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Agro-morphological characterization of *Detarium microcarpum* Guill & Perr, edible and non-edible (toxic) *Detarium senegalense* J. F. Gmelin on three types of substrates

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Abstract

Forest fruits play an important role on the economy of rural households in Casamance. The fruits of *Detarium microcarpum* and *Detarium senegalense* are the most produced and marketed. However, regeneration of *D. microcarpum* and *D. Senegalense* remains limited due to seed exports. This study aimed to assess the germination capacity of seeds as well as the growth and development of *D. microcarpum* and edible and non-edible (toxic) *D. Senegalense* seedlings on three substrates derived from Faidherbia albida (Del.) A. Chev, *Elaeis guineensis* Jacq. And *Anacardium occidentale* L. forest soils. After crushing, germination and growth parameters (diameter, height and number of leaves were determined and measured. The germination dynamics revealed early emergence from 10 to 20 days for D. microcarpum and edible *D. senegalense* on all the substrates. Toxic *D. senegalense* recorded a later germination from 30 to 60days after sowing. The overall germination rate was 50.93%. There was a significant difference between the different treatments for all the parameters studied. The analysis of variance showed a significant difference ($P<0.05$) between varieties and substrates for the studied parameters. Principal component analysis revealed significant correlations between parameters such as germination rate, number of leaves, and height and crown diameter of the plants.

Keywords: Germination; Growth; *Detarium senegalense*; *Detarium microcarpum*; Substrates

1. Introduction

Some woody species are endangered due to overexploitation, lack of regeneration by natural seeding facing annual firewood, and the disappearance of their ecological habitats [1]. Indeed, the uncontrolled exploitation of plant formations leads to the rapid regression or even total disappearance of certain species that are very important to the population [2]. Among these woody species are *Detarium microcarpum* Guill & Perr and *Detarium senegalense* J F Gmelin, whose harvesting mobilizes many producers after the cashew and mango campaigns. The kernels of the seeds and the fruits of these species have been the subject of a flourishing trade in West Africa in the past [3]. This collection and sale of kernels has largely negatively impacted the natural regeneration of these species and consequently their survival [3]. Thus, *Detarium senegalense* has a status of vulnerable species after its inclusion on the IUCN red list [4]. The stands of Detarium are treated by the loss and the fragmentation of the habitat. The density of adult individuals as well as regeneration is very low [3]. The intensity of collection caused the rarity of natural regeneration. Young seedlings and saplings are rare, despite the relatively important presence of fruits and seeds under the some natural relict stand of *Detarium*. Several questions emerging from all these observations concerned the absence of natural regeneration under the mother plants and factors limiting seed germination and seedling survival around the mother plants of these species. To provide some answers, the present study was initiated to evaluate the germination capacities of seeds collected from two species of *Detarium*. It is specifically to assess the effect of different substrates (*Faidherbia albida,*

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Elaeis guineensis and *Anacardium occidentale forest soils*) on the germination and growth of *Detarium microcarpum* Guill & Perr and edible and non-edible *Detarium senegalense*.

2. Material and methods

2.1 Study area

The experiment was conducted at the Practical Application Farm of the Department of Agroforestry Assane Seck University of Ziguinchor. The farm is geographically located at 12°32' 57.2'' north latitude and 16°16' 37.3'' west longitude (Figure 1). This farm is located in an area characterized by average rainfall between 1300 and 1500 mm per year [5]. The Ziguinchor region is characterized by a South Sudanese coastal climate [6]. Relative humidity influenced by the Harmattan is low in January, February and March.

