Maréchal et al. 2014). As a scientific challenge, it seems urgent to develop conservation strategies to compensate for the ever-increasing pressures on certain species that could lead to their extinctions, while taking human needs into account. In African savannah zone, trees and shrubs play a

key role in the ecological balance in the face of the advance of the desert (Maazou et al. 2017). These trees are also the main source of goods and services essential to populations (Avana-Tientcheu et al. 2019). However, these trees are overexploited for their multiple roles (food, medicine, timber and firewood, cultural, rituals etc.) by the populations, but also threatened mainly by the strong demography, climatic variations and systems of land use (Maponmetsem et al. 2011; Segla et al. 2016; Dumenu 2019). In Côte d'Ivoire, the most important among these savannah tree species are savannah Iroko (*Chlorophora regia* A. Chev.), Karité (*Vitellaria paradoxa* CF Gaertn), Rônier (*Borassusaethiopum* Mart.), Caïllédrat (*Khaya senegalensis* Desr. A. Juss), Vène (*Pterocarpus*

*erinaceus*Poir.) And Néré (*Parkia biglobosa* Jacq. Benth). We focus on this last species (*Parkia biglobosa*).

Parkia biglobosa of the Fabaceae family and of the Mimosoideae subfamily is a nourishing species with multiple functions (food, medicine, energy, culture, ritual, soil restoration: leguminous) whose economic, sociocultural, nutritional and energetic importance, medicinal and agroforestry has been widely documented in West Africa (Sina 2006; Koura et al. 2013; Maisharou and Larwanou 2015; Maazou et al. 2017). The species is distributed from Senegal to Uganda and is highly valued for its seeds fermented in "Soumbara" or African mustard; a very nutritious and highly prized product to enhance the taste of various dishes in many Sahelian countries (Azokpota et al. 2006). Likewise, the pulp of néré seeds is eaten directly or combined with wheat flour, corn or millet to make donuts (Avana-Tientcheu et al. 2019). Néré seeds increase the protein intake of the diet of rural populations in Sudano-Sahelian areas, which is mainly made up of cereals (Maponmetsem et al. 2011; Eba'a et al. 2013).

Despite its important socio-economic role and the threat to the genetic diversity of its stands, *Parkia biglobosa* is so far in the wild and few studies are available on its regeneration, conservation and sustainable management. In our opinion, taking human needs (food security) into account in developing a strategy for the sustainable management of the species should also consider its domestication (artificial regeneration). This domestication could open up long prospects for in-depth research, in particular on the efficient use of its agroforestry potential and its conservation. In this current context of climate change, the study of the germination and development of seedlings of this species with respect to a changing environment could appear as a good start to its domestication in quantity and quality. Several research questions were developed to specify the objectives of our study. These are: (i) Could the ever-changing environment have an effect on seed germination and seedling growth? (ii) are the dendrometric characteristics of the mother plant (ideal choice of seed trees) necessary to obtain a good

germination rate and vigorous seedlings? (iii) is the choice of vigorous seedlings resistant to climatic stress necessary? (iv) do seedlings of this species adapt to different types of environment? (v) could the germination or morphology parameters of the seedlings guide the choice of an environment conducive to the implementation of an agroforestry program based on *Parkia biglobosa*? etc. This study was carried out in an attempt to answer all of these questions. The objective of this study is to contribute to the conservation of *Parkia biglobosa* by its domestication on a large scale in Côte d'Ivoire, taking into account environments foreign to its natural environment. Specifically, it involves (1) testing its adaptive power to different new climates, (2) evaluating the effect of three distinct environments on the germination of its seeds and the development of its seedlings and (3) of evaluate the effect of characteristics of mother plants on the germination of its seeds and the development of its seedlings.

II. MATERIAL AND METHODS

Plant material

The plant material is composed firstly of seeds obtained after dehulling of ripe fruits (figure 1a), from six distinct mother trees spaced about 400 m apart in the same stand of *Parkia biglobosa* and secondly of three-month-old seedlings (figure 1b), resulting from the germination of seeds harvested under the six mother trees. All seeds were collected at the same time in late April 2019 from trees in good physiological condition at the experimental station (DeFo) of the CNRA (*Centre National de Recherche Agronomique*) in the Korhogo department of Côte d'Ivoire. The dendrometric characteristics of the mother trees and seeds are listed in Table 1. The plant material used is the property of the CNRA of Côte d'Ivoire and the authorisation to use this plant material was given to us within the framework of this study thanks to a partnership agreement signed and available on request between the said structure and our study project (EFISA).



Fig. 1 Images of hulling, sorting of healthy seeds and measurement of the dimensions of each seed (a) and then of three-month-old seedlings in the greenhouse.

