Trial on the production and use of compost made from pterygota bequaertii crushed material and Terminalia Ivorensis A Chev crushed material for the production of *Gmelina arborea* seedlings : results in the nursery and after transplanting (Daloa, central western Côte d'Ivoire).

ABSTRACT *(The abstract needs to be compressed or made more concise and descriptive)*

The over-exploitation of natural resources in the semi-deciduous forests of the Côte d'Ivoire forest zone has led to the degradation of the vegetation cover. This has reduced the ecological continuity of the semi-deciduous forest biomes in the forest zone. To restore these ecosystems, plantations of agroforestry species are recommended. However, nursery production of these types of trees using seed or vegetative propagation techniques faces a number of problems, such as the use of substrates with unfavourable physico-chemical properties and often contaminated with pathogens. This article presents the results of a trial conducted at the UJLOG experimental plot in Daloa to produce and evaluate the agronomic characteristics of compost made from Pterygota bequaertii and Terminalia Ivorensis A Chev for the production of Gmelina arborea seedlings. To this end, after the compost was made, four compost-based substrates and a forest humus-based control were prepared, characterised from a physical and chemical point of view and tested in the nursery. Seedling growth and root regeneration capacity measured in the nursery, as well as recovery after planting, were the parameters used to judge the quality of the seedlings and the effect of the compost. The results show that pterygota bequaertii and Terminalia Ivorensis A Chev have good composting properties, and their compost can be easily produced with or without a stimulator. The behaviour of the plants in the five substrates also showed that significant qualitative improvements were recorded in the plants reared in the compost-based substrates compared with the control plants. The results obtained show that the constituent elements of the substrates (droppings, bursa, carbonised sawdust) combined with pterygota bequaertii grindings and Terminalia Ivorensis A Chev grindings, depending on how they are prepared, have a significant effect on the physico-chemical parameters recorded (pH, total porosity, aeration and retention porosity, electrical conductivity, nitrogen, phosphorus, etc.); electrical conductivity, nitrogen, phosphorus and potassium), and consequently, on germination (germination percentage) and vegetative behaviour (height, diameter, number of leaves and robustness ratio), as well as a better root regeneration capacity and a better recovery of the Gmelina arborea plants in the field compared with the control plants (forest compost). It is therefore possible to improve the quality of Gmelina arborea seedlings by using pterygota bequaertii compost and Terminalia Ivorensis A Chev as a growing medium instead of forest compost.

Keywords : composting, substrate, *Gmelina arborea*, nursery, germination and vegetative behavior (Please capitalize each starting letter of keywords)

1. INTRODUCTION

The African continent recorded the highest forest loss between 2000 and 2010, with around 3.4 million hectares lost annually [1]. This loss of forest cover is mainly due to the expansion of agriculture and rangelands, and excessive harvesting for fuelwood and charcoal. This situation is reflected in the fragmentation of natural formations [2] The fragmentation of natural forests and the scarcity and disappearance of valuable tree species have led to a reduction in the ecological continuity of the major biomes of the semi-deciduous forests of the forest zone. Côte d'Ivoire's forest area, for example, which stood at 16 million hectares in 1960, is now estimated at around 2.5 million hectares [3]. Over-exploitation of the forest for timber and energy and bush fires are the causes of this loss [4].

Against this backdrop of degradation, meeting people's needs for wood-based forest products requires the restoration of degraded forests [5] and the establishment of artificial plantations [6]. To achieve this, modern forest nurseries need to be created as part of a sustainable development approach that respects the environment. Thus, the notion of competitive agriculture to meet the growing needs of the world's population and respect the environment remains a necessity, in order to meet the challenges. With this in mind, recent research has focused on adapting new techniques and processes. These include composting, which enables the biological decomposition and stabilisation of organic substrates ([7] ; [8]), making it a more environmentally-friendly method of managing organic waste while promoting ecological farming practices, and above all an important aspect of fertilisation in sustainable agriculture.

However, the use of compost remains lower in Côte d'Ivoire, particularly in modern forest nurseries. Potting soils are still the most commonly used substrate for producing seedlings, especially non-standardised soils, which have poor physical and chemical characteristics that are unfavourable to plant growth and encourage the multiplication of pathogens, with repercussions for young seedlings as soon as they are planted. Hence the failure of the reforestation operations that have been going on for years in Côte d'Ivoire.

In this context, the development of growth substrates by composting available and reproducible organic matter is proving to be an alternative for solving the crucial problem of soil fertility and optimising forest plant production. What's more, organic farming is recognised by society as an environmentally-friendly production method.

So, instead of incinerating plant biomass from various forestry operations, tree pruning in towns and stubble, it can be recovered, composted and used to make growing substrates for raising seedlings of various species in nurseries. Composting fresh plant biomass is an essential step in stabilising organic materials [9]. The results obtained in nurseries that have used substrates based on compost of forestry and agricultural waste to raise seedlings of various species have been very satisfactory ([10]; [11]; [12]). However, before compost can be used more widely, a number of concerns need to be addressed regarding the availability and accessibility of the material in question, production costs, agronomic characteristics, behaviour in cultivation and the existence of economic and ecological prejudices associated with its large-scale use.

Among the species that could offer a renewable source of green matter for composting, *Pterygota bequaertii* and *Terminalia Ivorensis* A Chev. Offer real potential, in particular because of their rapid growth, which allows them to be used in short rotation, and their availability in relation to the areas planted throughout the country in recent years.

