Trial on the production and use of compost made from*Pterygotabequaertii*crushedmaterial and *Terminaliaivorensis* A Chevcrushedmaterial for the production of *Gmelinaarborea*seedlings :AstudyfromDaloa, central western Côte d'Ivoire

ABSTRACT

The over-exploitation of naturalresources in the semi-deciduousforests of the Côte d'Ivoire forest zone has led to the degradation of the vegetation cover. This has reduced the ecologicalcontinuity of the semi-deciduousforest biomes in the forest zone. To restore theseecosystems, plantations of agroforestryspecies are recommended. However, nursery production of these types of treesusingseed or vegetative propagation techniques faces a number of problems, such as the use of substrateswithunfavourable physico-chemicalproperties and oftencontaminatedwithpathogens. This article presents the results of a trial conducted at the UJLOG experimental plot in Daloa to produce and evaluate the agronomiccharacteristics of compost made fromPterygotabequaertii and TerminaliaIvorensis A Chev for the production of Gmelinaarboreaseedlings. To this end, after the compost was made, four compost-basedsubstrates and a forest humus-based control wereprepared, characterisedfrom a physical and chemical point of view and tested in the nursery. Seedlinggrowth and root regenerationcapacitymeasured in the nursery, as well as recoveryafterplanting, were the parametersused to judge the quality of the seedlings and the effect of the compost. The results show thatpterygotabequaertii and TerminaliaIvorensis A Chev have good compostingproperties, and their compost can beeasilyproducedwith or without a stimulator. The behaviour of the plants in the five substratesalsoshowedthatsignificant qualitative improvementswererecorded in the plants reared in the compost-basedsubstratescomparedwith the control plants. The resultsobtained show that the constituent elements of the substrates (droppings, bursa, carbonisedsawdust) combinedwithpterygotabequaertiigrindings and TerminaliaIvorensis A Chevgrindings, depending on how they are prepared, have a significanteffect on the physico-chemicalparametersrecorded (pH, total porosity, aeration and retentionporosity, electricalconductivity, nitrogen, phosphorus, etc.); electricalconductivity, nitrogen, phosphorus and potassium), and consequently, on germination (germination percentage) and vegetativebehaviour (height, diameter, number of leaves and robustness ratio), as well as a better root regenerationcapacity and a betterrecovery of the Gmelinaarborea plants in the fieldcomparedwith the control plants (forest compost). It istherefore possible to improve the quality of Gmelinaarboreaseedlings by usingpterygotabequaertii compost and TerminaliaIvorensis A Chev as a growing medium instead of forest compost.

Keywords : Composting, Substrate, *GmelinaArborea*, Nursery, Germination, VegetativeBehavior

1. INTRODUCTION

The African continent recorded the highestforestlossbetween 2000 and 2010, witharound 3.4 million hectares lostannually[1]. This loss of forest cover ismainly due to the expansion of agriculture and rangelands, and excessive harvesting for fuelwood and charcoal. This situation isreflected in the fragmentation of natural formations [2] The fragmentation of naturalforests and the scarcity and disappearance of valuabletreespecies have led to a reduction in the ecologicalcontinuity of the major biomes of the semi-deciduousforests of the forest zone. Côte d'Ivoire'sforest area, for example, whichstood at 16 millions hectares in 1960, isnowestimated at around 2.5 million hectares [3]. Over-exploitation of the forest for timber and energy and bush fires are the causes of thisloss[4].

Against thisbackdrop of degradation, meeting people'sneeds for wood-basedforestproductsrequires the restoration of degradedforests[5] and the establishment of artificial plantations [6]. To achievethis, modern forest nurseries need to becreated as part of a sustainabledevelopmentapproachthat respects the environment. Thus, the notion of competitive agriculture to meet the growingneeds of the world's population and respect the environmentremains a necessity, in order to meet the challenges. Withthis in mind, recentresearch has focused on adapting new techniques and processes. Theseincludecomposting, which enables the biologicaldecomposition and stabilisation of organicsubstrates([7] ;[8]), makingit a more environmentally-friendlymethod of managingorganicwastewhilepromotingecologicalfarming practices, and above all an important aspect of fertilisation in sustainable agriculture.However, the use of compost remainslower in Côte d'Ivoire, particularly in modern forest nurseries. Pottingsoils are still the mostcommonlyusedsubstrate for producingseedlings, especially non-standardisedsoils, which have poorphysical and chemicalcharacteristicsthat are unfavourable to plant growth and encourage the multiplication of pathogens, withrepercussions for youngseedlings as soon as they are planted. Hence the failure of the reforestation operationsthat have been going on for years in Côte d'Ivoire.In thiscontext, the development of growthsubstrates by compostingavailable and reproducibleorganicmatterisproving to be an alternative for solving the crucial problem of soilfertility and optimisingforest plant production. What's more, organicfarmingisrecognised by society as an environmentally-friendly production method.