Table 1 Dendrometric characteristics of the mother trees and seeds of *Parkia biglobosa* used

Mother trees	DBH (cm)	H (m)	Age (year)	GPS coordinates		Number of seeds	Seed mass (g)		
				Longitude	Latitude		Mini	Maxi	Mean
1	29.30	10	20	-5.54872 W	9.56728 N	360	0.17	0.24	0.26 ± 0.04 a
2	16.24	6.5	14	-5.54763 W	9.56644 N	360	0.09	0.28	0.21 ± 0.04b
3	34.08	16.5	20	-5.55056 W	9.56873 N	360	0.17	0.27	0.23 ± 0.02ab
4	13.54	8.5	12	-5.54908 W	9.56742 N	360	0.14	0.33	0.20 ± 0.05b
5	22.45	12.5	20	-5.55097 W	9.5687 N	360	0.11	0.27	0.19 ± 0.02 b
6	36.94	15.5	20	-5.55094 W	9.55686 N	360	0.21	0.31	0.26 ± 0.02a
Pr > F							0.003		

DBH = Diameter at chest height in centimetres; H = Height in metres; W = West; N = North; Mini = Minimum in grams; Maxi = Maximum in grams

III. METHODS

Study sites

The trials were implemented from May to September 2019 in three sites, two in Côte d'Ivoire and one in France with different microclimates. Of the two sites in Côte d'Ivoire, one was at the CNRA forest experimental station (hereafter DeFo: *Développement des forêts*) in

Korhogo, and the other at the UJLoG (*Université Jean Lorougnon Guédé*) University in Daloa. The trial in France took place in a controlled environment, in Greenhouse 8 at CIRAD (The French agricultural research and international cooperation organization working for the sustainable development of tropical and Mediterranean regions) in Montpellier. The characteristics of the study sites are listed in Table 2.

Table 2 Geographical location and characteristics of study sites (Millan 2016, Akaffou et al. 2019, Hérault et al. 2020).

Study sites or Environments	Coordinates	Vegetation	Climate	Temperature	Rainfall (mm/year)	Soil type
Korhogo (DeFo)	9°570'80556''N 5°542'88889''W	Clear forest (wooded and grassy)	Tropical dry	26.6 – 35.7 °C	817 - 1216	Ferruginous (90%) and Ferralitic (10%) superficial gravelly soil, deep gravel with a heavy texture, low in organic

		savannah)				matter, highly desaturated.
Daloa (UJLoG)	6° 909'6363''N 6°438'1157''W	Dense rain forest	Wet tropical (sub-equatorial)	21 – 34 °C	1000 - 1900	Ferralitic, deep, acidic and desaturated in exchangeable bases, rich in organic matter
Montpellier (Greenhouse)	43°64981'N 3°86842'W	in the greenhouse	in the greenhouse ^e	24 °C (night) - 32 °C (day)	10 cm ³ per week	Mixture of Substrate Soil 1, Neuhaus N2 Bio, Tref Rice CIRAD 2 and extra-silice sand from biot

C° = degrees Celsius; mm = millimetre; **Substrate 1** =Iron, trace elements, perlite and coconut fibre; **Neuhaus N2 Bio** =vegetable co-composting, blond and black peat; **Tref Rice CIRAD 2** = clay, volcanic sand, perlite no. 2, coconut, Irish white peat and fine blond peat

Setting up the tests

Seed harvesting

Mature fruits were harvested in April and May 2019 on the mother trees using long wooden sticks forks attached or by knocking the top of the tree with stones. The mature fruit collected under each mother tree was husked by hand to remove the thorny shells from the seeds. The seeds were then divided into three batches. Each batch contained seeds from all six mother trees, i.e. 120 healthy seeds were selected per mother tree and per study site after sorting all the seeds collected (120 seeds x 6 mother trees x 3 test sites giving a total of 2,160 seeds of *Parkia biglobosa*).

Preparation of the trials and equipment

Environment 1 and 2: Korhogo and Daloa Nurseries

Polyethylene black bags with drainage holes measuring 20 x 10 cm were filled with local soil and arranged in one block comprising six sub-blocks. Each sub-block was labelled with the mother trees serial number and geographic coordinates and contained seeds harvested on and under one mother tree. Each sub-block contained 60 bags of soil prepared to receive two seeds each. The seeds from each mother tree were soaked in water for 24 hours to break seed dormancy and then sowed directly at a depth of approximately 2 cm in the bags at a rate of two seeds per bag. Before planting, the seeds were treated with granulated FURADAN to control rodents and after seedling emergence, the pre-leaves were treated with DECIS to limit insects' attacks. Nursery maintenance consisted of daily watering and manual weeding.

Environment 3: CIRAD greenhouse in Montpellier

Polyester black pots with drainage holes measuring 30 x 15 cm (figure 1b) were filled with a mixture of potting compost as specified above (Table 2). The pots were arranged in labelled blocks and sub-blocks in metal bins arranged in the same way as in Korhogo and Daloa. The seeds were sown in the same way as those from the other two sites in Côte d'Ivoire. Biological protection consisted of treatment with BIOBEST against greenhouse whiteflies. The pots were watered daily (10 cm³ per week). all the pots occupied an area of about 12 m².