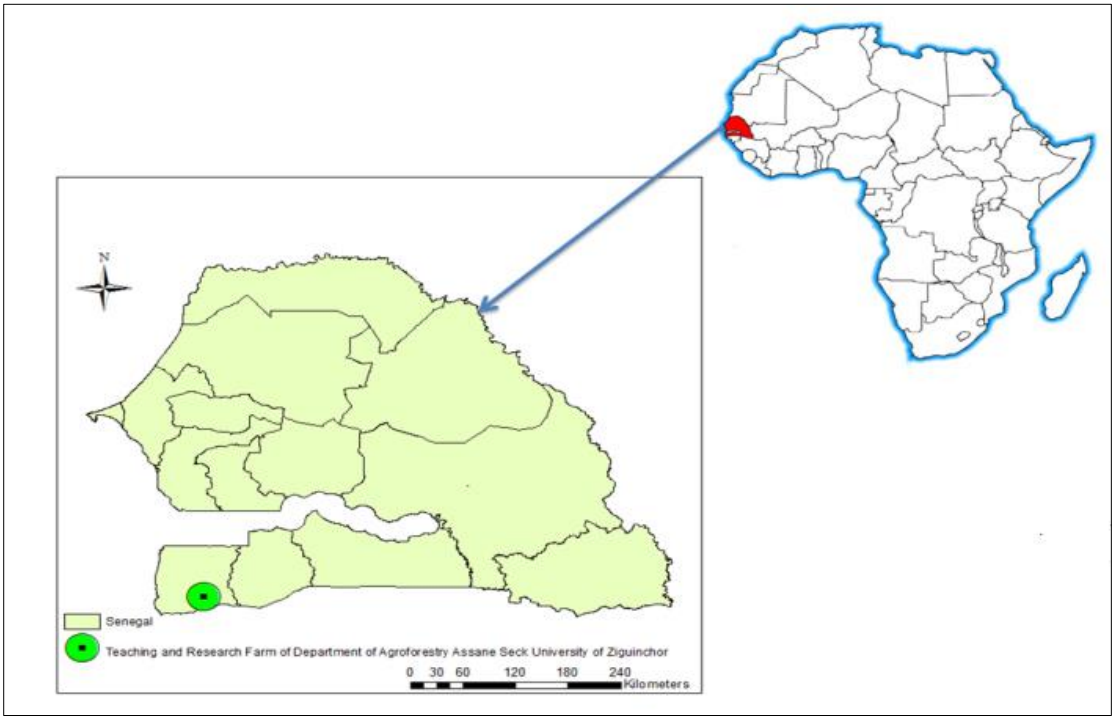

Figure 1 Location of Practical Application farm of Department Agroforestry Assane Seck University of Ziguinchor [7]

2.2 Vegetal material

The *Detarium* seeds used were harvested in Basse Casamance. *D. microcarpum* and edible *D. Senegalense* seeds were collected from Baïla and Kaparang (Ziguinchor) and non-edible (toxic) *D. senegalense seeds* from Hitou (Ziguinchor). Seeds were collected from healthy and vigorous individuals in Baïla, Kaparang and Hitou area.

2.3 Experimental design and treatments

The experiment was based on a split-plot design of two factors (species and substrates) resulting six treatments randomized with six replicates over four months. The species were *Detarium microcarpum* (Dm), edible *Detarium senegalense* (eDs) and toxic *Detarium senegalense* (tDs). The Substrates were three different forest soil mixtures under *Faidherbia albida* (Fa), *Elaeis guineensis* (Eg) and *Anacardium occidentale* (Ao). The combinations between the two factors gave nine treatments which were AoDm, EgDm, FaDm, AoeDs, EgeDs, FaeDs, AotDs, EgtDs and FatDs. The substrates and species were randomized in the large and small plots respectively (Figure 2).

Bloc 1	Bloc 2	Bloc 3	Bloc 4	Bloc 5	Bloc 6
AoDm 111	FaeDs 233	EgtDs 322	AoDm 411	FaDm 531	EgtDs 622
AotDs 112	FaDm 231	EgeDs 323	AoeDs 413	FatDs 532	EgeDs 623
AoeDs 113	Fa tDs232	EgDm 321	AotDs 412	FaeDs 533	EgDm 621
EgDm 121	AoeDs 213	FatDs 332	FaeDs 433	EgDm 521	AoDm 611
EgeDs 123	AoDm 211	FaeDs 333	FaDm 431	EgtDs 522	AotDs 612
EgtDs 122	AotDs 212	FaDm 331	FatDs 432	EgeDs 523	AoeDs 613
FatDs 132	EgDm 221	AotDs 312	EgeDs 423	AoDm 511	FatDs 632
FaDm 131	EgeDs 223	AoeDs 313	EgDm 421	AoeDs 513	FaDm 631
FaeDs 133	EgtDs 222	AoDm 313	EgtDs 422	AotDs 512	FaeDs 633

Dm:.*Detarium microcarpum, eDs*: edible *Detarium senegalense*, tDs: toxic *Detarium senegalense, Fa: Faidherbia albida* , Eg:.*Elaeis guineensis* , Ao: *Anacardium occidentale* .