So, instead of incinerating plant biomassfromvariousforestryoperations, treepruning in towns and stubble, it can berecovered, composted and used to makegrowingsubstrates for raisingseedlings of variousspecies in nurseries. Compostingfresh plant biomassis an essential step in stabilisingorganicmaterials[9]. The resultsobtained in nurseries that have usedsubstratesbased on compost of forestry and agricultural waste to raiseseedlings of variousspecies have been verysatisfactory ([10],[11];[12]). However, before compost can beused more widely, a number of concernsneed to beaddressedregarding the availability and accessibility of the material in question, production costs, agronomiccharacteristics, behaviour in cultivation and the existence of economic and ecologicalprejudicesassociatedwithits large-scale use.

Among the speciesthatcouldoffer a renewable source of green matter for composting, *Pterygotabequaertii* and *TerminaliaIvorensis* A Chev. Offer real potential, in particularbecause of theirrapidgrowth, whichallowsthem to beused in short rotation, and theiravailability in relation to the areas plantedthroughout the country in recentyears.Consequently, itseemsnecessary to undertakestudiesaimed at proposing to companiesinvolved in forestry, in particular SODEFOR in Côte D'Ivoire, and to privateforest plant producers, suitablesubstrates to beused in order to obtain optimal and lesscostly productions.

This article presents the results of a studycarried out at the experimental plot of the Jean Lorougnon Guédé University in Daloa to assess the possibilities of introducing compost into the forestseedling production process by producing a compost of Pterygotabequaertii and TerminaliaIvorensis A Chev, characterisingit and assessingitseffect on the quality of Gmelinaarboreaseedlings in the nursery and aftertransplanting 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, wasused 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 islocated 383 km from Abidjan (the economic capital). In 2012, ithad an estimated population of 2,681,789. It isalso the 3rd mostpopulous city, after Abidjan and Bouaké [13]. The climateisthat of the Guineandomain, characterised by an equatorial and sub-equatorialregimewithtworainfall maxima. June represents the peak of the long rainyseason and September the peak of the short rainyseason. Thesetwo maxima are separated by one or twomonths of varyingrainfall[14]. The geological formations are Middle Precambrian, dominatedmainly by granites, with a few intrusions of schist and flysch. According to studiescarried out by Dabin*et al*.[15], the soils in the Daloa department are ferralitic and moderatelyleached (or desaturated). The soilcharacteristicsinclude a lessacidic pH (5.3 to 6.5), a higher content of exchangeable bases (5 to 8 cmol.kg-1) and a muchhigher saturation rate (40 to 50%). As a result, the organicmatterdevelopsbetter and stabilises in a humus-bearing horizon, with the C/N ratio generallyaround 9 to 12 [16].

Plant material

The plant materialused in thisstudyconsisted of *Gmelinaarborea*seedsharvested in the Bouafle-Torssclassifiedforest.

Biologicalmaterials

The biologicalmaterialconsists of the compostingmaterial, i.e. :

- **Main compostingmaterial**

The main materialwassawdust made up of crushedpterygotabequaertii and crushedTerminaliaIvorensis. The sawdust came from a sawmill in the Kennedy1 district of the town of Daloa, where mounds of sawdust in cups werefound, the sole purpose of whichwas to producecharcoal. Depending on the type of compost wereused. Thesewere banana leaves (*Musa Paradisiaca L.*) and shavings of the samewoodcollectedfrom a carpenter's shop in the town.

- **Compost activators and compost improvers**

Depending on the compost heap, one of the activators "A bio-activatorobtainedusing EM (effective micro-organism) technology" or cow'spursewereused as inoculum for compostingsubstrates. In order to improve the agronomic value of the final composts, rice bran, chickendroppings, coffee husks and cocoahuskswereused in certain piles. The droppingswerecollectedfrom a poultryfarm in the town of Daloa, which has hundreds of them. The cocoashells came from a plantation on the outskirts of the town. The coffee hulls come from a storage area that dates back severalyears to the abattoir district in the town of Daloa.