Data Collection

Seeds germination and seedling development parameters

A total of 2160 seeds were evaluated for the entire study. 120 seeds per mother tree (constituting a sub-block) were evaluated per study site (120 x 6 = 720 seeds in total on each site). However, a total of 540 seedlings were sorted and then evaluated for this entire study. The morphology of 30 vigorous and three-month-old seedlings resulting from the germination of the seeds of each mother tree (in each sub-block) was evaluated on each study site (30 x 6 = 180 seedlings in total for each site of study). All morphological parameters were measured using a ruler graduated in centimetres and an electronic caliper in millimeter. Five germination parameters and nine development parameters were evaluated, there are recorded in Table 3.

Table 3 Germination development parameters evaluated

	Parameters	Definitions
Germination parameters	1-Waiting time or latency time	The time it takes for the first seed to germinate from the sowing of all the seeds(Amani et al. 2015; Douma et al. 2019)
	2-Germination delay	The period between the sowing of each seed and the appearance of each seedling (N'golo et al. 2018; Douma et al. 2019);
	3-Germination speed	The average time needed until 50% of the seeds have germinated (Berka and Abdelkader 2001; Diatta et al. 2009; Douma et al. 2019);
	4-Spreading time or germination duration	The period between germination of the first seed and the last seed (Amani et al. 2015; Douma et al. 2019);
	5-Germination rate	The number of seeds sprouted divided by the number of total seeds sprouted, expressed as a percentage (Zerbo et al. 2010; Gorgon et al. 2015; Akaffou et al. 2019).
Development parameters	1-Seedling height (SH)	The length between the collar and the apex of the seedling
	2-Diameter at the collar of the seedling (Dcol)	The base thickness of the main stem of the seedling
	3-Number of main leaves (LN°)	The number of main leaves on the main stem of the seedling
	4-Main leaf length (LL)	The length from the beginning of the petiole to the end of the primary rachis of the compound leaves on the main stem of the seedling
	5-Main leaf width (LW)	The width of the main compound leaf or the line connecting the tip of two opposite leaflets perpendicular to the primary rachis at the center of the main compound leaf
	6-Number of primary leaflets(N°Leaf1)	The number of primary leaflets of the main leaf and arranged along the rachis or the number of secondary leaves consisting of secondary leaflets (tertiary leaf).
	7-Primary leaflet length (LLeaf1)	The length of the secondary rachis of the primary leaflet or length of secondary leaf
	8-Width of the primary leaflets (WLeaf1)	The width of the primary leaflet or secondary leaf
	9-Length of the internodes (LIN)	The length connecting two nodes or the length of two points of successive insertions of organs or leaf scars, from the base to the apex of the seedling

Data analysis

The statistical analyses were first performed using one-dimensional descriptive statistics, link analysis (linear regression, correlation, and covariance) and multidimensional analysis (principal component analysis PCA) with XLSTAT 2020 version 7.5. The difference between the germination and morphology parameters was assessed using a two-factor multivariate analysis (MANOVA) with SAS software version 9.4. The Student-Newman-Keuls test at the 5% threshold was used for post-hoc comparisons.

IV. RESULTS

Description of the germination process for *Parkia biglobosa* seeds

The germination of *Parkia biglobosa* is hypogeal generally with a thick epicotyl at the base reaching an average of 2.07 mm in diameter at the collar and an average of 8.3 cm in length about 22 days after sowing. The pre-leaves are composed and bipinnate with generally 4 primary leaflets who composed an average of 11 pairs of secondary leaflets. The leaves following the pre-leaves are generally composed of two primary leaflets. Subsequently, the seedling produces bipinnate compound leaves with

more and more primary leaflets (up to 10 primary leaflets with an average of 36 pairs of secondary leaflets at three months of age). Phyllotaxis is alternating spiro-disc at this stage and each leaf carries two stipules, one of which has the leaf sheath and another at the end of the leaf (at the point of insertion of the last two primary leaflets, at the end of the rachis).

Germination and development parameters at each study site

Germination parameters

Environment 1: Korhogo nursery

At the Korhogo nursery, the first germinations started on the 7th day and the 9th day with seeds from mother trees number 4 and 1 respectively. The shortest time to germination were obtained from seeds of mother tree number 1, with a variation of 9 to 24 days around an average of 18.04 ± 4.18 days. As for the best germination speed, it was 18 days and was obtained from mother tree number 1 as well. Short germination spread times were observed in mother trees number 1, 3 and 4 in 15, 18 and 18 days respectively. Finally, the good germination rates were 90% and 93.33% respectively in the seeds of mother trees 1 and 3.