Figure 2 Experimental split-plot design for seed distribution in substrates

2.4 Data collection

The measurement of the cross-sectional diameter of the seeds was done with the caliper before crushing. Seeds of edible *Detarium senegalense* variety (eDs), toxic *D. senegalense* variety (tDs) and *D. microcarpum* (Dm) were crushed and soaked in water for 48 hours before being sown. A germination test was performed to evaluate germination rate. To facilitate the lifting of their dormancy, *Detarium senegalense* and *Detarium microcarpum* nuts were crushed and the seeds soaked in warm water for 48 hours. For each species, 36 seeds were taken from the stock and put in germination condition in biodegradable bags on a forest soil substrate (*Faidherbia albida*, *Elaeis guineensis* and *Anacardium occidentale*). A total of 108 seeds were used for the germination test. The seeds were sown vertically at a depth of 5 cm depending on the size of the seeds. The monitoring of the germinating seeds was done every day for a period of 40 days counting from the first germinated seed. Seedling emergence was recorded daily over a 40-day period. Counting the number of seeds that emerged and plumule emergence was considered to determine the germination rate. A seed is considered to have germinated when the cotyledons separate to allow the radicle to emerge [8]. The germination rate was calculated per species according to the substrate. The following parameters were calculated from the various data collected:

$$Germination\ rate = \frac{Number\ of\ germinated\ seeds}{Total\ number\ of\ seeds} * 100$$

Growth parameters such as diameter, height and number of leaves of the seedling were evaluated. The height was measured using a ruler graduated in centimeters, the diameter using a caliper graduated in millimeters and number of leaves was counted. These parameters were determined in 20-day intervals. The experiment lasted four months after determining the growth parameters of the plants.

2.5 Data processing and analysis

The collected data were subjected to analysis of variance (ANOVA) and Tukey's tests of comparison with R Studio software. Friedman's paired k-samples test was applied comparing germination rates of different seed types for each substrate. Principal component analysis (PCA) was performed to find out the relationship between different of the parameters such as germination rate, number of leaves, and height and crown diameter with R Studio software. The statistical significance was set at 0.05.

3. Results

3.1 Seed morphology and size

Seed size varied with species (p≤0.0001). Seeds of toxic *D. senegalense* were significantly larger and wider (5.17±0.31 and 4.85±0.51 Cm) than edible *D. senegalense* (4.49±0.50 and 3.81±0.55 Cm) and *D. microcarpum* (3.35±0.55 and 2.94±0.47 Cm). In addition, width and length were proportional with a strong positive correlation (r=0.9) (Figure 3).

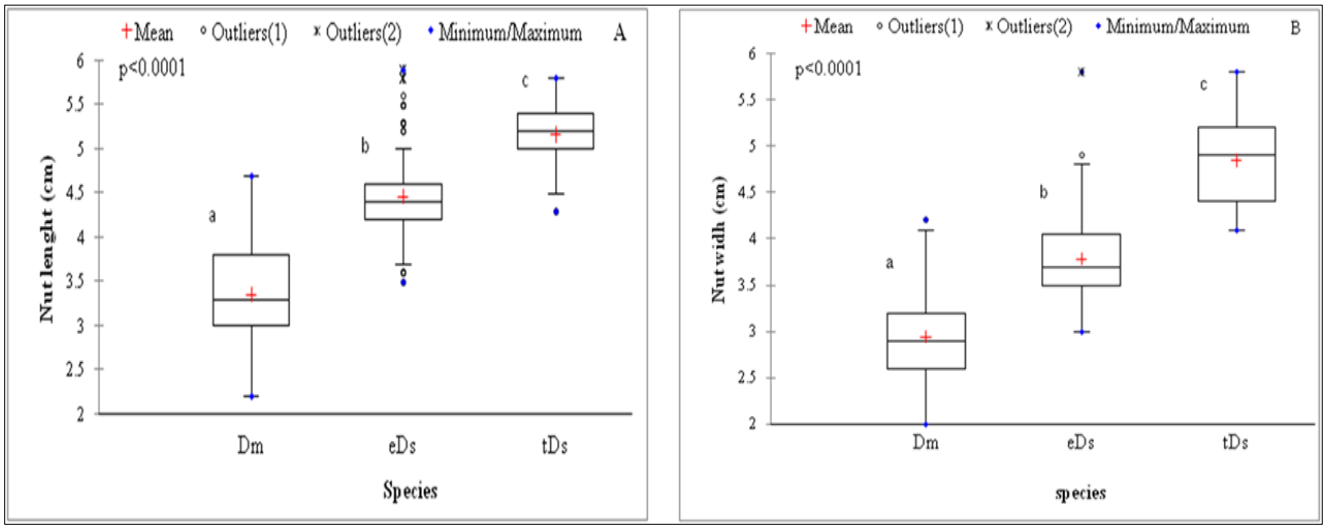

Figure 3 Length (A) and width (B) of *D. Microcarpum* (Dm), *toxic D. senegalense* (tDs) and edible *D. senegalense* (eDs) nuts

Seed size and weight from nut crushing varied by species (p<0.0001). Seeds from toxic *D senegalense* were larger and heavier than those from edible *D senegalense* and *D. microcarpum* (p<0.0001) (Figure 4).

