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Optimization of the agromorphological parameters of *Myrianthus Arboreus* (P. Beauv) by cuttings

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Abstract
The objective of this study is to optimize the agromorphological parameters of Myrianthus arboreus by cutting in Côte d'Ivoire.
Two hundred (200) cuttings taken from five (05) plants of Myrianthus arboreus from Daloa with broad leaves and fruits with high solid quarters were sown, observed and then measured. Two types of sowing, oblique sowing as well as horizontal and soil-covered sowing were tested. Four variables related to germination capacity were observed and four others related to growth capacity were measured respectively on the 20th, 30th and 40th day after germination of the cutting. The results showed that the germination and growth ability variables of cuttings varied according to the type of seeding. Cuttings sown horizontally and covered with soil showed the best germination and growth capacity. In addition, these cuttings showed an early appearance of the first leaf of the bud. This suggests that horizontal seeding of the soil-covered cuttings could be recommended for Myrianthus arboreus cuttings in the nursery.

Keywords: myrianthus arboreus, cuttings, oblique seeding, horizontal seeding, côte d'ivoire

1. Introduction
In many countries, remarkable trees are mobilized by cutting stem or branch fragments from cuttings [1, 2]. In Africa, several cuttings trials have shown that this method is the best alternative for rapid fruit production [3, 4]. The knowledge of better conditions for cuttings helps species to be domesticated and contributes to their conservation [5]. Cuttings that produce plants identical to the mother plant remain the most appropriate method for safeguarding the genetic heritage threatened with extinction. This is the example of the work of [6] on the *Myrianthus arboreus* species.
This plant exists in the forest areas of Central and West Africa. It is an alicament with several socio-economic interests, namely nutritional value [7], economic [8], medicinal [9] and agronomic [10] importance. Consumed by populations for its nutritional value, *Myrianthus arboreus* constitutes a real source of nutritional supplements and financial resources in rural areas and plays an important role in the survival of populations [11].
Myrianthus arboreus is a highly sought-after tree in several regions of Africa for its multiple uses. It deserves not only to be protected in the wild but also to be domesticated with a view to its introduction into existing peasant production systems. But the implementation of such an approach requires the control of the conditions of the cuttings in order to develop a better improvement strategy and ensure the sustainability of the species. To achieve this objective, cuttings taken from five (5) plants in Daloa were sown obliquely and horizontally in order to identify the type of sowing suitable for the regeneration of *Myrianthus arboreus*.

2. Material and Methods
2.1. Study Sites
The experiments were conducted at the Jean Lorougnon Guédé University of Daloa (6°90'94" North and -6°43'77" West) in the Centre-West of Côte d'Ivoire, precisely at the nursery (Figure 1). The climate is of humid tropical type with two rainy seasons, from March to June and from September to October, alternating with two dry seasons. The longest is from November to February.

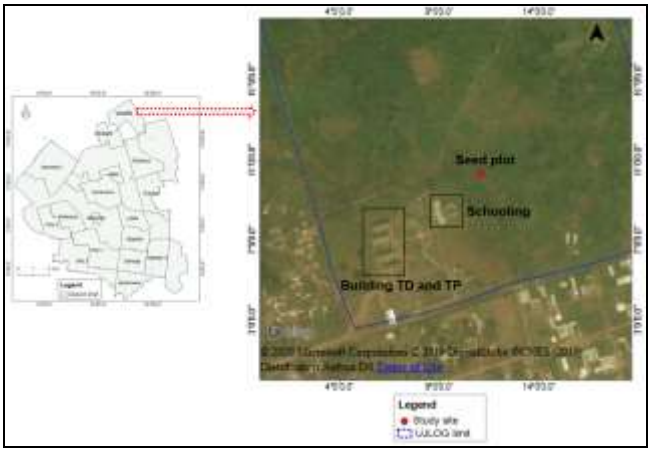

Fig 1: Geographical location of the study site.

2.2. Plant Material
The work focused on the five successful wild plants of *M. arboreus* de Daloa from the agromorphological study, namely Ma031-Da, Ma035-Da, Ma040-Da, Ma041-Da and Ma042-Da. These plants have broad leaves with high solid quartered fruits. A total of 200 cuttings were sown and then observed.

2.3. Collection and Preparation of Cutting
Elderly stems with a diameter between 2 and 3 cm were taken from five mother plants. From each mother plant, 40 cuttings were taken. Each cutting had at least one knot and was 14 cm long, 10 cm below the knot and 4 cm above it (Figure 2).

Fig 2: *M. arboreus* cutting ready for seeding.

2.4. Experimental Device

A totally randomized system was established on a 19.68 m^2 plot of land equivalent to the dimensions of 8.2 m long and 2.4 m wide. This system consisted of 200 cuttings, 100 of which were sown obliquely and 100 of which were sown horizontally and then covered with soil. The cuttings were distributed in 40 rows and five columns. Each of these rows were separated from each other by 20 cm and the columns by 40 cm (Figure 3).