Consequently, it seems necessary to undertake studies aimed at proposing to companies involved in forestry, in particular SODEFOR in Côte D'Ivoire, and to private forest plant producers, suitable substrates to be used in order to obtain optimal and less costly productions.

This article presents the results of a study carried out at the experimental plot of the Jean Lorougnon Guédé University in Daloa to assess the possibilities of introducing compost into the forest seedling production process by producing a compost of Pterygota bequaertii and Terminalia Ivorensis A Chev, characterising it and assessing its effect on the quality of Gmelina arborea seedlings in the nursery and after transplanting to the experimental plot.

1. MATERIAL AND METHODS

1.1. Study site

The experimental site at the Université Jean Lorougnon Guédé, in the town of Daloa, was used to conduct the experiments.

Daloa is a town in west-central Côte d'Ivoire, in West Africa. The capital of the Haut-Sassandra region, Daloa is located 383 km from Abidjan (the economic capital). In 2012, it had an estimated population of 2,681,789. It is also the 3rd most populous city, after Abidjan and Bouaké [13]. The climate is that of the Guinean domain, characterised by an equatorial and sub-equatorial regime with two rainfall maxima. June represents the peak of the long rainy season and September the peak of the short rainy season. These two maxima are separated by one or two months of varying rainfall [14]. The geological formations are Middle Precambrian, dominated mainly by granites, with a few intrusions of schist and flysch. According to studies carried out by Dabin *et al*. [15], the soils in the Daloa department are ferralitic and moderately leached (or desaturated). The soil characteristics include a less acidic pH (5.3 to 6.5), a higher content of exchangeable bases (5 to 8 cmol.kg-1) and a much higher saturation rate (40 to 50%). As a result, the organic matter develops better and stabilises in a humus-bearing horizon, with the C/N ratio generally around 9 to 12 [16].

Plant material

The plant material used in this study consisted of *Gmelina arborea* seeds harvested in the Bouafle-Torss classified forest.

Biological materials

The biological material consists of the composting material, i.e. :

- Main composting material

The main material was sawdust made up of crushed pterygota bequaertii and crushed Terminalia Ivorensis. The sawdust came from a sawmill in the Kennedy1 district of the town of Daloa, where mounds of sawdust in cups were found, the sole purpose of which was to produce charcoal. Depending on the type of compost were used. These were banana leaves (*Musa Paradisiaca L.*) and shavings of the same wood collected from a carpenter's shop in the town.

- Compost activators and compost improvers

Depending on the compost heap, one of the activators "A bio-activator obtained using EM (effective micro-organism) technology" or cow's purse were used as inoculum for composting substrates. In order to improve the agronomic value of the final composts, rice bran, chicken droppings, coffee husks and cocoa husks were used in certain piles. The droppings were collected from a poultry farm in the town of Daloa, which has hundreds of them. The cocoa shells came from a plantation on the outskirts of the town. The coffee hulls come from a storage area that dates back several years to the abattoir district in the town of Daloa.

1.2. Methodology

Composting

-Shredding of composted biomass

The aim of this phase was to produce compost for nursery trials. Crushed pterygota bequaertii and Terminalia Ivorensis A. Chev is the plant material used to produce the compost. Our various shreds are derived from the serial wake of these two species.

-Windrowing and composting process

The shredded material was immediately placed in windrows measuring 1.50 m x 1.50 m x 1.30 m on a platform covered with a slightly sloping tarpaulin to facilitate drainage of the compost leachate. To stimulate the composting process, activators were added when the shredded material was swathed. The shreds were deposited in layers of fresh material, to which certain organic materials were added as a source of nitrogen, phosphorus and potassium.

A total of 4 windrows were created :

Table 1 : Components of composts and the control

Types of substrat	Component parts (%)									
	Sb	**Sbc**	**Fp**	**Bv**	**Sr**	**Cca**	**Ccaf**	**Fb**	**Fm**	**Tf**
S0										100
SA	50		20		20				10	
SB	60	25					10	5		
SC	40	20	10	20		10				
SD	50		20	30						

S: substrate; Sb: sawdust; Sbc: calcined sawdust; Fp: chicken droppings; Bv: cow dung; Sr: rice bran; Cca: cocoa hull; Ccaf: coffee hull; Fb: dried banana leaf; Fm: moringa leaf; Tf: forest soil. S0 : control.

Setting up a nursery

Construction of the shade house

An 80 m2 (10 m long by 8 m wide) shade structure was built to house the plants. Like the shades usually recommended, it is 2 m high and has a slight slope with two sides to allow rainwater to drain off easily. It was then covered with palms (the leaves of the palm tree) to reflect most of the sunlight. During the early stages of their development, young plants need relatively dense shade to grow optimally, leaving only 25 to 50% of the total light, in order to reflect as closely as possible the sunlight conditions in the undergrowth [17]. Palms were also placed around the shaded area to protect the young plants from domestic animals and improve shading within the shaded area.

Experimental set-up

The trial was conducted using a randomised complete block design with three replicates and one factor level. It consisted of 15 elementary plots (1 species x 5 substrate levels x 3 blocks), each 1 m long and 0.5 m wide. Each elementary plot contained 30 nursery phytocells, for a total of 450 phytocells for the whole trial. The blocks were separated by 1 m, and each block contained 150 phytocells, with 30 phytocells per elementary plot. The individual plots in each block were separated by a tray.