Environment 2: Daloa nursery

In Daloa nursery, the smallest germination latency was 4 days and was observed in seeds of mother tree number 4. The smallest germination delays were observed in seeds of mother trees number 1, 3 and 4 with respective variations from 10 to 21 days around an average of 16.13 ± 2.78 days, from 13 to 30 days with an average of 17.98 ± 4.01 days and from 4 to 27 days around an average of 16.64 ± 5.68 days. The fastest germination speeds were 15, 16 and 18 days, respectively observed in seeds of mother trees number 1, 4 and 3. The smallest germination duration was 11 days and observed in seeds of the mother tree number 1. As for the best germination rates, they were observed in the seeds of mother trees number 1, 2, 3, 4 and 6 with respectively rates of 100%, 95.50%, 100%, 92, 50% and 100%.

Environment 3: Montpellier greenhouse

In Montpellier greenhouse, the smallest germination latency times were 9 and 14 days and were observed in seeds of mother trees number 6 and 3 respectively. The shortest time to germination was observed in seeds of mother tree number 5 with a variation of 21 to 46 days around an average of 29.43 ± 11.81 days. The seeds of mother tree number 6 obtained a very good germination speed (17 days) unlike the others. The seeds of mother tree number 5 had short germination times (25 days) compared to the others. As for the germination rates,

they were higher than in the seeds of mother trees number 1, 5 and 6 (respectively 80%, 70% and 70%).

Development parameters

Environment 1: Korhogo nursery

At the Korhogo nursery, the greatest sowing heights were obtained from seedlings resulting from the germination of seeds of mother tree number 3 (20.4 ± 2.61 cm). Large mean diameters were observed in seedlings grown from seed germination of mother tree 3 (2.61 ± 0.12 mm) and 4 (2.51 ± 0.43 mm). The number of leaves was higher in seedlings resulting from seed germination of mother tree number 6 (4.02 ± 0.42). As for the length of the leaves, it was greater in seedlings from mother tree 1 (11.11 ± 0.59 cm) and 6 (10.11 ± 1.34 cm). Leaf width was greatest in seedlings originating from seed germination of mother tree number 1 (10.2 ± 0.23 cm). The number of primary leaflets was higher in seedlings from mother trees 5 (5.63 ± 0.34) 3 (5.21 ± 0.26). Primary leaflet length was greater in seedlings originating from seed germination of mother trees 3 (7.51 ± 0.14 cm) and 6 (7.46 ± 0.21 cm). The largest primary leaflet widths were observed in seedlings from mother trees number 4 (4.21 ± 0.34 cm) and 3 (3.81 ± 0.21 cm). Finally, the longest internodes were observed in seedlings from the seeds of mother tree 1 (3.57 ± 0.2 cm).

Environment 2: Daloa nursery

In Daloa nursery, the greatest sowing heights were observed in seedlings resulting from the germination of seeds from mother tree number 5 (28.1 ± 2.27 cm). The largest diameters were observed in seedlings resulting from the germination of seeds of mother tree 6 (4.42 ± 0.29 mm). Leaf numbers were highest in seedlings of seeds from mother trees number 6 (4.89 ± 0.28), 1 (4.75 ± 0.45), 3 (4.56 ± 0.21), 5 (4.46 ± 0.51) and 2 (4.32 ± 0.51). The longest leaf lengths were observed in seedlings of mother trees 5 (13.52 ± 1.08 cm), 6 (12.24 ± 1.54 cm) and 1 (12.2 ± 0.31 cm). The greatest widths were observed in seedlings of the seeds of mother trees 5 (13 ± 0.54 cm) and 6 (12.31 ± 0.34 cm). Primary leaflet numbers were highest in seedlings of mother trees 5 (5.58 ± 0.37), 1 (5.2 ± 0.22), 6 (5.03 ± 0.52) and 3 (5 ± 0.46). The longest primary leaflets were observed in seedlings of mother trees 6 (9.76 ± 0.64 cm), 4 (9.65 ± 0.36 cm), 3 (8.56 ± 0.37 cm) and 1 (8.21 ± 0.36 cm). Primary leaflet widths were greater in seedlings from mother trees 6 (4.26 ± 0.33 cm), 2 (4.23 ± 0.22 cm) and 3 (4.21 ± 0.54 cm). As for internode lengths, they were greater in seedlings resulting from the germination of seeds from mother trees 5 (3, 47 ± 0.54 cm), 2 (3.42 ± 0.36 cm) and 4 (3.28 ± 0.37 cm) and.