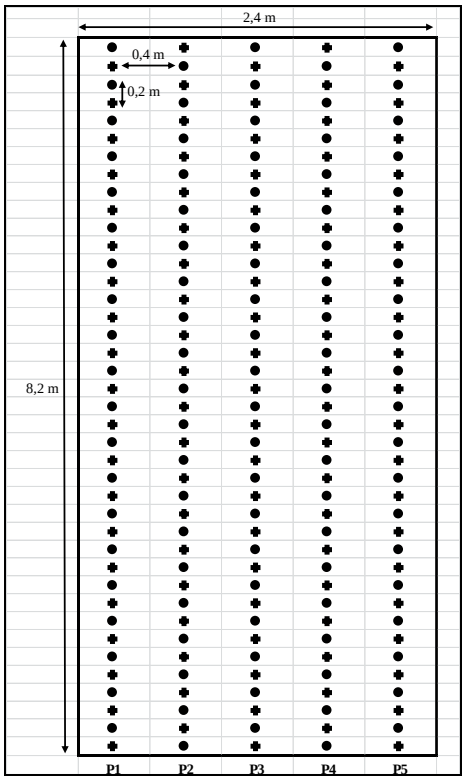

Fig 3: Schematic diagram of the experimental set-up.

Oblique sown cuttings;
Cuttings seeded horizontally and covered with soil;
P1, P2, P3, P4 and P5: mother plants of the respective plants 1, 2, 3, 4 and 5.

2.5. Environmental Conditions of the Experiment

The trial was set up during 2019, from May to July. Throughout the experiment, the average temperature was 29°C with an average daily variation of 25°C to 35°C. Humidity averaged 56% with a variation of 45% to 70%.

2.6. Seeding of Cutting and Cultivation Management

Two types of seeding were carried out with the 200 cuttings by sinking them 5 cm deep into the soil. One hundred cuttings were sown obliquely and one hundred others horizontally and then covered with soil (Figure 4). One watering was done daily and also weeding to avoid competition with weeds.

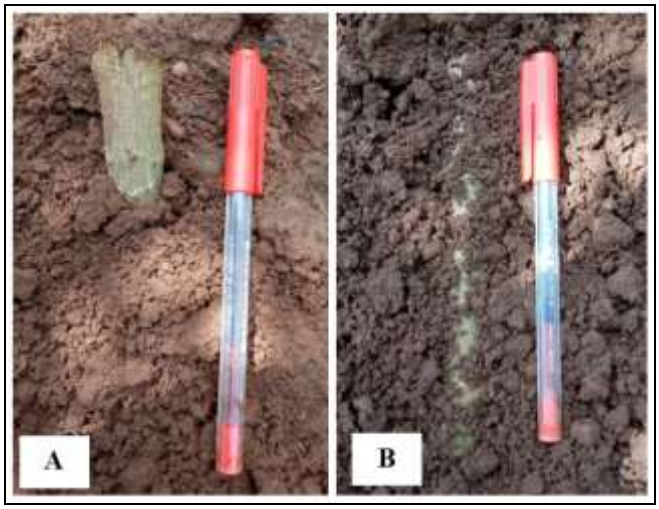

Fig 4: Different types of seeding of *M. arboreus* cuttings.

A: Cuttings seeded obliquely and B: Cuttings seeded horizontally and covered with soil.

2.7. Data Collection

On each type of cuttings seeding, parameters related to the germination and subsequent growth of *M. arboreus* buds were observed and measured. In total, four germination variables were observed: germination rate (RaGerm), mortality rate (RaMor), germination time (TGerm) and first leaf appearance date (DDF). Concerning the growth habit, four variables were measured respectively on the 20^{th}, 30^{th} and 40^{th} day after bud germination: bud height (HB1, HB2, HB3), bud leaf length (Lf1, Lf2, Lf3), bud leaf width (lf1, lf2, lf3) and bud collar diameter (Dc1, Dc2, Dc3). Observations and measurements lasted 60 days from June to August. All observed and measured parameters are recorded in Table I.

Table 1: Parameters and measurement period.

Parameters	Codes	Period of measurement
Germination rate	RaGerm	At the end of the test of sowing
Mortality rate	RaMor	At the end of the test of sowing
Germination time	TGerm	At the end of the test of sowing
First leaf appearance date	DDF	Day of appearance of the first leaf for each germinated cutting
Bud height	HB	20th, 30th and 40th day after germination of the cutting
Bud leaf length	Ll	20th, 30th and 40th day after germination of the cutting

Bud leaf width	Wl	20th, 30th and 40th day after germination of the cutting
Bud collar diameter	Dc	20th, 30th and 40th day after germination of the cutting

2.8. Statistical Analysis Method
The data obtained in this study were analyzed using Statistica version 7 [12] and were subjected to four types of analysis. These were descriptive statistical analysis, multivariate analysis of variance (MANOVA), analysis of variance (ANOVA), and Student's t-test.