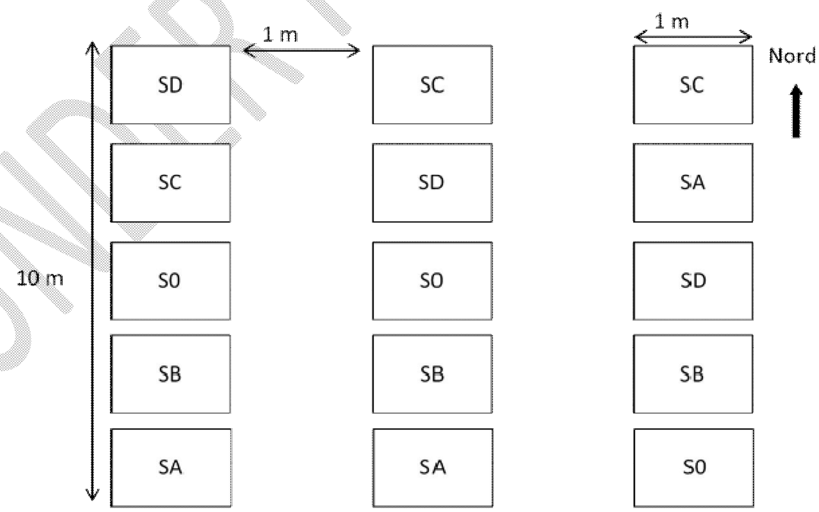

***Figure 1** : Experimental design*

Sowing

Direct sowing of seeds at a rate of 2 seeds per phytocell was carried out early in the morning before sunrise in order to conserve moisture inside the phytocells. We sowed 300 seeds for this purpose. The seeds were watered the day before and after sowing to ensure that they germinated properly. In order to make it easier for the seedlings to emerge from the soil, an opening of 2 to 3 cm was made in the phytocels before placing the seeds in the epicotylated position (a sowing method that consists of placing the seed in the soil with the cotyledonary part pointing upwards).

Measurements and observations

In order to assess the performance of the substrates developed, measurements of germination rate, germination dynamics, height H (cm), crown diameter D (mm), leaf area and biomass (g) were carried out on a 25% sample of plants from each substrate during and at the end of the rearing cycle. The plants measured were randomly selected and labelled to facilitate monitoring. The robustness ratio of height to diameter (H/D) (cm.mm-1) was then calculated. To determine the dry biomass, the stems and roots of the sampled plants were placed in an oven maintained at 80°C for 24 hours, then weighed.

Study of root regeneration capacity and recovery after transplanting

In order to evaluate the performance of the bred plants in the five substrates tested, 10 plants from each substrate were randomly selected and transplanted with their root ball into larger containers (polyethylene bags with a volume of 4000 cm3) potted with soil. After two months of transplanting, the roots of all the plants were carefully removed from the sand and gently washed so as not to damage their roots, particularly the newly formed ones. Root regeneration capacity was assessed by measuring the number, length and biomass of new roots formed outside the initial root ball.

In order to confirm the results obtained in the nursery, a confirmation trial was carried out in an experimental plot located close to the breeding nursery. To this end, nine one-year-old plants were randomly selected from each substrate and transplanted with their root ball into planting holes measuring 50 cm x 50 cm x 50 cm by edge, opened with a pickaxe. Planting was carried out in a randomised complete block design with three replications, involving a total of 45 plants. Apart from two waterings during the summer, the plants were not fertilized and received no other maintenance.

The recovery of plants from each substrate was determined after six months of transplanting by deducting the number of dead plants from the total number of plants planted. The recovery rates obtained were used for correlation tests with the collar diameters and H/D ratios of the plants at planting, on the one hand, and with the root regeneration capacity measured in the nursery, on the other.

1.3. Statistical analysis of data The data

collected was subjected to statistical tests using Statistica 7.1 software. An analysis of variance made it possible to assess the effects of amendments on *Aloe vera* sucker growth. The hypothesis of equality of averages was assessed at α risk = 5%. If this last hypothesis was rejected, the Newman-Keuls multiple comparison test (at α risk threshold = 5%) made it possible to classify the averages into homogeneous groups.

3. RESULTS

3.1. Assessment of the physical and chemical parameters of the substrates

3.1.1. Physical characteristics of the growth substrates

The figure illustrates the evolution of the total, aeration and retention porosities of the five growth substrates studied. The five substrates tested all met the rules for assessing total and aeration porosities ; however, substrate S0 did not meet the requirements for retention porosity (minimum 30%). In terms of total porosity, the substrates (S0, SC) and (SA, SB, SD) did not differ significantly from each other. With regard to retention porosity, the SA and SC substrates did not differ significantly from each other. Finally, with regard to aeration porosity, the substrates (SA, SC) and (SD, S0) did not differ significantly.(Adjust the indications in Figure 2 as it is overlaping with the graph.)