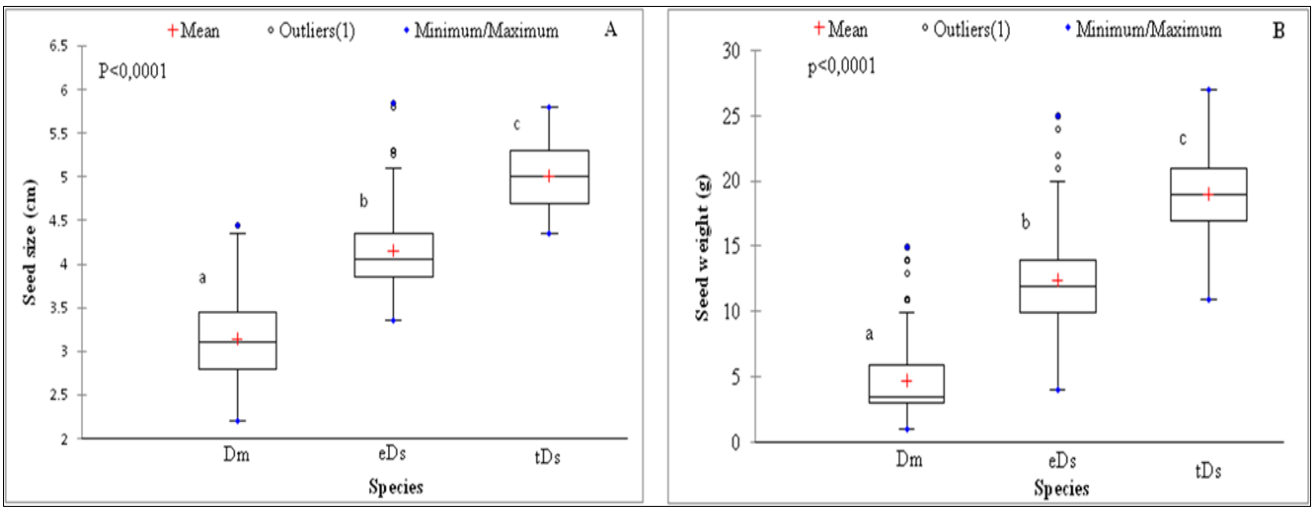

Figure 4 Seed size (A) and weight (B) of *D. microcarpum* (Dm), toxic *D. senegalense* (tDs) and edible *D. senegalense* (eDs)

3.2 Germination

The germination dynamics varied according to the varieties and the substrates. The highest germination rate was recorded with *D. microcarpum* seeds followed by edible *D. senegalense* (p≤0.038) in all substrates (Figure 5).