3. Results
3.1. Study of Parameters of the Different Obliquely Sown *M. Arboreus* Individuals
The obliquely seeded individuals showed etiolated and variable aspects over time (Figure 5).

Fig 5: Appearance of obliquely sown *M. arboreus* buds after germination.

A: Bud after 10 days germination, B: Bud after 20 days germination, C: Bud after 30 days germination and D: Bud after 40 days germination.

3.1.1. Result of the Analysis of the Different Individuals of *M. Arboreus* According to the Set of Parameters
The multivariate analysis of variance (MANOVA) carried out on the one hand on the variables relating to the germinative faculty and on the other hand on the variables relating to the growth of cuttings, showed a highly significant difference for the individual factor. The values of *F* were 7.84 and 7.28 respectively, for a probability level $p < 0.001$. This observed difference reflects the variation of the different parameters (taken together) as a function of the individual factor. Thus, at least one of the parameters varied according to the individuals. For each parameter, the individual factor was therefore subjected to single-factor analyses of variance (ANOVA 1), in order to determine which parameters actually varied among individuals.

3.1.2. Analysis of Individuals According to *M. Arboreus* Germination Parameters
The ANOVAs performed on the germination parameters germination time, date of appearance of the first bud leaf, germination rate and mortality rate (Table II) showed that germination time and date of appearance of the first bud leaf did not vary between individuals. For the other two, the germination time and first bud leaf appearance varied highly significantly by individual ($p < 0.001$). Indeed, Ma040-Da, Ma041-Da and Ma042-Da had the highest germination rate compared to Ma031-Da and Ma035-Da. Regarding the mortality rate, the highest mortality was observed among Ma031-Da and Ma035-Da individuals while the lowest was observed among Ma040-Da individuals.

Table 2: Characteristics of individuals according to germination parameters of obliquely seeded *M. arboreus*.

Individuals and statistical parameters	Variables related to germinative capacity			
	TGerm (d)	DDF (d)	RaGerm (%)	RaMor (%)
Ma031-Da	12 ± 2 ^{a}	07 ± 1 ^{a}	30 ± 2.61 ^{d}	70 ± 2.61 ^{a}
Ma035-Da	13 ± 3 ^{a}	09 ± 2 ^{a}	35 ± 3.11 ^{c}	65 ± 3.11 ^{b}
Ma040-Da	12 ± 2 ^{a}	08 ± 2 ^{a}	50 ± 1.83 ^{a}	50 ± 1.83 ^{d}
Ma041-Da	11 ± 2 ^{a}	08 ± 2 ^{a}	40 ± 4.04 ^{b}	60 ± 4.04 ^{c}
Ma042-Da	11 ± 2 ^{a}	08 ± 1 ^{a}	40 ± 5.18 ^{c}	60 ± 5.12 ^{c}
F	1.78 ns	1.25 ns	35.57 ***	35.57 ***
p	0.16	0.31	0	0

Note: On the same column, the means followed by the same letter are not significantly different (Fisher's 5% LSD test).
ns: not significant; highly significant : ***$p \leq 0.001$; *p*: % probability; *F*: Fisher's LSD test; TGerm: Germination time; DDF: First leaf appearance date; RaGerm: Germination rate ; RaMor: Mortality rate and d: day.

3.1.3. Analysis of Individuals According to *M. Arboreus* Growth Parameters
The analysis of variance (ANOVA) performed on the growth variables at different dates (Tables III, IV and V) showed that the ANOVA measured at days 20th, 30th and 40th varied between individuals ($p < 0.05$; $p < 0.01$ and $p < 0.001$).
On day 20th, analysis of variance (ANOVA) on bud height, length of first bud leaf, width of first bud leaf and diameter at bud collar indicated that the width of first bud leaf and diameter at bud collar did not vary between individuals. In contrast, bud height and length of the first bud leaf varied highly and very significantly between individuals ($p < 0.001$ and $p < 0.01$, respectively). Indeed, the highest buds were from individual Ma031-Da and the smallest were from individual Ma041-Da. For the length of the first leaf of the bud, the largest were recorded from individuals Ma041-Da and Ma042-Da but the smallest were from individual Ma035-Da (Table III).

Table 3: Characteristics of individuals according to growth parameters of *M. arboreus* sown obliquely on the 20th day after germination.