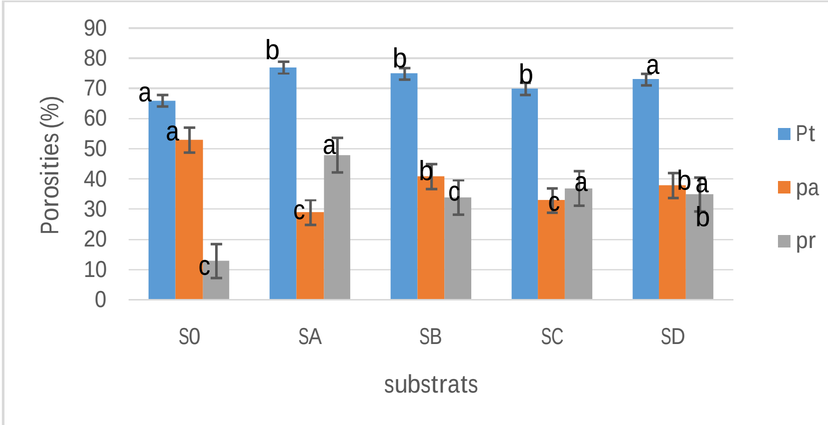

***Figure 2** : Total (Pt), aeration (Pa) and retention (Pr) porosities of the growth substrates tested.*

Means followed by the same letter do not differ significantly according to Duncan's test at the 5% threshold for the same porosity parameter. Means for each parameter (same-coloured vertical bars) followed by different letters indicate the presence of significant differences between substrates at the 5% threshold according to Duncan's test.

3.1.2. Chemical characteristics of growth substrates

3.1.2.1. Organic element and phosphorus content.

The levels of organic matter and phosphorus measured are shown in Table II. The contents of carbon, organic matter, nitrogen and the C/N ratio varied significantly ($p < 0.05$) between the different substrates. The organic substrates SA, SB, SC and SD induced higher contents compared with the control substrate (S0). Cot (50.2±0.16%), Mo (90.3±0.65%) and N (5.76±0.04%) contents were higher in the SC substrate than in the other substrates. The C/N ratio varied between 8 and 19. The mineral substrate (S0) had the highest ratio (19.8±0.19). On the other hand, the phosphorus content of the SD organic substrate (76.67±0.33 mg.kg-1) appeared to be higher. The phosphorus content of the control substrate (74.23±0.25 mg.kg-1) was also higher than that of the organic substrates SA (64.47±0.02) and SB (74.01±0.19).

Table 2 *:* Organic matter and phosphorus content of composts

Types of substrate	Compositions of organic elements in composts				Phosphore
	Cot (%)	M.Org (%)	N (%)	C/N	P (mg/kg)
S0	22,9±0,20d	41,3±0,31d	1,16±0,05d	19,8±0,19a	74,23±0,25c
SA	45,6±0,26c	82,1±0,90c	3,4±0,30c	13,4±0,22b	64,47±0,02d
SB	46,6±0,31b	83,8±0,50b	4,1±0,12b	11,4±0,09c	74,01±0,19c
SC	50,2±0,16a	90,3±0,65a	5,76±0,04a	8,7±0,34c	75,53±0,46b
SD	47,3±0,33b	85,2±0,23b	4,32±0,30b	11,0±0,76d	76,67±0,33a
Test T, P	0,000***	0,000***	0,000***	0,000***	0,000***

*The means of each parameter (vertical bars of the same colour) followed by different letters indicate the presence of significant differences between substrates at the 5% threshold according to Duncan's test. S0 *: forest loam, SA: formulation 1, SB: formulation 2, SC: formulation3, SD: formulation 4.*

3.1.2.2. Element content of the absorbent complex

The absorbent complex element contents measured are shown in Table III. It can be seen that Ca^{2+} (2.36 mg.kg-1), Mg^{2+} (19.66 mg.Kg-1), Na^{+} (0.69 mg.kg-1) and CEC (41±0.02a cmol.kg-1) contents are higher in SC substrates. The Ca^{2+}, Mg^{2+}, Na^{+} and CEC contents varied significantly ($p < 0.05$) between the different substrates. The organic substrates SA, SB, SC and SD induced higher contents compared with the mineral substrate (S0).

Table 3 : Absorbent complex element content of composts

Types of substrats	absorbent complex				
	K^{+}	Ca^{2+}	Mg^{2+}	Na^{+}	CEC
S0	2,56±0,10c	20,43±0,12c	18,60±0,20b	0,58±0,03e	24±0,17c
SA	2,79±0,05b	20,79±0,02b	17,67±0,03c	0,61±0,02d	36±0,05ab
SB	2,9±0,06ab	20,87±0,17b	19,89±0,16a	0,63±0,02c	25±0,09c
SC	2,94±0,05a	21,36±0,02a	19,68±0,19a	0,69±0,02a	41±0,02a
SD	2,84±0,02ab	20,69±0,03bc	18,46±0,05b	0,66±0,01b	37±0,05b
Test T, P	0,000***	0,000***	0,000***	0,000***	0,000***

*The means of each parameter (vertical bars of the same colour) followed by different letters indicate the presence of significant differences between substrates at the 5% threshold according to Duncan's test. S0 *: forest loam, SA: formulation 1, SB: formulation 2, SC: formulation3, SD: formulation 4.*

3.2. Growth of *Gmelina arborea* plants

3.2.1. Height of *Gmelina arborea* plants

The growth in height of *Gmelina arborea* plants during their development cycle in the nursery is shown in figure 40A from the fourth week after sowing to the tenth week after sowing. It varied from 10.67 to 90.00 cm on average. Growth curves differed between substrates. The SA, SB, SC and SD substrates induced greater growth than the S0 control at all measurement times. Maximum growth in height was recorded in plants on the SC substrate (H=90.00 cm) where cow dung, chicken droppings, cocoa pods and carbonised sawdust were added to the sawdust (pterygota bequaertii grindings and Terminalia Ivorensis grindings). Individuals from substrate S0 (forest loam) recorded the lowest values (H=58.50 cm) at the last data collection.