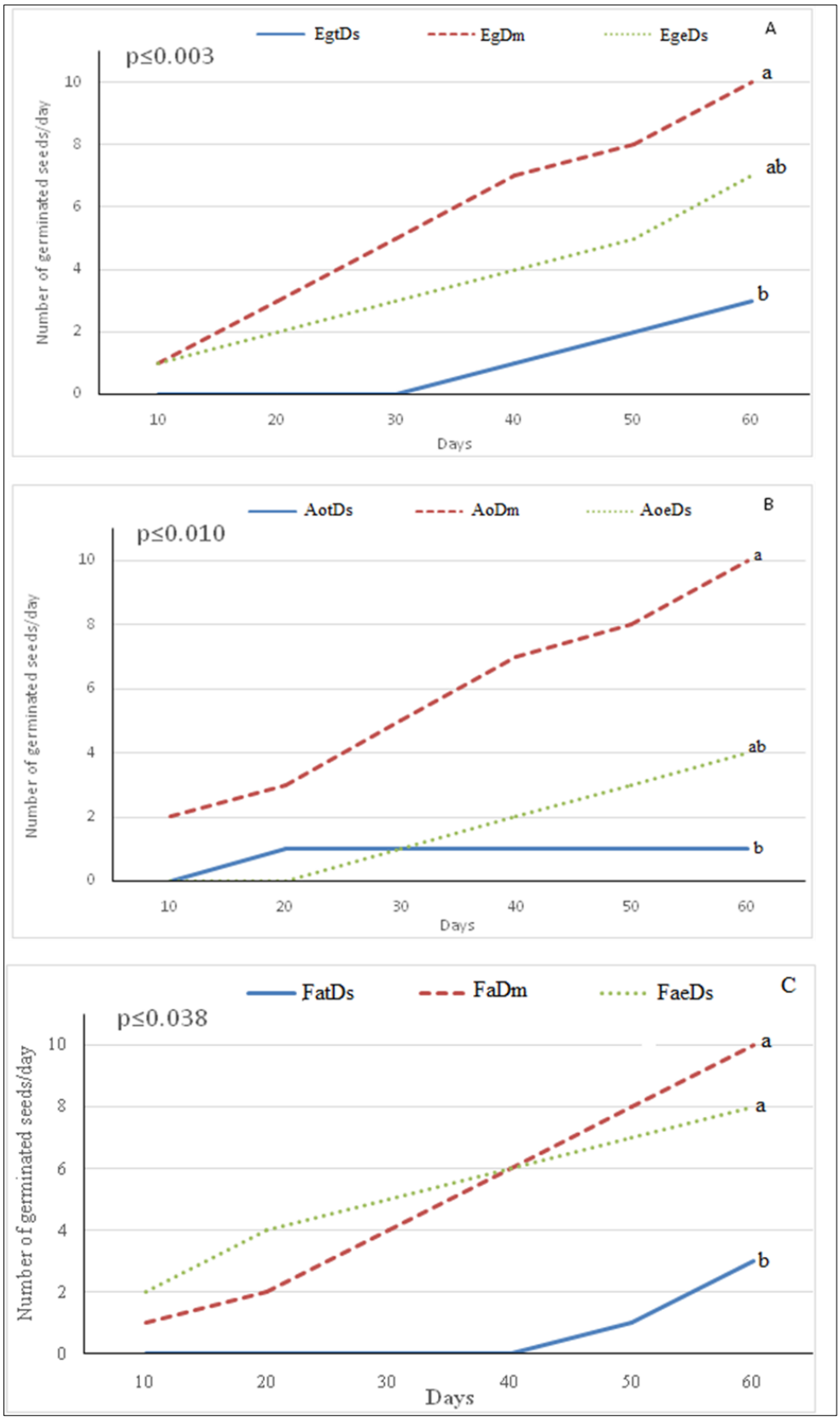

Figure 5 Number of germinated seeds per day in substrates of *Elaeis guineensis* (A), *Anacardium occidentale* (B) and *Faidherbia albida* (C)

Overall, the germination rate was 50.93 ±38.23% (Table 1). Germination rate did not vary according substrate ($p>0.05$). However, the germination rate was significantly different between species ($p<0.0001$). *D. Microcarpum* recorded the

higher germination rate (94.44± 2.32%) followed by edible *D. Senegalense* (41.66± 5.00%) and toxic *D. Senegalense (*05.6± 2.32%). Germination rate varied significantly among treatments (p<0.0001). Indeed, toxic *D. senegalense* revealed the lowest germination rates which were 8.33±20.41%, 16.67±25.82% and 25.00±41.83% on *A. occidentale*, *E. Guineensis* and *F. albida* respectively (Table 1).

Table 1 Effects of substrate, species and treatments on germination rate

Parameters		**Germination rate (%)**	**P value**
Substrates	Fa	41.66±5.02[a]	P>0.05
	Ao	52.77±5.06[a]	
	Eg	47.22±5.06[a]	
Species	tDs	05.6± 2.32[a]	P< 0.0001
	Dm	94.44± 2.32[c]	
	eDs	41.66± 5.00[b]	
Treatments	AoDm	83.33 ±25.82[g]	P< 0.0001
	EgDm	83.33 ±25.82[g]	
	FaDm	83.33 ±25.82[g]	
	FaeDs	66.67 ±25.82[f]	
	EgeDs	58.33 ±20.41[e]	
	AoeDs	33.33 ±25.82[d]	
	FatDs	25.00 ±41.83[c]	
	EgtDs	16.67 ±25.82[b]	
	AotDs	08.33 ±20.41[a]	

Results are expressed as mean ± SD, letters a, b, c, d, e and f are groups (groups with different letters are significantly different).