Individuals and statistica parameters	Variables related to bud growth on the 20th day after germination			
	HB1 (cm)	Ll1 (cm)	Wl1 (cm)	Dc1 (cm)
Ma031-Da	2.73 ± 0,33 ^{a}	1.95 ± 0.19 ^{a}	1.07 ± 0.12 ^{a}	0.47 ± 0.08 ^{a}
Ma035-Da	2.34 ± 0,29 ^{b}	1.73 ± 0.17 ^{b}	0.96 ± 0.1 ^{a}	0.46 ± 0.13 ^{a}
Ma040-Da	2.08 ± 0,18 ^{c}	1.98 ± 0.12 ^{a}	1.09 ± 0.11 ^{a}	0.49 ± 0.13 ^{a}
Ma041-Da	1.98 ± 0,17 ^{c}	2 ± 0.18 ^{a}	1.06 ± 0.17 ^{a}	0.4 ± 0.11 ^{a}
Ma042-Da	2.04 ± 0,16 ^{c}	2.01 ± 0.08 ^{a}	1.16 ± 0.14 ^{a}	0.44 ± 0.1 ^{a}
F	13.05 ***	4.51 **	2.39 ns	0.78 ns
p	0	0.005	0.07	0.55

Note: On the same column, the means followed by the same letter are not significantly different (Fisher's 5% LSD test).
ns: not significant; highly significant : ***$p \leq 0.001$; highly significant: **$p \leq 0.01$; p: % probability; F: Fisher's LSD test; HB1: Bud height on the 20th day after germination of the cutting; Ll1: Bud leaf length on the 20th day after germination of the cutting; Wl1: Bud leaf width on the 20th day after germination of the cutting and Dc1: Bud collar diameter on the 20th day after germination of the cutting.

At day 30th, analysis of variance (ANOVA) performed on the same growth parameters revealed that these parameters varied significantly ($p < 0.05$) and highly significant ($p < 0.001$) depending on the individuals. The highest buds were observed in Ma031-Da while the lowest were Ma041-Da and Ma042-Da. Individual Ma040-Da had the largest snares, the longest and broadest leaves while individual Ma041-Da showed the lowest performance (Table IV).

Table 4: Characteristics of individuals according to growth parameters of *M. arboreus* sown obliquely on day 30th after germination.

Individuals and statistical parameters	Variables related to bud growth on the 30th day after germination			
	HB2 (cm)	Ll2 (cm)	Wl2 (cm)	Dc2 (cm)
Ma031-Da	3.29 ± 0.39 ^{a}	2.67 ± 0.16 ^{a}	1.93 ± 0.08 ^{a}	0.78 ± 0.1 ^{b}
Ma035-Da	2.91 ± 0.27 ^{b}	2.69 ± 0.21 ^{a}	1.91 ± 0.17 ^{a}	0.77 ± 0.18 ^{b}
Ma040-Da	2.76 ± 0.22 ^{b}	2.71 ± 0.2 ^{a}	2 ± 0.16 ^{a}	0.95 ± 0.15 ^{a}
Ma041-Da	2.41 ± 0.16 ^{c}	2.23 ± 0.21 ^{b}	1.63 ± 0.14 ^{b}	0.76 ± 0.11 ^{b}
Ma042-Da	2.4 ± 0.17 ^{c}	2.28 ± 0.14 ^{b}	1.95 ± 0.09 ^{a}	0.79 ± 0.08 ^{b}
F	15.94 ***	13.35 ***	9.7 ***	3.37 *
p	0	0	0	0.02

Note: On the same column, the means followed by the same letter are not significantly different (Fisher's 5% LSD test).
Highly significant : ***$p \leq 0.001$; significant: *$p \leq 0.05$; p: % probability; F: Fisher's LSD test; HB2: Bud height on the 30th day after germination of the cutting; Ll2: Bud leaf length on the 30th day after germination of the cutting; Wl2: Bud leaf width on the 30th day after germination of the cutting and Dc2: Bud collar diameter on the 30th day after germination of the cutting.
On day 40th, the analysis of variance (ANOVA) carried out on bud height, length of the first bud leaf, width of the first bud leaf and diameter at the bud collar showed that the width of the first bud leaf did not vary between individuals. However, bud height, length of the first bud leaf and crown diameter varied significantly ($p < 0.05$) and highly significantly ($p < 0.001$) between individuals. Indeed, the highest buds were from individual Ma031-Da versus the smallest from individual Ma042-Da. Regarding the length of the first bud leaf, the largest were recorded in individual Ma035-Da versus individual Ma042-Da who presented the smallest. Individual Ma042-Da provided the largest snares while individual Ma040-Da provided the smallest (Table V).

Table 5: Characteristics of individuals according to growth parameters of *M. arboreus* sown obliquely at 40th days after germination.