Figure 3B shows the average daily increases in height per substrate. A rapid deceleration phase was observed in plants on substrates S0 (from 1.77 to 0.7 6 cm/d), SA (2.29 1.38 cm/d), SB (from 1.91 to 0.94 cm/d), SC (from 1.90 to 1.69 cm/d) and SD (1.98 to 1.57 cm) between days 28 and 35. This was followed by a clear growth phase for plants on the S0 and SC substrates and a rapid growth phase for plants on the SD substrates, with average daily gains greater than those for plants on the SA substrates (1.33 mm/d) on day 42. Then, on day 49, there was a rapid deceleration phase in SB and SC substrate plants and a slight deceleration in S0 control substrate plants. From day 49 to day 56, with the exception of the SA substrate plants, there was a rapid increase in the plants of the other substrates. A reversal of the trend was observed on day 56.

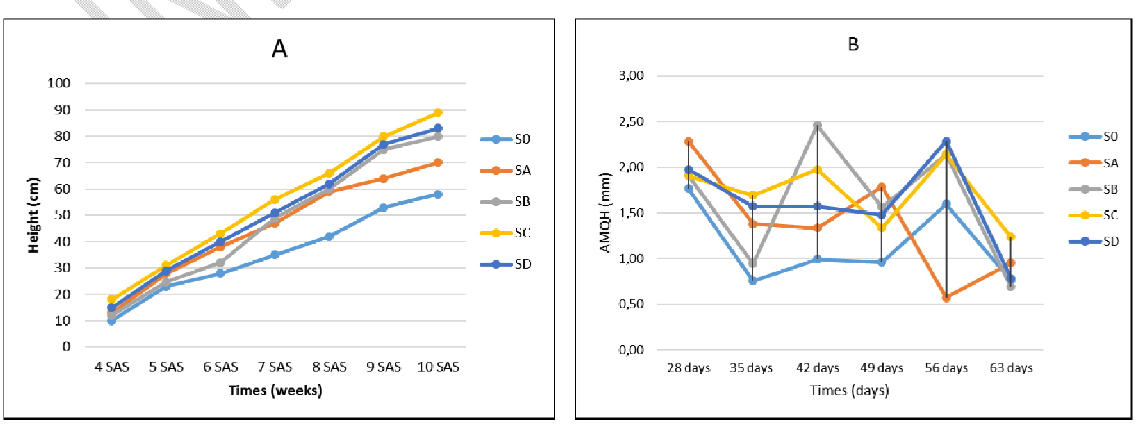

Figure 3 : Height growth of *Gmelina arborea* plants (A) ; Average daily growth of plants per substrate (B)

3.2.2. *Growth in diameter*

The Figure 4 shows that the growth in thickness of the *Gmelina* stem evolved continuously from the 4th week to the 10th week after sowing. It varied from 2.96 to 15.05 mm. Thickness growth curves differed between substrates. The SA, SB, SC and SD substrates induced greater growth than the control (S0). At the last measurement, maximum growth in thickness was recorded in plants on the SC substrate (D=15.05 mm) where a combination of cow dung, chicken droppings, cocoa pods and sawdust carbonised with sawdust (pterygota bequaertii grindings and Terminalia Ivorensis grindings) was used. At this date, the individuals in substrate S0 (D=9.00 mm), which is forest loam, recorded the lowest thickness values. The SB and SD substrates showed the same thickness at the 10th SAS (D= 13.62 mm).

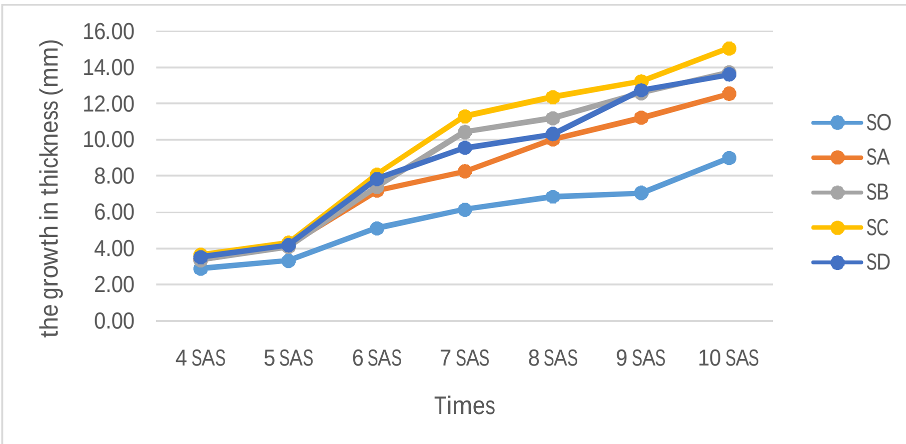

Figure 4 : the growth in thickness of the stems of *Gmelina arborea*

3.2.3. <u>Plant robustness ratio</u>

The results relating to this parameter are shown in Figure 5. The robustness ratio of Gmelina arborea seedlings produced on each cultivation substrate studied during the growth surveys carried out. At the first measurement, i.e. 5 weeks after sowing, all the substrates showed a robustness ratio of robustness index of less than 7, except for substrate S0. However, at the first measurement, only the SA substrate had a robustness index of less than 7.