Environment 3: Montpellier greenhouse

In the Montpellier greenhouse, the greatest heights of the seedlings were observed in the seedlings resulting from the germination of the seeds of the mother trees 4 (28.2 ± 2.11 cm), 6 (27.62 ± 2.66 cm), 2 (27.4 ± 2.05 cm). The high diameters were observed in seedlings of mother trees 1 (3.71 ± 0.27 mm), 3 (3.67 ± 0.41 mm), 5 (3.57 ± 0.25 mm) and 6 (3.31 ± 0.20 mm). Leaf numbers were highest in seedlings of mother tree 1 (5.6 ± 0.17). The longest leaf lengths were observed in seedlings grown from seed germination of mother tree 2 (14.23 ± 1.35 cm). The largest leaf widths were observed in seedlings from mother trees 1 (12.31 ± 0.54 cm), 2 (13.96 ± 0.52 cm) and 6 (12.08 ± 0.44 cm). Primary leaflet numbers were highest in seedlings of mother trees 3 (5.64 ± 0.51), 4 (5.26 ± 0.54) and 6 (5.28 ± 0.22). The long primary leaflet lengths were observed in seedlings of mother trees 2 (10.56 ± 0.47 cm)

and 6 (11.28 ± 0.24 cm). The large widths of the primary leaflets were observed in seedlings of mother trees 5 (4.59 ± 0.16 cm) and 6 (4.67 ± 0.43 cm). finally, internode lengths were greater in seedlings of mother trees 3 (3.97 ± 0.30 cm) and 5 (3.9 ± 0.44 cm).

Global trend of assessed parameters

Germination parameters

Figure 2 gives a global overview of all germination parameters observed at the three study sites and indicates that the germination was best in Daloa and Montpellier environments. The highest values for germination waiting time, germination delay, germination speed and germination duration were recorded in Korhogo environment. The Montpellier greenhouse ranked second for all germination variables observed (fig. 2).

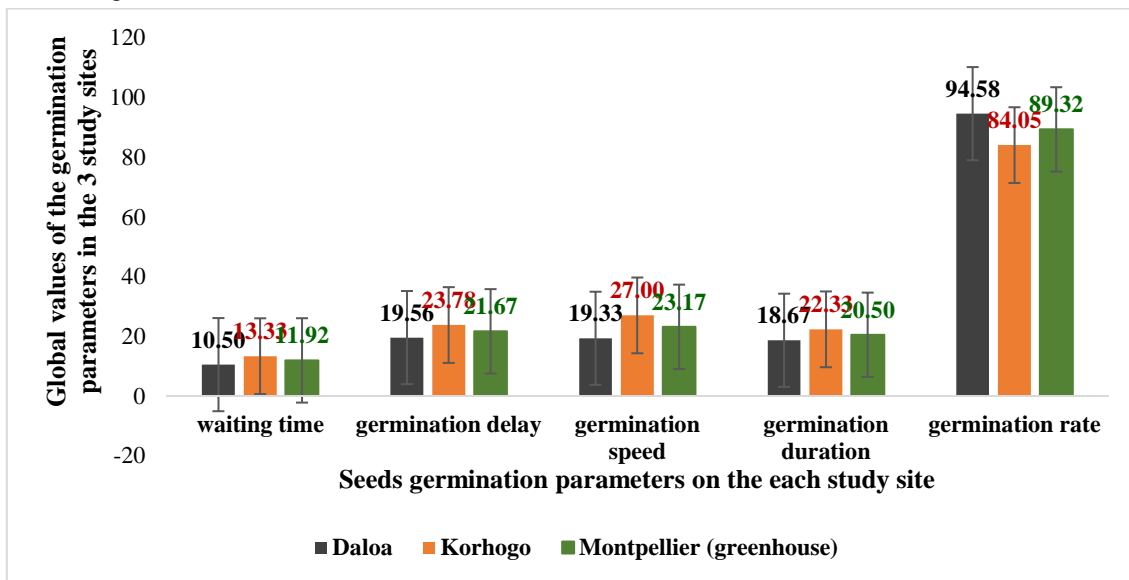


Fig. 2 Comparison of each germination parameter at the 3 study sites.

Influence of environment and mother trees on seeds germination

The comparison of seeds germination compared to the experimental sites, revealed a significant variability between the three study sites for all the germination

parameters evaluated ($P < 0.05$) (Table 4). The variance analysis of germination parameters (Table 4) shows, however, that all the germination variables observed overall are statistically identical from one mother tree to another ($p > 0.05$) on the three experimental sites.

Table 4 Comparison of germination parameters assessed according to the environment and mother trees used
For each character, values with the same letters are not statistically different at the 5% threshold.

Environments/ Mother trees	waiting time	germinationdelay	germination speed	germination duration	germination rate
Korhogo nursery	17.83 ± 2.12	34.69 ± 1.32 a	39.83 ± 7.19 a	38 ± 3.58 a	64.44 ± 4.44 b
Daloa nursery	10.50 ± 1.38	19.56 ± 1.34 c	19.33 ± 1.74 b	18.66 ± 2.33 b	94.58 ± 3.62 a