Individuals and statistical parameters	Variables related to bud growth on the 40th day after germination			
	HB3 (cm)	Lf3 (cm)	lf3 (cm)	Dc3 (cm)
Ma031-Da	4.16 ± 0.25 ^{a}	3.43 ± 0.16 ^{a}	2.65 ± 0.1 ^{a}	1.03 ± 0.16 ^{ab}
Ma035-Da	3.7 ± 0.25 ^{b}	3.51 ± 0.19 ^{a}	2.71 ± 0.16 ^{a}	1.03 ± 0.21 ^{ab}
Ma040-Da	3.55 ± 0.29 ^{b}	3.41 ± 0.19 ^{a}	2.62 ± 0.2 ^{a}	0.92 ± 0.18 ^{b}
Ma041-Da	3.29 ± 0.31 ^{c}	3.39 ± 0.19 ^{a}	2.66 ± 0.11 ^{a}	1.06 ± 0.12 ^{ab}
Ma042-Da	3.15 ± 0.18 ^{c}	2.96 ± 0.16 ^{b}	2.7 ± 0.13 ^{a}	1.19 ± 0.08 ^{a}
F	15.41 ***	11.39 ***	0.53 ns	3.33 *
p	0	0	0.72	0.021

Note: On the same column, the means followed by the same letter are not significantly different (Fisher's 5% LSD test).
ns: not significant; highly significant : ***$p \leq 0.001$; significant: *$p \leq 0.05$; p: % probability; F: Fisher's LSD test; HB3: Bud height on the 40th day after germination of the cutting; Ll3: Bud leaf length on the 40th day after germination of the cutting; Wl3: Bud leaf width on the 40th day after germination of the cutting and Dc3: Bud collar diameter on the 40th day after germination of the cutting.

3.2. Study of the Parameters of the Different Individuals of *M. Arboreus* Sown Horizontally and Covered with Soil

Horizontally seeded and soil-covered individuals showed vigorous and variable aspects over time (Figure 6).

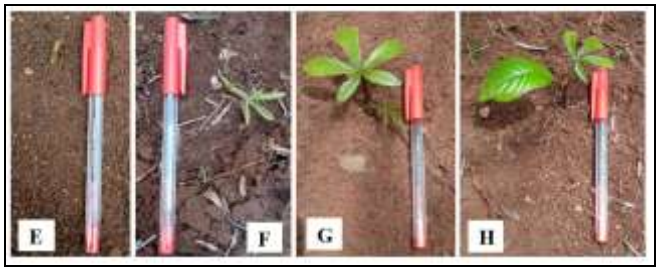

Fig 6: Appearance of horizontally seeded *M. arboreus* buds covered with soil after germination.

E: Bud after 10 days germination, F : Bud after 20 days germination, G : Bud after 30 days germination and H : Bud after 40 days germination.

3.2.1. Result of the Analysis of the Different Individuals of *M. Arboreus* According to the Set of Parameters

The multivariate analysis of variance (MANOVA) carried out on the one hand on the variables relating to the germinative faculty and on the other hand on the variables relating to the growth of cuttings, showed a significant and highly significant difference for the individual factor. The *F* values were 1.87 and 6.27 respectively, with a respective probability level of $p < 0.05$ and $p < 0.001$. This observed difference reflects the variation of the different parameters (taken together) as a function of the individual factor. Thus, at least one of the parameters varied according to the individuals. The individual factor was therefore subjected, for each of the parameters, to single-factor analyses of variance (ANOVA 1), in order to find out which parameters actually varied between individuals.

3.2.2. Analysis of Individuals According to *M. Arboreus* Germination Parameters

The ANOVAs performed on the germination parameters, i.e. germination time, date of appearance of the first bud leaf, germination rate and mortality rate (Table VI) showed that germination time and date of appearance of the first bud leaf did not vary between individuals. For the other two, they varied very significantly between individuals ($p < 0.01$). Indeed, individual Ma041-Da had the highest germination rate and individual Ma042-Da had the lowest. For the mortality rate, it is higher in individual Ma042-Da and lower in individual Ma041-Da.

Table 6 : Characteristics of individuals by germ parameters of *M. arboreus* horizontally seeded and covered with soil.

Individuals and statistical parameters	Variables related to germinative capacity			
	TGerm (d)	DDF (d)	RaGerm (%)	RaMor (%)
Ma031-Da	18 ± 4 ^{a}	06 ± 2 ^{a}	75 ± 9.64 ^{b}	25 ± 9.63 ^{ab}
Ma035-Da	18 ± 3 ^{a}	06 ± 2 ^{a}	75 ± 12.1 ^{b}	25 ± 12.17 ^{b}
Ma040-Da	18 ± 3 ^{a}	06 ± 2 ^{a}	75 ± 13.63 ^{b}	25 ± 13.63 ^{ab}
Ma041-Da	17 ± 3 ^{a}	06 ± 2 ^{a}	85 ± 5.59 ^{a}	15 ± 5.59 ^{c}
Ma042-Da	19 ± 3 ^{a}	06 ± 2 ^{a}	70 ± 10.92 ^{b}	30 ± 16.1 ^{a}
F	0.97 ns	0.64 ns	4.26 **	4.85 **
p	0.43	0.63	0.004	0.002

NB: On the same column, the means followed by the same letter are not significantly different (Fisher's 5% LSD test).
ns: not significant; very significant : $^{**}p \leq 0.01$; *p*: % probability; *F*: Fisher's LSD test; TGerm: Germination time; DDF: First leaf appearance date; RaGerm: Germination rate ; RaMor: Mortality rate and d: day.