Growth parameters such as diameter at the base, height and number of leaves of the seedling were studied (Table 2). Variation in substrate type had no significant effect on the height of *Detarium* seedlings. However, the *E. guineensis* substrate induced a higher growth in diameter than the *A. occidentale* and *F. albida* soils. Similarly, the potting soil of *A. occidentale* induced a higher leaf production than the plants grown on substrate of *F. albida*. Concerning the species factor, the plants of the two ecotypes of *D. senegalense* offered higher values of diameter, height and leaf biomass than those obtained with the plants of *D microcarpum* (p<0.0001).Comparison of diameters between treatments revealed lower values for *D. microcarpum* . However, a significant difference was noted for the varieties of Detarium and substrates. The highest diameters were recorded in *E. guineensis* potting soil r for both *D. senegalense*. The *F. albida* potting soil gave the lowest diameters. The height varied according to the treatments. Indeed*, D. Microcarpum* had the lowest height on the three types of substrates. A significant difference was found between edible and toxic *D. Senegalense* on A. occidentale and *E. guineensis* soils (p<0.018). The height of toxic *D. Senegalense* on *F. albida* substrates was approximately equal to *D. microcarpum*. Leaf production of seedlings varied according to the treatment (Figure 6). The number of leaves was influenced by the substrates and the species. The high number of leaves was produced in A. Occidentale (4.52±0.17) followed by E. Guineensis (4.25±0.19) and F. Albida (3.90±0.18).Edible and toxic *D. Senegalense* produced significantly higher number of leaves than *D. microcarpum* (3.45±0.10).Except for the toxic *D. senegalense* on *F. Albida* soil substrate, both edible and toxic *D. senegalense* had an important number of leaves.

Table 2 Growth parameters according to substrates and species

Substrate /Species	Type	Diameter (cm)	Height (cm)	Number of leaves
Substrates	Ao	0.52±0.02[a]	17.20±0.65[a]	4.52±0.17[b]
	Eg	0.60±0.02[b]	17.54±0.71[a]	4.25±0.19[ab]
	Fa	0.51±0.02[a]	15.71±0.71[a]	3.90±0.18[a]
p-value		0.009	0.156	0.041
Species	tDs	0.64±0.04[b]	21.31±0.12[b]	5.41±0.30[b]
	Dm	0.48±0.01[a]	14.07±0.39[a]	3.45±0.10[a]
	eDs	0.66±0.02[b]	22.15±0.60[b]	5.81±0.15[b]
p-value		<0.0001	<0.0001	<0.0001

Results are expressed as mean ± SD, letters a, b, c, d, e and f are groups (groups with different letters are significantly different).