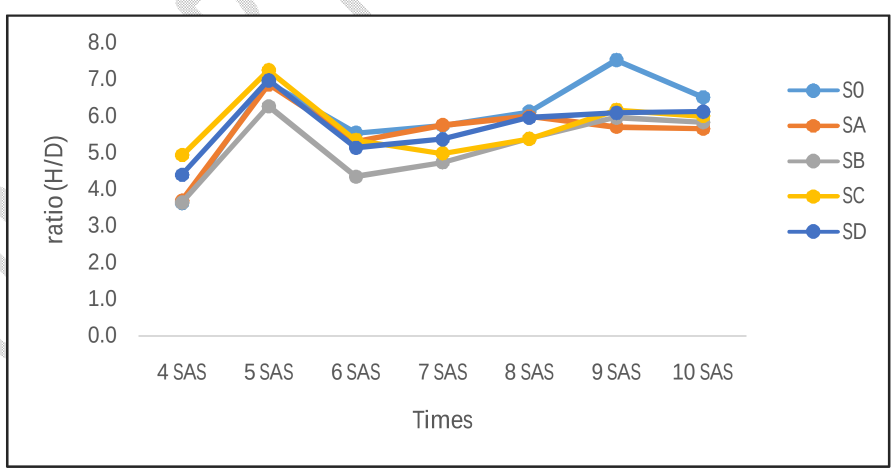

Figure 5 *:* Robustness ratio of *Gmelina arbore* plants

3.2.4. <u>Stem biomass/root biomass ratio</u>

The figure 6 shows that the MFA/MFR ratio varies between the different substrates, with the highest value recorded for the SB treatment (1.56). The lowest value was recorded for the S0 substrate (0.82). For the other substrates, the values of this parameter lie within this range with a ratio of far from the equilibrium that was established between the two systems for the SA substrate (1.20). Finally, the SC and SD substrates appear to generate equal ratios. This finding was confirmed by the statistical test, which proved to be highly significant.

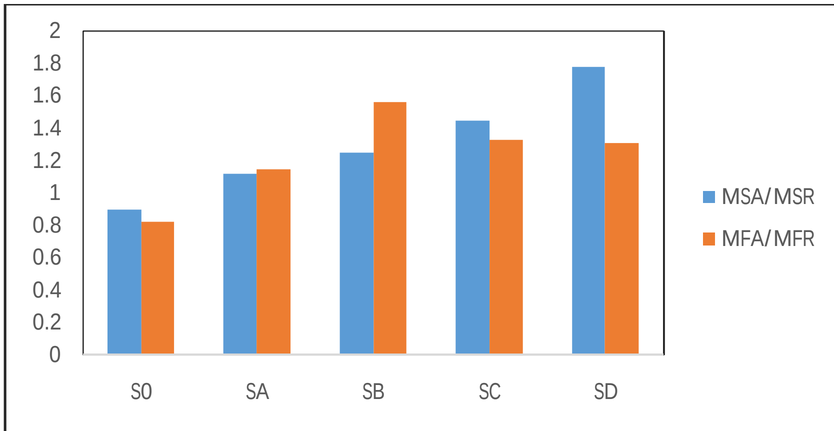

Figure 6 : stem/root biomass ratio

3.3. Study of root regeneration capacity and recovery after transplanting

3.3.1. Root regeneration capacity

Table 4 shows the results obtained concerning the emission of new roots in *Gmelina arborea* plants from the five substrates after transplanting into local soil. Evaluation of the root regeneration capacity showed that all the plants emitted new roots outside the initial root ball (Figure). The number of new roots emitted varied between 22 and 38 (Table 3). Among the five substrates, the highest number of new roots emitted was recorded in the SC substrates (sawdust + cow dung + chicken dung + cocoa pod), i.e. 38.67±1.53. The best elongations were obtained in the plants on the organic substrates compared with the forest loam control, with averages ranging from 32.33 to 82.33 cm compared with 28.33 cm in the control plants. The new root dry matter produced was 3.03 to 5.17 g for plants raised in organic substrates, compared with 1.35 g for control plants. Statistical analysis of the data (ANOVA) revealed a highly significant difference between the substrates in terms of both the number of new roots produced and root elongation. The same was true for total root biomass (P-value < 0.05). Plants grown on the SC substrate performed better in assessing the root regeneration capacity of *Gmelina arborea* plants.