3.2.3. Analysis of Individuals According to *M. Arboreus* Growth Parameters

The analysis of variance (ANOVA) performed on the growth variables at different dates indicated that growth measured at days 20th, 30th and 40th varied between individuals ($p < 0.001$).

At day 20th, the analysis of variance (ANOVA) performed on bud height, length of first bud leaf, width of first bud leaf and diameter at the bud collar showed that all these parameters varied highly significantly between individuals ($p < 0.001$). Indeed, the highest buds and the largest first leaves were from individual Ma031-Da as opposed to individual Ma041-Da. As for the width of the first leaf and the diameter of the bud collar, the best performances were recorded in Ma042-Da while the worst were observed respectively in Ma031-Da and Ma040-Da (Table VII).

Table 7: Characteristics of individuals according to growth parameters of *M. arboreus* horizontally seeded and covered on the 20th day after germination.

Individuals and statistical parameters	Variables related to bud growth on the 20th day after germination			
	HB1 (cm)	Ll1 (cm)	Wl1 (cm)	Dc1 (cm)
Ma031-Da	3.55 ± 0.37 ^{a}	3.07 ± 0.22 ^{a}	2.18 ± 0.13 ^{c}	0.61 ± 0.11 ^{b}
Ma035-Da	3.18 ± 0.22 ^{b}	2.77 ± 0.12 ^{b}	2.39 ± 0.12 ^{a}	0.64 ± 0.08 ^{ab}
Ma040-Da	3.16 ± 0.23 ^{b}	2.66 ± 0.15 ^{bc}	2.35 ± 0.15 ^{ab}	0.53 ± 0.1 ^{c}
Ma041-Da	3.05 ± 0.14 ^{b}	2.65 ± 0.12 ^{c}	2.28 ± 0.15 ^{bc}	0.66 ± 0.1 ^{ab}
Ma042-Da	3.16 ± 0.21 ^{b}	2.76 ± 0.18^{bc}	2.41 ± 0.19 ^{a}	0.7 ± 0.07 ^{a}
F	9.76 ***	16.97 ***	5.9 ***	7.12 ***
p	0	0	0	0

Note: On the same column, the means followed by the same letter are not significantly different (Fisher's 5% LSD test).
Highly significant : $^{***}p \leq 0.001$; *p*: % probability; *F*: Fisher's LSD test; HB1: Bud height on the 20th day after germination of the cutting; Ll1: Bud leaf length on the 20th day after germination of the cutting; Wl1: Bud leaf width on the 20th day after germination of the cutting and Dc1: Bud collar diameter on the 20th day after germination of the cutting.

At day 30th, the analysis of variance (ANOVA) performed on the same growth parameters revealed that these parameters varied highly significantly ($p < 0.001$) depending on the individuals. The highest buds and longest first leaves were observed in individual Ma031-Da as opposed to individual Ma041-Da. Individual Ma042-Da had the largest leaves and the largest collars against individuals Ma031-Da and Ma040-Da respectively (Table VIII).

Table 8: Characteristics of individuals according to growth parameters of *M. arboreus* horizontally seeded and covered on the 30th day after germination.

Individuals and statistical parameters	Variables related to bud growth on the 30th day after germination			
	HB2 (cm)	Ll2 (cm)	Wl2 (cm)	Dc2 (cm)
Ma031-Da	4.4 ± 0.41 [a]	3.87 ± 0.21 [a]	2.95 ± 0.14 [c]	0.98 ± 0.14 [bc]
Ma035-Da	3.87 ± 0.25 [bc]	3.43 ± 0.14 [c]	3.13 ± 0.12 [ab]	1.05 ± 0.09 [ab]
Ma040-Da	3.99 ± 0.23 [b]	3.45 ± 0.13 [bc]	3.13 ± 0.14 [ab]	0.95 ± 0.1 [c]
Ma041-Da	3.8 ± 0.16 [c]	3.43 ± 0.12 [c]	3.08 ± 0.16 [b]	1.06 ± 0.1 [a]
Ma042-Da	3.93 ± 0.2 [bc]	3.56 ± 0.19 [b]	3.2 ± 0.2 [a]	1.1 ± 0.17 [a]
F	12.53 ***	20.9 ***	5.73 ***	5.14 ***
p	0	0	0	0

Note: On the same column, the means followed by the same letter are not significantly different (Fisher's 5% LSD test).
Highly significant : ***$p \leq 0.001$; *p*: % probability; *F*: Fisher's LSD test; HB2: Bud height on the 30th day after germination of the cutting; Ll2: Bud leaf length on the 30th day after germination of the cutting; Wl2: Bud leaf width on the 30th day after germination of the cutting and Dc2: Bud collar diameter on the 30th day after germination of the cutting.