Montpellier greenhouse	13.33 ± 1.84 ab	23.77 ± 1.36 b	27 ± 2.47 ab	22.33 ± 2.14 b	84.05 ± 3.83 a
Pr > F	0.036	0.001	0.018	0.001	0.001
Mother tree-1	13.33 ± 3.84 a	24.07 ± 7.01 a	21.66 ± 5.24 a	23 ± 10.07 a	90 ± 5.77 a
Mother tree-2	17 ± 2.08 a	27.63 ± 4.06 a	32.66 ± 8.97 a	25.33 ± 4.48 a	78.05 ± 14.37 a
Mother tree-3	14.66 ± 1.20 a	25.92 ± 5.20 a	32 ± 11.13 a	28.33 ± 10.83 a	84.44 ± 12.37 a
Mother tree-4	11 ± 5.57 a	25.32 ± 6.26 a	34 ± 13.74 a	31 ± 5.68 a	78.39 ± 11.02 a
Mother tree-5	15 ± 3.05 a	26.55 ± 1.45 a	29 ± 3.05 a	24.66 ± 1.45 a	71.39 ± 3.20 a
Mother tree-6	12.33 ± 2.02 a	26.56 ± 3.37 a	23 ± 4.58 a	25.67 ± 5.61 a	83.88 ± 8.73 a
Pr > F	0.828	0.996	0.864	0.972	0.828

Development parameters

Influence of environment and mother trees on seedlings development

The comparison of experimental sites compared to the seedling morphology (Table 5) revealed that there is a significant difference between the study sites for the variable's height, diameter, number of leaves, length of

leaves, length of primary leaflets and internode length ($P < 0.05$). Unlike leaf width, number of primary leaflets and width of primary leaflets which were statistically identical regardless of the study site ($p > 0.05$). The results of variance analysis (Table 5) of seedlings morphology in relation to their origin (mother tree) showed that the set of development parameters evaluated were identical in the whole of a mother tree to another ($p > 0.05$).

Table 5 Comparison of morphological parameters assessed according to the environment and mother trees used

For each character, values with the same letters are not statistically different at the 5% threshold.

Environments/ Mother trees	SH (cm)	Dcol (mm)	N°L	LL (cm)	LW (cm)	N°Leaf l	LLeafl (cm)	WLeaf l (cm)	LIN (cm)
Korhogo nursery	19.51±0. 74 b	2.21±0. 15 b	3.52±0. 12 b	9.37±0. 49 b	9.01±0. 47 a	4.65±0. 34 a	6.69±0. 31 b	3.12±0. 32 a	2.45±0.2 b
Daloa nursery	25.52±0. 83 a	3.12±0. 34 a	4.38±0. 23 a	11.57± 0.57 a	10.86± 0.67 a	4.96±0. 18 a	8.46±0. 44 a	3.82±0. 19 a	2.98±0.2 ab
Montpellier greenhouse	26.35±0. 85 a	3.29±0. 19 a	4.65±0. 22 a	12.73± 0.53 a	11.22± 0.83 a	5.02±0. 19 a	9.49±0. 55 a	3.81±0. 28 a	3.54±0.1 9 a
Pr > F	0.001	0.015	0.003	0.002	0.076	0.545	0.002	0.138	0.016
Mother tree-1	23.27±2. 84 a	2.74±0. 49 a	4.53±0. 69 a	12.28± 0.70 a	11.25± 0.61 a	4.88±0. 22 a	7.43±0. 49 a	3.35±0. 15 a	2.84±0.3 9 a
Mother tree-2	23.41±2. 27 a	2.45±0. 34 a	3.94±0. 34 a	11.05± 1.59 a	10.78± 1.61 a	4.59±0. 02 a	8.27±1. 15 a	3.47±0. 39 a	3.15±0.3 1 a
Mother tree-3	23.03±1. 74 a	2.89±0. 39 a	4.23±0. 36 a	10.56± 1.14 a	9.37±1. 05 a	5.28±0. 18 a	8.54±0. 58 a	3.67±0. 36 a	2.90±0.6 0 a
Mother tree-4	22.89±3. 05 a	2.93±0. 46 a	3.76±0. 38 a	9.83±1. 13 a	9.08±0. 87 a	5.07±0. 38 a	8.46±1. 12 a	3.81±0. 2 a	2.87±0.5 1 a
Mother tree-5	25.53±1. 67 a	2.94±0. 63 a	4.31±0. 37 a	12.13± 1.33 a	10.37± 1.35 a	4.93±0. 37 a	7.10±0. 85 a	3.51±0. 63 a	3.45±0.2 6 a

Mother tree-6	26.61±2. 56 a	3.31±0. 52 a	4.31±0. 29 a	11.50± 0.69 a	11.33± 0.86 a	4.52±0. 64 a	9.50±1. 11 a	3.70±0. 77 a	2.74±0.5 4 a
Pr> F	0.961	0.879	0.812	0.651	0.611	0.674	0.537	0.983	0.883

SH: seedling height; **Dcol:** Diameter of the seedlings; **N°L:** Number of main leaves; **LL:** Main leaf length; **LW:** Main leaf Width; **N°Leafl:** Number of primary leaflets; **LLeafl:** Primary leaflet length; **WLeafl:** Width of the primary leaflets; **LIN:** Length of the internodes; **cm:** centimetres; **mm:** millimetres.