1.2. Methodology

Composting

-Shredding of compostedbiomass

The aim of this phase was to produce compost for nursery trials. Crushedpterygotabequaertii and TerminaliaIvorensis A. Chevis the plant materialused to produce the compost. Our variousshreds are derivedfrom the serial wake of thesetwospecies.

-Windrowing and composting process

The shreddedmaterialwasimmediatelyplaced in windrowsmeasuring 1.50 m x 1.50 m x 1.30 m on a platform coveredwith a slightlysloping tarpaulin to facilitate drainage of the compost leachate. To stimulate the composting process, activatorswereaddedwhen the shreddedmaterialwasswathed. The shredsweredeposited in layers of freshmaterial, to which certain organicmaterialswereadded as a source of nitrogen, phosphorus and potassium.

A total of 4 windrowswerecreated :

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: calcinedsawdust; Fp: chickendroppings; Bv: cowdung; Sr: rice bran; Cca: cocoahull; Ccaf: coffee hull; Fb: dried banana leaf; Fm: moringa leaf; Tf: forestsoil. S0 : control.

Setting up a nursery

Construction of the shade house

An 80 m2 (10 m long by 8 m wide) shade structure wasbuilt to house the plants. Like the shadesusuallyrecommended, itis 2 m high and has a slightslopewithtwosides to allowrainwater to drain off easily. It wasthencoveredwithpalms (the leaves of the palm tree) to reflectmost of the sunlight. During the early stages of theirdevelopment, young plants needrelatively dense shade to growoptimally, leavingonly 25 to 50% of the total light, in order to reflect as closely as possible the sunlight conditions in the undergrowth[17]. Palmswerealsoplacedaround the shaded area to protect the young plants fromdomesticanimals and improveshadingwithin the shaded area.

Experimentalset-up

The trial wasconductedusing a randomisedcomplete block design withthreereplicates and one factor level. It consisted of 15 elementary plots (1 species x 5 substratelevels x 3 blocks), each 1 m long and 0.5 m wide. Eachelementary plot contained 30 nursery phytocells, for a total of 450 phytocells for the whole trial. The blocks wereseparated by 1 m, and each block contained 150 phytocells, with 30 phytocells per elementary plot. The individual plots in each block wereseparated by a tray.

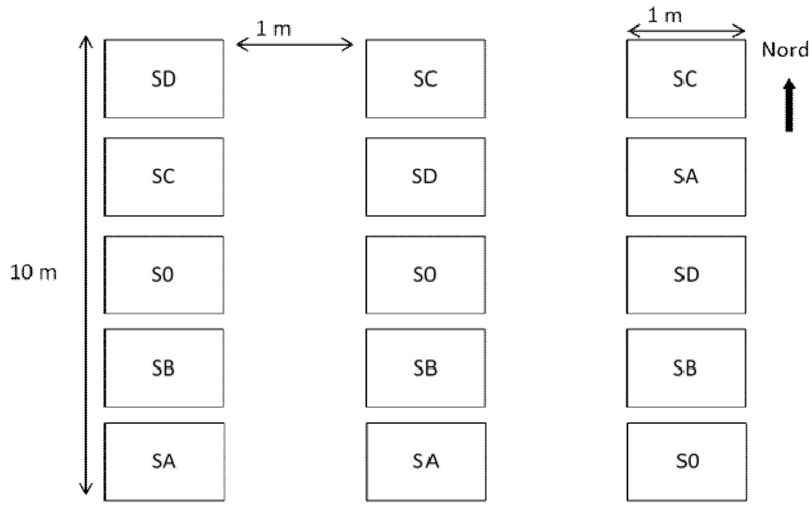

***Figure 1** : Experimental design*

*Test. S0 *: forest loam, SA : Substrate A, SB : Substrate B, SC : Substrate C, SD: Substrate D*

Sowing

Direct sowing of seeds at a rate of 2 seeds per phytocellwascarried out early in the morningbeforesunrise in order to conserve moistureinside the phytocells. Wesowed 300 seeds for thispurpose. The seedswerewatered the daybefore and aftersowing to ensurethattheygerminatedproperly. In order to makeiteasier for the seedlings to emergefrom the soil, an opening of 2 to 3 cm was made in the phytocelsbeforeplacing the seeds in the epicotylated position (asowingmethodthatconsists of placing the seed in the soilwith the cotyledonary part pointingupwards).