At day 40th, analysis of variance (ANOVA) carried out on bud height, length of the first bud leaf, width of the first bud leaf and diameter at the bud collar showed that these parameters varied highly significantly ($p < 0.001$) depending on the individuals. Indeed, the tallest and the largest first bud leaves were from individual Ma031-Da versus the smallest from individuals Ma041-Da and Ma035-Da respectively. The largest first leaves and the largest snares were recorded from individual Ma042-Da versus individuals Ma031-Da and Ma040-Da respectively (Table IX).

Table 9: Characteristics of individuals according to growth parameters of *M. arboreus* horizontally seeded and covered on the 40th day after germination.

Individuals and statistical parameters	Variables related to bud growth on the 40th day after germination			
	HB3 (cm)	**Ll3 (cm)**	**Wl3 (cm)**	**Dc3 (cm)**
Ma031-Da	5.34 ± 0.42 [a]	4.64 ± 0.19 [a]	3.75 ± 0.14 [c]	1.36 ± 0.12 [b]
Ma035-Da	4.85 ± 0.19 [b]	4.23 ± 0.14 [b]	3.98 ± 0.13 [ab]	1.45 ± 0.11 [a]
Ma040-Da	4.89 ± 0.26 [b]	4.24 ± 0.13 [b]	3.93 ± 0.14 [b]	1.34 ± 0.12 [b]
Ma041-Da	4.66 ± 0.24 [c]	4.24 ± 0.12 [b]	3.88 ± 0.16 [b]	1.46 ± 0.1 [a]
Ma042-Da	4.83 ± 0.21 [bc]	4.28 ± 0.21 [b]	4.07 ± 0.29 [a]	1.49 ± 0.08 [a]
F	13.33 ***	18.37 ***	6.59 ***	5.64 ***
p	0	0	0	0

Note: On the same column, the means followed by the same letter are not significantly different (Fisher's 5% LSD test).
Highly significant : ***$p \leq 0.001$; *p*: % probability; *F*: Fisher's LSD test; HB3: Bud height on the 40th day after germination of the cutting; Ll3: Bud leaf length on the 40th day after germination of the cutting; Wl3: Bud leaf width on the 40th day after germination of the cutting and Dc3: Bud collar diameter on the 40th day after germination of the cutting.

3.3. Effect of Different Types of Seeding on the Parameters of *M. Arboreus* Cutting

The multivariate analysis of variance (MANOVA) carried out on the one hand on the variables relating to the germination capacity and on the other hand on the variables relating to the growth of cuttings, showed a highly significant difference for the standard seeding factor. The *F* values were 8.38 and 5.4 respectively for a probability level $p < 0.001$. This observed difference reflects the variation of the different parameters (taken together) as a function of the typical seeding factor. These analyses of variance show that the type of seeding has a highly significant effect on all variables. Thus, at least one of the parameters varied according to the type of seeding. The seeding type factor for each parameter was therefore subjected to analyses of comparison of the mean (Student's t-test) in order to find out which parameters actually varied according to the type of seeding. Student's t-test indicated that this difference was due to all traits measured.

At the end of this analysis, horizontally seeded cuttings covered with soil showed the best germination and growth parameters (Tables X, XI, XII and XIII).

Table 10: Effect of seeding types on germination parameters of *M. arboreus* cuttings.

Seeding types and statistical parameters	Variables related to the germination capacity of cuttings			
	TGerm (d)	**DDF (d)**	**RaGerm (%)**	**RaMor (%)**
BeO	12 ± 2	08 ± 2	40.13 ± 7.6	59.87 ± 7.6
BeH	18 ± 3	06 ± 2	76.32 ± 11.5	23.68 ± 12.93
t	-12.1***	6.16***	-17.74***	15.83***
p	0	0	0	0

Highly significant : ***$p \leq 0.001$; *p*: % probability; *t*: Student test; TGerm: Germination time; DDF: First leaf appearance date; RaGerm: Germination rate and RaMor: Mortality rate; d: day ; BeO: Oblique sown cuttings and BeH: Cuttings sown horizontally and covered with soil.

Table 11: Effect of seeding types on growth parameters of *M. arboreus* cuttings on the 20th day after germination.

Seeding types and statistical parameters	Variables related to bud growth on day 20th after germination of cuttings			
	HB1 (cm)	Ll1 (cm)	Wl1 (cm)	Dc1 (cm)
BeO	2.2 ± 0.34	1.94 ± 0.17	1.07 ± 0.14	0.45 ± 0.11
BeH	3.22 ± 0.29	2.78 ± 0.22	2.32 ± 0.17	0.63 ± 0.11
t	-16.81***	-20.68***	-39.93***	-8.15***
p	0	0	0	0

Highly significant : ***$p \leq 0.001$; *p*: % probability; *t*: Student test; HB1: Bud height on the 20th day after germination of the cutting; Ll1: Bud leaf length on the 20th day after germination of the cutting; Wl1: Bud leaf width on the 20th day after germination of the cutting ; Dc1: Bud collar diameter on the 20th day after germination of the cutting ; BeO: Oblique sown cuttings and BeR: Horizontally sown cuttings covered with soil.