Figure 3 shows the projection of study site and morphological parameters of all the seedlings on the PCA 1-2 (biplot). The analysis of the matrix of factor weights allowed the extraction of two components that explain 100% of the variability and therefore the total variation between the morphological characteristics of the seedlings and the environments. Plan 1-2 is characterized by

eigenvalues of 97.57% for axis F1 and 2.43% for axis F2. The different descriptors contributing to the formation of the first (F1) and second component (F2) form a single group consisting of the Daloa and Montpellier (greenhouse) sites characterized by all morphological parameters higher than those of the seedlings in Korhogo site.

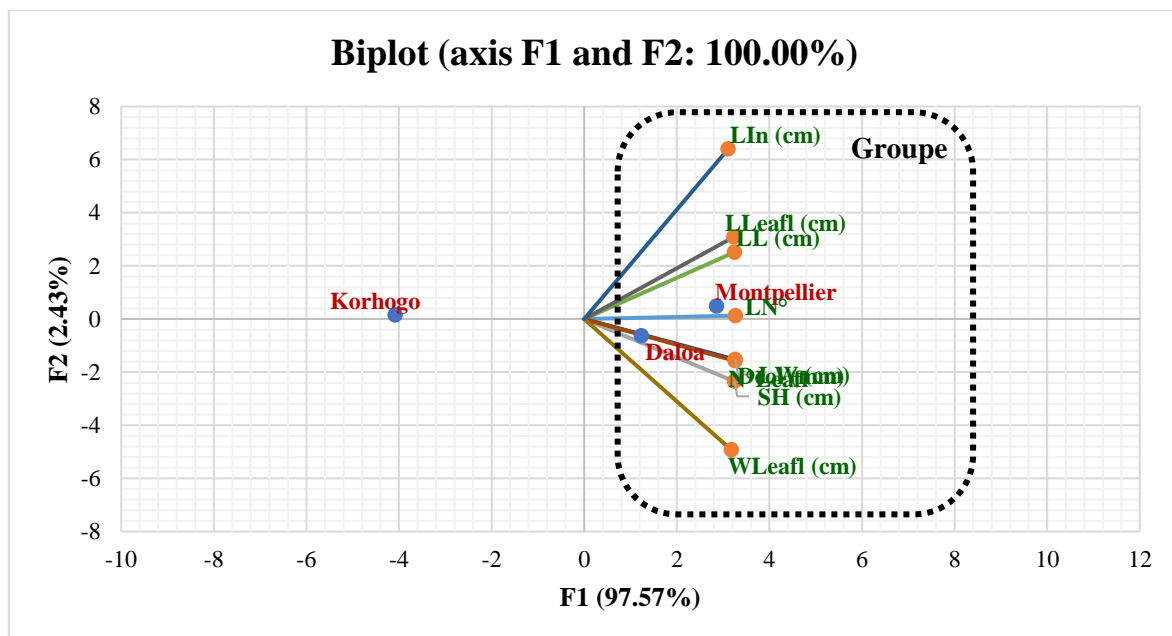


Fig. 3 Projection of study sites and morphological parameters observed in PCA Plan 1-2 as a function of the type of axis

V. DISCUSSION

Germination and seedling morphology parameters

The germination of *Parkia biglobosa* was found to be hypogeal, in agreement with Douma et al. (2019) and Millogo (2014). Seeds were peeled then soaked in water to break dormancy. Previous studies reported that integumentary inhibition or pericarpic and embryonic dormancy are major causes of low germination rates (Diatta et al. 2009). These integument inhibitory effects have been observed in many species including *Pterocarpus santalinus* (Rajendrudu and Naidu 2001), *Maeruacrassifolia* (Diatta et al. 2009), *Faidherbiaalbida* (Ameri et al. 2017), *Pterocarpus erinaceus* (N'golo et al. 2018) and *Parkia biglobosa* (Douma et al. 2019).

Seeds and seedlings from seed germination of mother trees number 1, 3 and 6 performed best regardless of the study site; probably because of the size of the seeds collected on and under these mother trees. These three mother trees have the greatest dendrometrics characteristics among all the mother trees selected for this study. These mother trees could be identified as very good parents for the production of vigorous, resistant genotypes and elite trees for the establishment of permanent plots within the framework of the execution of a reforestation or agroforestry program. This study shows that large trees with large diameters produce large seeds which in turn generate vigorous seedlings. This observation could be studied on a large number of mother trees in order to consolidate the results and popularize them in a paying

environment for a domestication and a large-scale sustainable management of this species. Several studies have shown that seed size plays a large role in successful germination and the production of vigorous seedlings that are resilient to climatic stress (Gunaga et al. 2007; Gunaga and Vasudeva 2011; Mao et al. 2019 etc.).