Table 4 *:* Root regeneration capacity of *Gmelina arborea* plants in relation to substrates

Substrats	▪ **Root regeneration capacity**		
	New root number	Mean length (cm)	Total biomass (g)
S0	22,00±1,00d	28,33±1,53e	1,35±0,03d
SA	31,00±1,73c	32,33±2,52d	3,03±0,16c
SB	33,67±1,15b	39,00±1,00c	3,11±0,17c
SC	38,67±1,53a	82,33±2,52a	5,17±0,35a
SD	34,33±1,15b	54,67±2,52b	3,53±0,25b
P value	0,000***	0,000***	0,000***

*The means of each parameter (vertical bars of the same colour) followed by different letters indicate the presence of significant differences between substrates at the 5% threshold according to Duncan's test. S0 *: forest loam, SA: formulation 1, SB: formulation 2, SC: formulation3, SD: formulation 4.*

3.3.2. Recovery rates of plants from the five substrates after six months of transplanting.

The results concerning the recovery rates of *Gmelina arborea* plants subsequently measured after six months of transplanting in the field varied according to the substrates (Figure). With recovery rates ranging from 52% to 85%, the recovery of plants on compost-based substrates was much higher than that of plants on the control substrate (S0) without compost (forest loam), which had a recovery rate of 52%. The substrate (SC) was favourable to seedling recovery, with a rate of 85%, followed by the SD substrate (81%). The substrate (S0) was detrimental to recovery, with a mortality rate of 48%. The SA and SD substrates, on the other hand, had recovery rates of 66% and 76% respectively.

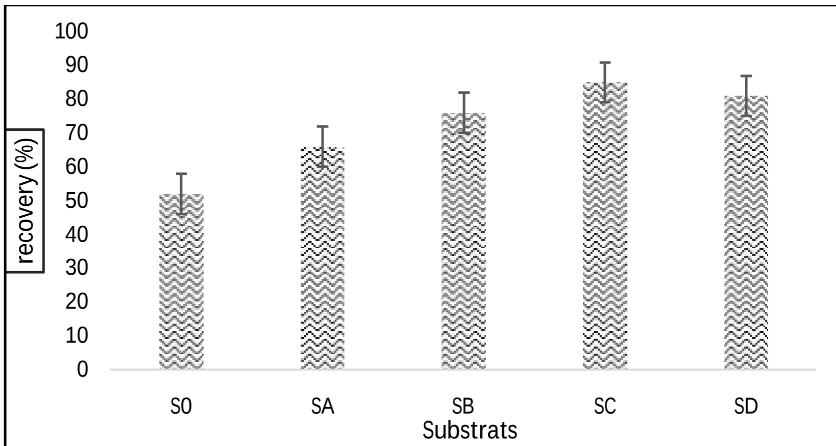

Figure 7 *: Recovery rate of Gmelina arborea plants from five substrates after six months of transplanting*

4. DISCUSSION

In the first phase of the project, composts were produced from crushed *Pterygota bequaertii* and crushed *Terminalia Ivorensis*, with inputs including cow's purse, poultry droppings, cocoa husks, coffee husks and carbonised sawdust.

The four substrates produced by composting were then used to rear *Gmelina arborea* seedlings above ground. The results of the physical and chemical characterisation of the five substrates tested were, on the whole, in favour of the substrates containing compost compared with the control without compost (local soil). The pH of the various composts shifted slightly towards alkalinity, ranging from 7.33 for SD compost, 7.38 for SC compost and 7.58 for SA and SB composts. This trend towards alkalinity in composts is due to the production of CO2 and organic acids by microbial metabolism during the decomposition process by microorganisms [18]. The pH defines the state of the absorbent complex. Indeed, these alkaline pHs offer favourable conditions for improving biological properties and the availability of soil cations [19]. The chemical characteristics of the 4 composts and the forestry topsoil (S0 control) showed that agricultural and forestry residues are rich in certain primary mineral elements such as potassium and phosphorus. All the composts had higher levels of fertilising elements than the forestry topsoil. Furthermore, the SC compost (sawdust+ cow dung+ ; chicken dung+ cocoa pod+ carbonised sawdust) had the highest levels of fertilising elements (N, P, K, Ca, Mg). This could be explained by the combined contribution of chicken droppings and cow purse. In fact, chicken droppings are the most nitrogen-rich of all livestock effluents. Measurements showed an average nitrogen content of 5.76% with a C/N ratio of 8.7. The high levels of potassium (K) in SB, SC and SD compost could also be explained by the wood ash (carbonised sawdust) inputs. The ashes of Wood is both a basic residue against soil acidity and a source of essential minerals such as Ca, P, K and Mg ([20] ; [21]).