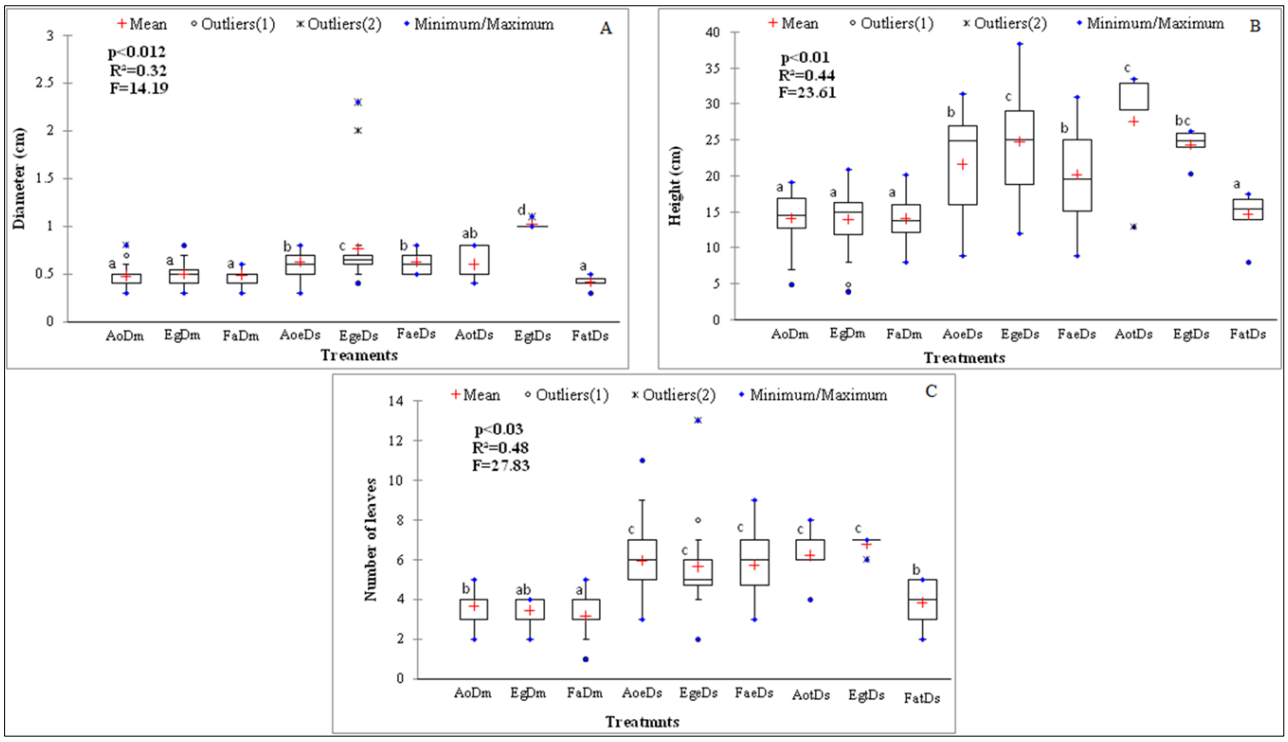

Figure 6 Diameter (A), height (B) and number of leaves (C) by treatment

3.3 Relationship between the germination rate and growth parameters

Bartlett's test applied to the studied parameters (germination rate, height, number of leaves and diameter) attested significant correlations between the variables (p-value< 0.001). The number of leaves was significantly correlated with height (0.88) and diameter (0.87). However, the germination rate was negatively correlated with diameter (-0.42), height (-0.68) and number of leaves (-0.67) (Table 4). The number of leaves (29.98%), height (27.35%) and diameter (24.07%) contributed 81.37% to the formation of the F1 axis while germination rate (66.31%) and diameter (30.46%) contributed 96.78% to the formation of the F2 axis. With the high germination rate of D. *Microcarpum were associated with high germination rate,* low values of diameter, height and number of leaves. In contrast, edible *D. senegalense* were characterized by high diameter, height and number of leaves. The same is true for toxic *D senegalense* planted on *E. guineensis* substrate. Toxic *D. senegalense* were characterized by low germination rate, high height and number of leaves (Figure 7).

Table 3 Correlation between parameters (germination, height, number of leaves and diameter)

Variables	Diameter	Height	Number of leaves	Germination rate
Diameter	1			
Height	0.74	1		
Number o fleaves	0.87	0.88	1	
Germination rate	-0.45	-0.68	-0.65	1