Overall, the germination parameters were as good as our expectation and imagination. Despite the non-treatment of the seeds with sulfuric acid (H₂SO₄), nor the scarification of the seeds or hot water for the lifting of dormancy, we obtained rates of up to 100% in natural areas as foreign to this species. In Niger, Douma et al. (2019) treated *Parkia biglobosa* seeds with sulfuric acid (H₂SO₄), which resulted in a two-day lag time, a four-day germination rate, and a germination rate of 80-92%. With the scarified seeds of *Parkia biglobosa*, the same authors obtained a latency time of three days, a germination rate of four days and a germination of 100%. When they heated the seeds, the germination rate was only 16-24%. Yet without nursery treatment, Amonum et al. (2016) obtained a latency time of six days, a germination rate of 33 days, the total germination time was 31 days, and the seed germination rate was 58.86%. Similarly, in a study on the viability of *Parkia biglobosa* seeds in Burkina Faso, Millogo (2014) obtained with seed banks a low germination rate (0.83-14.67%). According to him, this was due to a remarkably high loss of genetic diversity. The results of this study on seedling morphology are comparable to those obtained in Niger by Douma et al. (2019) but in disagreement with the studies by Gnanglè et al. (2010) in Benin. These last authors obtained with five (5) growth accelerators on plants of *Parkia biglobosa* in 140 days an average height of 26.3 cm, an average diameter of 6.6 mm with an average of 8.5 leaves. We had thought that *Parkia biglobosa* seeds would not grow in an environment other than its natural range. However, the seeds germinated there (Daloa nursery and Montpellier greenhouse) more efficiently with more vigorous seedlings than those in its area of origin (Korhogo). This is undoubtedly the cause of more lenient environments (fertile soil, higher air humidity, favorable temperature, etc.) than in its natural zone (low humidity, high temperature, poor soil). This species shows its ability to adapt to different foreign environments through this study. For guaranteed conservation (domestication), this species could be introduced into permanent agroforestry systems throughout the territory of Côte d'Ivoire. In addition, it is a species that restores soil fertility (leguminous plant). It could therefore be a replacement solution for the chemical fertilizers used permanently in the fallow areas of the savannah (natural environment for the species) and forest areas (environment foreign to the species) of the country.

The analysis of variance showed that the mother trees do not significantly influence each parameter of germination and seedling morphology for all three sites ($P > 0.05$). Indeed, this is normal since it is the seeds and seedlings of the same mother trees that were evaluated on all three sites. But, taken in isolation site by site, the parameters of germination and seedling morphology differ from one mother tree to another for each site. We believe that the dendrometric characteristics of mother trees should be considered in seed collections for studies of germination and production of seedlings for species conservation (domestication). However, the comparison of the germination and development parameters of the seedlings according to each of the three experimental sites indicated that the three sites differ significantly for all the parameters evaluated ($P < 0.05$). In fact, each site is made up of its own distinct microclimatic characteristics (type of soil, availability of water in the soil and in the ambient air, temperatures, etc.). Korhogo is located in a savannah zone (poor, arid soil with high temperatures, dry tropical climate), Daloa is located in a forest zone (rich and humid soil, mild temperature, humid tropical climate) and the Montpellier greenhouse is stable with a potting soil is made up of a mixture of substrates rich in mineral elements. Several studies have shown the effect of climate or climatic zone, soil, mother trees and seed provenance on plant growth and development (Giordano 1972; Assogbadjo et al. 2006; Dianda et al. 2009; Sambe et al. 2010).

VI. CONCLUSION

This study showed that the dendrometric characteristics of mother trees could be a factor in the selection of vigorous seed and seedlings in the context of conservation (domestication) of *Parkia biglobosa*. The larger the mother trees are, the larger the seeds they produce, which in turn generate more vigorous seedlings. This study also showed that this species is adaptable to foreign environments. It grows better in a milder environment that is different from its native area. Overall, the mother trees did not statistically influence each germination and development parameter for all three sites combined. However, analysis of variance showed that germination and seedling development parameters differed from one experimental site to another. A rich soil and a stable or humid tropical climate (Montpellier greenhouse and Daloa site) guarantee good germination and seedling development in *Parkia biglobosa*. These results are useful and could be used as decision support tools to guide conservation (domestication) and agroforestry programmes based on *Parkia biglobosa*. This study could be extended

to other endangered species in order to safeguard humanity.

VII. AUTHOR'S CONTRIBUTION

Beda Innocent Adji: Conception, methodology, supervision, software, formal analysis, writing the paper, resources, data acquisition and analysis. **Sélastique Doffou Akaffou:** Project administration, methodology, resources, data acquisition, supervision, writing the paper - original project, research and acquisition of funding. **Sylvie Sabatier:** Project administration, methodology, resources, data acquisition, supervision, writing the paper - original project, research and acquisition of funding.

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DATA AVAILABILITY

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest either between the authors, or between the organisations which financed the work, or on the site used for the experiments. All the authors agree to the publication of the submitted version of the paper.

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