From the point of view of total porosity, the SA and SB substrates presented the highest values, i.e. 77% and 75% respectively. With regard to retention porosity, the SA (48%) and SC (37%) substrates showed the highest values. Finally, with regard to aeration porosity, the SD (38%) and S0 (53%) substrates showed the highest values. Furthermore, according to [22], (2017) the normal values of porosities in a compost are Pt ≥ 50%, Pa ≥ 20% and Pr ≥ 30%. Thus relatively to our results It is possible to conclude that SA, SC and SD substrates have the best porosities compared to the other substrates by combining the three porosities studied. This could be explained in part by the composition of the SC and SD composts. These substrates contain cow dung compared with the other composts and the S0 control. This enabled more efficient retention of water and nutrients, thus minimising substrate leaching and providing better conditions for off-soil plant growth [23]. Regarding the aggregate composition of the different types of compost, small-sized particles (< 2 mm) make up the largest proportion regardless of the type of compost. The 4 types of compost all have a high proportion of small, fairly homogeneous particles. The high proportion of fine elements in SA compost (80%) is explained by the presence of rice bran. From the point of view of root ball consistency, the sawdust-based substrates provided better root ball cohesion than the control substrate. The bulk densities of the compost-based substrates were logically lower than those of the control substrate (forest compost). The control substrate was the densest (0.46 g/cm3). From a practical point of view, the low density of the compost-based substrates, and consequently their lightness, makes it easier to handle the boxes in the nursery and when travelling to the reforestation site, compared with the heavier control substrate. A plastic crate containing 20 polyethylene bags filled with compost weighs less than 10 kg, whereas it weighed 16 kg with the control substrate (forest compost). In terms of growth, the SA, SC and SD organic substrates showed good plant development compared with the S0 control substrate. The SC substrate was highly significant, followed by the SD substrate, in terms of height, number of leaves, length and width of the third leaves and diameter at the crown, compared with the S0 control treatment (forest compost). The differences in plant growth observed between the composts themselves and between them and the S0 control are thought to be a function of the properties of the composts. These properties constitute the anchoring and exploration support for the roots of the seedlings, in which they must find sufficient quantities of the nutritional resources (water, nutrients, mineral elements) necessary for their growth and development. These properties are physical (aeration porosity, water content, wettability), chemical (pH, salinity, levels of mineral elements such as nitrogen, phosphorus and potassium) and biological. In addition, the high organic matter content of SA, SB, SC and SD composts (82.1%, 83.8%, 90.3% and 85.2% respectively) compared with the S0 control (41.3%) could give them an appreciable amending value [24]. According to [25], 2008, EC is a good indicator of the nutrient content of composts. Indeed, higher values mean more mineral elements. According to [25], 2008 and [26], compost is considered to have good electrical conductivity when the EC is less than 400 (mmoh/cm3). SC and SD composts, which contain chicken droppings and cow dung and are therefore richer in nitrogen than other substrates, are said to stimulate vegetation by accelerating the formation and growth of plant vegetative organs. Several authors ([27]; [28]) claim that using composts produced from organic waste makes nutrients available and promotes plant growth. The poor development of the plants in the control substrate can be attributed to the unsuitable physical and chemical properties and to the competition exerted by the weeds colonising this substrate compared with compost-based substrates. Composting has a negative effect on weed germination [29] and the development of several pathogenic fungi. which adversely affect plant quality [30].

The emission of new roots is a good indicator of plant performance after transplanting [31]. It is one of the most widely used performance tests [32]. The root system is a crucial attribute for the success of reforestation. The results obtained in this trial showed that All the plants of the target species grown on the organic substrates, compared with the S0 control (forest loam), developed new roots from the root apices that were surrounded by air. The new roots developed more deeply, confirming the pivotal nature of the roots of these species. According to [33] (1990), the most common threat to the survival of newly planted seedlings is desiccation. Their ability to extract water rapidly from their environment is therefore the most sought-after survival attribute in arid regions. The survival rate recorded for plants of the three target species on organic substrates could therefore be justified by their rapid deep growth. This rapid deep growth allows the roots to quickly reach the lower, wetter horizons, increasing the survival potential under the particularly dry conditions of the study area. Indeed, the ability of seedlings to survive the shock of transplantation lies in the capacity of their root system to rapidly establish functional connections with the soil and restore the soil-plant-atmosphere continuum ([34], [35], [36]). The performance of plants grown on this substrate compared with other substrates (compost) and with the control really confirmed the superiority of root regeneration observed in the nursery phase.

5. CONCLUSION

The aim of this work was to evaluate the possibilities of introducing compost into the forest seedling production process by producing a compost of Pterygota bequaertii and Terminalia Ivorensis A Chev, characterising it and evaluating its effect on the quality of *Gmelina arborea* seedlings in the nursery and after transplanting to experimental plots.

The composting process based on pterygota bequaertii grindings and Terminalia Ivorensis A Chev grindings had a significant influence on the maturity index and the physico-chemical characteristics of our substrates. Based on the direct evaluation (maturity ; total, aeration and retention porosities ; chemical parameters) of the composts, according to the formulations. Indirect evaluation (germination behaviour of Gmelina arborea seeds and vegetative behaviour of nursery plants). In addition, at the end of the three phases of this study, significant qualitative improvements were recorded in the Gmelina arborea plants reared in compost-based substrates compared with the control plants. Plants raised in compost were clearly better developed in the nursery and performed better in the field. The four composts produced can therefore be used to raise good quality Gmelina arborea seedlings. However, given the performance of the SC composts used in this study, with chicken droppings and cow dung as inputs, and their availability in the study, and for purely economic reasons, we can be satisfied with this one. In addition to the better growing conditions offered to *Gmelina arborea* seedlings by the compost of pterygota bequaertii shred and Terminalia Ivorensis A Chev shred compared with conventional substrate, compost rearing minimises the costs associated with controlling weeds and pathogens associated with rearing in forest humus. In addition, given its invasive nature and the areas recently planted with *Pterygota bequaertii* and *Terminalia Ivorensis* A Chev, the supply of green matter for composting does not pose a problem.

This study showed that composting Pterygota bequaertii shreds and Terminalia Ivorensis A Chev shreds could provide a real alternative for the production of quality seedlings, thus contributing to the success of reforestation operations. It is all the more interesting in that the adoption of compost based on forestry and agricultural waste could allow both a sustainable increase in forestry production (in the case of Gmelina arborea) and a reduction in environmental pollution and the degradation of forest soils. In this way, the forestry sector will be able to play its part in environmentally-friendly agriculture.

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