Values in bold are different from 0 with a significance level alpha=0,05

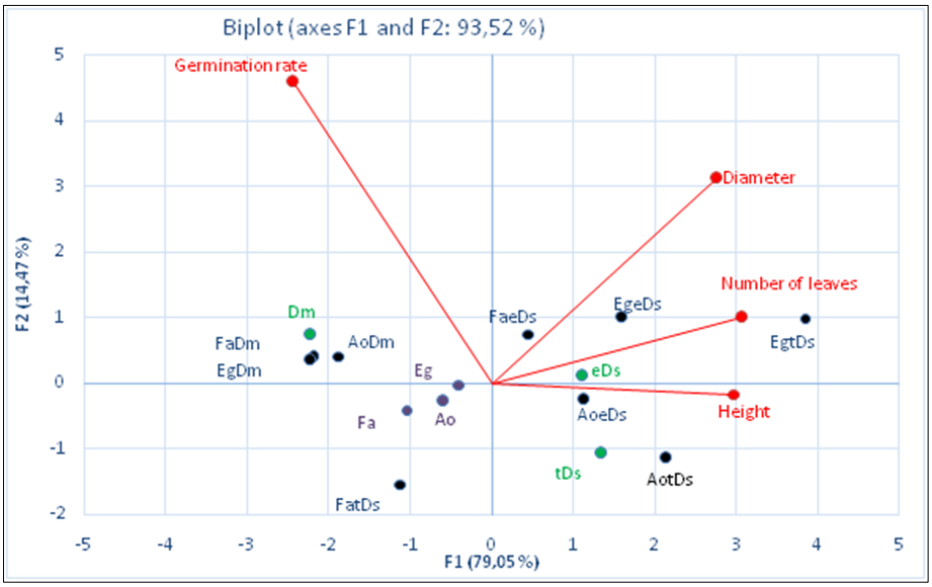

Figure 7 Relationship factors (species and substrate) and vegetation parameters

4. Discussion

This study showed that seeds germinated from 10 to 60 day after sowing. Germination was early with *D. microcarpum* and edible *D. senegalense* but late with toxic *D. senegalense*. However Dossa et al. [3] showed a germination time of 20 days for these *D. senegalense* seeds. Other sources revealed that the germination time of the seeds can range from 42 to 70 days after sowing [9]. The germination rate varied between 5.60% for toxic *D. Senegalense,* 41.66% for edible *D. senegalense* and 94.44% for *D. Microcarpum.* These germination rates for *D. senegalense* remained low compared to the result of Dossa et al. [3] who noted germination rate of 76% for the same species in Benin. This great difference could be linked to the erosion of the germination power of seeds. The low germination rate obtained with toxic *D. senegalense* could be due to the level of substances responsible for its toxicity. Indeed, this variety is not palatable to animals. This behaviour of the animals towards the variety is the only criterion of distinction between these two varieties of *D. senegalense*. And this difference in rate could contribute to differentiate the two varieties of *D. Senegalense*. This germination rate is lower than that of *Diospyros mespiliformis* Hochst ex A. DC with a germination rate of 55.4% [10], *Sclerocarya birrea* (A. Rich.) Hochst with a germination rate of 68.33% [11]. These data seemed close to those of Sangeetha and Mani [12] for whom germination of mango seeds required 6 to 30 days. Furthermore for *Detarium senegalense* the nuts could remain in the substrate at most up to 60 days after sowing before plants appeared. However, there is differential germination rate between the two species of *Detarium* sown. Thus, these results showed that the dormancy of *Detarium* nuts varied from one species to another. Substrates of *A. occidentale, E. guineensis* and *F. albida* did not influence seed germination rate differently but earlier growth parameters such as diameter and leaf production. And according to Normand [13], mango which is a legume like *Detarium* can grow on different types of various substrates. Apart from the fertility provided, these three substrates could be important because of the inocula of microorganisms that could act by stimulating the growth parameters of the plants. Indeed, the *F. albida* potting soil would have less stimulating effect on diameter growth and leaf biomass production than those of *A. occidentale* and *E. guineensis.* Finally, the height of the trees would depend not only on the fertility and therefore the quality of the substrate

but also on the rainfall of the station. And *Detarium* is a legume like mango whose development depends on exogenous factors and climate [14]. Whiley [15] argued that the number of leaves is temperature dependent during the initiation phase and increases with temperature. Diameter growth varied with treatment. Thus, *Detarium senegalense* showed a significant difference in high diameter on *Elaeis guineensis* substrate than on *Faidherbia albida* and *Anacardium occidentale* substrates. The growth of toxic *D. senegalense* was better on *E. guineensis* substrate while *D. microcarpum* grew at the same rate on all three substrates. The inedible or toxic variety Cavin et al. [16] is reported to contain a glycosidic cyanogen derivative, 6'-O-galloyl-(R)-epiheterodendrin, one of the, compound(s) responsible for toxicity. The leaves of this toxic variety are differentiated by soft leaflets, bright green above and green below, and by a slightly more fibrous pulp as described by Cavin et al. [16]. Could the low germination rate of this toxic D. senegalense be related to its toxicity? The results showed negative correlations between germination rate and growth parameters (diameter, number of leaves and height). This relationship of proportionality between number of leaves, diameter and height was reported by Touckia [17] with *Jatropha curcas* L. Dossa et al. [3] in Benin also reported significant correlations between germination rate and height of seedlings in the nursery for *D. senegalense*.

5. Conclusion

This study on the germination and growth of two *Detarium* species such as *Detarium microcarpum* and edible and toxic *Detarium senegalense* in three substrates showed differences in seed size, germination rate and growth parameters at nursery. Quantitative measurements on germination rate, number of leaves, diameter and height attested that edible *Detarium senegalense* performed better than toxic *Detarium senegalensis* and *Detarium microcarpum*. The substrate influenced the vegetation parameters. *E. Guineensis* and *A. Occidentale* substrates increased more the growth parameters than *F. Albida*. These results were also important for the easy identification of toxic and edible *D. Senegalense.* The tests were also intended to improve the reproduction of Detarium species and varieties. The seedlings of *D. microcarpum* and edible and toxic *D. Senegalense could* therefore be produced in nurseries and used in planting and reforestation programs in degraded areas.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declared no conflict of interest.

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