Table 12: Effect of seeding types on growth parameters of *M. arboreus* cuttings on the 30th day after germination.

Seeding types and statistical parameters	Variables related to bud growth on day 30th after germination of cuttings			
	HB2 (cm)	Ll2 (cm)	Wl2 (cm)	Dc2 (cm)
BeO	2.72 ± 0.39	2.51 ± 0.28	1.89 ± 0.19	0.82 ± 0.14
BeH	3.99 ± 0.33	3.54 ± 0.23	3.1 ± 0.17	1.03 ± 0.12
t	-18.26***	-21.01***	-34.61***	-8.37***
p	0	0	0	0

Highly significant : ***$p \leq 0.001$; *p*: % probability; *t*: Student test; HB2: Bud height on the 30th day after germination of the cutting; Ll2: Bud leaf length on the 30th day after germination of the cutting; Wl2: Bud leaf width on the 30th day after germination of the cutting ; Dc2: Bud collar diameter on the 30th day after germination of the cutting ; BeO: Oblique sown cuttings and BeH: Horizontally sown cuttings covered with soil.

Table 13: Effect of seeding types on growth parameters of *M. arboreus* cuttings on the 40th day after germination.

Seeding types and statistical parameters	Variables related to bud growth on day 40th after germination of cuttings			
	HB3 (cm)	Ll3 (cm)	Wl3 (cm)	Dc3 (cm)
BeO	3.54 ± 0.42	3.34 ± 0.26	2.67 ± 0.15	1.04 ± 0.17
BeH	4.91 ± 0.35	4.32 ± 0.22	3.92 ± 0.21	1.42 ± 0.12
t	-18.58***	-21.17***	-33.76***	-13.76***
p	0	0	0	0

Highly significant : ***$p \leq 0.001$; *p*: % probability; *t*: Student test; HB3: Bud height on the 40th day after germination of the cutting; Ll3: Bud leaf length on the 40th day after germination of the cutting; Wl3: Bud leaf width on the 40th day after germination of the cutting ; Dc3: Bud collar diameter on the 40th day after germination of the cutting ; BeO: Oblique sown cuttings and BeH: Horizontally sown cuttings covered with soil.

4. Discussion

To determine the regeneration of *M. arboreus* by adequate cuttings, two main studies were conducted. The first was carried out using cuttings from five individuals of *M. arboreus* from the agromorphological evaluation. It involved sowing the cuttings obliquely and horizontally. The second was used to observe firstly, parameters related to the germination capacity of the seeded cuttings and secondly, to measure the growth variables of the germinated cuttings.

At the end of this experiment, it appears that whatever the type of sowing used, *M. arboreus* can be cut quite easily. Also the resumption of cuttings starts with the formation of the bud followed by its opening on the 10th day and the real leaves are set up on the 30th day after the cuttings are cultivated. These results confirm the work carried out by [6] who evaluated the germination capacity and characteristics of *M. arboreus* germination by cuttings.

The multivariate analysis of variance (MANOVA) showed that the type of seeding strongly influenced the germination and growth parameters of the *M. arboreus* individuals studied and these parameters varied among the different individuals. This highlights the existence of great agromorphological variability in this species. These results are similar to those obtained by [13] on the ability to cut *C. adansonii*. These authors reported that the ability of woody plants to propagate vegetatively depends on the genotype of each species.

Oblique seeded cuttings had a high mortality rate (59.87%) and a low germination rate (40.13%). These results could be explained primarily by the position of the cutting in the soil. These results are consistent with those of [6] who found in their study that the average recovery rate of obliquely seeded *M. arboreus* cuttings in three systems was 37.53%. Second, termite attack could be the cause of high mortality and low germination of cuttings. Indeed, several studies have shown that termites are responsible for the destruction of cassava cuttings [14; 15]. In addition, this could also be due to the drying of the aerial part of the cutting. In addition, a higher ambient temperature can lead to bud burst before root initiation and increase water loss by transpiration, which often causes cuttings to dry out and die [16].

Cuttings seeded horizontally and covered with soil produced the best growth parameters, a low mortality rate (23.68%) and a high germination rate (76.32%). The growth performance and survival of these cuttings could be explained by the horizontal position of the cuttings. These results reflect those obtained by [17] on *Cryptolepis sanguinolenta* and *Parquetina nigrescens* root segment cuttings, [4] on *Spathodea campanulata* root segment cuttings and [18] on *Psychotria ipecacuanha* root segment cuttings. Indeed, according to these authors, it appears that cuttings placed horizontally develop easily and give low mortality and high germination of cuttings.

5. Conclusion

This study assessed germination and growth parameters of five *M. arboreus* individuals by cuttings with two types of

seeding: oblique seeding and horizontal seeding covered with soil.

The results of the work undertaken for this purpose revealed that the horizontally seeded and soil-covered individuals had the best germination and growth capacity. Horizontal seeding of soil-covered cuttings may be advisable for cutting *M. arboreus* in the nursery.

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