Measurements and observations

In order to assess the performance of the substratesdeveloped, measurements of germination rate, germination dynamics, height H (cm), crown diameter D (mm), leaf area and biomass (g) werecarried out on a 25% sample of plants fromeachsubstrateduring and at the end of the rearing cycle. The plants measuredwererandomlyselected and labelled to facilitate monitoring. The robustness ratio of height to diameter (H/D) (cm.mm-1) wasthencalculated. To determine the dry biomass, the stems and roots of the sampled plants wereplaced in an ovenmaintained at 80°C for 24 hours, thenweighed.

Study of root regenerationcapacity and recoveryaftertransplanting

In order to evaluate the performance of the bred plants in the five substratestested, 10 plants fromeachsubstratewererandomlyselected and transplantedwiththeir root ballintolarger containers (polyethylenebagswith a volume of 4000 cm3) pottedwithsoil. Aftertwomonths of transplanting, the roots of all the plants werecarefullyremovedfrom the sand and gentlywashedso as not to damage theirroots, particularly the newlyformedones. Root regenerationcapacitywasassessed by measuring the number, length and biomass of new rootsformedoutside the initial root ball.

In order to confirm the resultsobtained in the nursery, a confirmation trial wascarried out in an experimental plot located close to the breeding nursery. To this end, nine one-year-old plants wererandomlyselectedfromeachsubstrate and transplantedwiththeir root ballintoplantingholesmeasuring 50 cm x 50 cm x 50 cm by edge, openedwith a pickaxe. Plantingwascarried out in a randomisedcomplete block design withthreereplications, involving a total of 45 plants. Apart fromtwowateringsduring the summer, the plants were not fertilized and received no other maintenance.

The recovery of plants fromeachsubstratewasdeterminedafter six months of transplanting by deducting the number of dead plants from the total number of plants planted. The recovery rates obtainedwereused for correlation tests with the collardiameters and H/D ratios of the plants at planting, on the one hand, and with the root regenerationcapacitymeasured in the nursery, on the other.

1.3. Statisticalanalysis of dataThe data

collectedwassubjected to statistical testsusingStatistica 7.1 software. An analysis of variance madeit possible to assess the effects of amendments on *Aloe vera*sucker growth. The hypothesis of equality of averageswasassessed at α risk = 5%. If this last hypothesiswasrejected,the Newman-Keuls multiple comparison test (at α riskthreshold = 5%) made it possible to classify the averagesintohomogeneous groups.

3. RESULTS

3.1. Assessment of the physical and chemicalparameters of the substrates

3.1.1. Physical characteristics of the growthsubstrates

The figure illustrates the evolution of the total, aeration and retentionporosities of the five growthsubstratesstudied. The five substratestested all met the rules for assessing total and aerationporosities ;however, substrate S0 did not meet the requirements for retentionporosity (minimum 30%). In terms of total porosity, the substrates (S0, SC) and (SA, SB, SD) did not differsignificantlyfromeachother. With regard to retentionporosity, the SA and SC substratesdid not differsignificantlyfromeachother. Finally, with regard to aerationporosity, the substrates (SA, SC) and (SD, S0) did not differsignificantly.

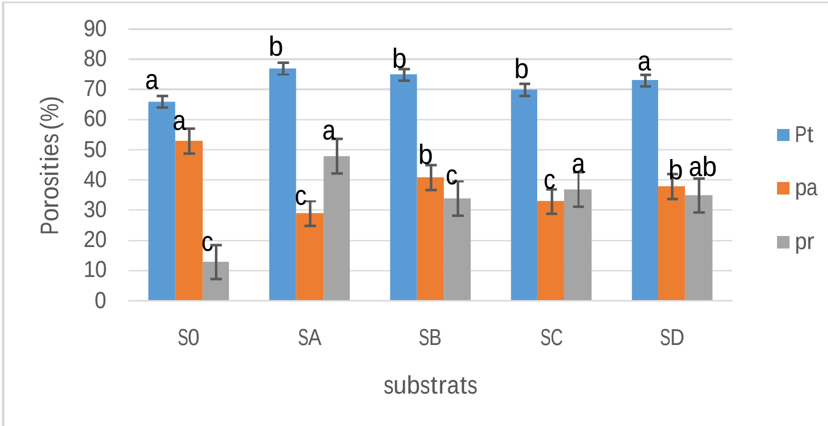

***Figure 2** : Total (Pt), aeration (Pa) and retention (Pr) porosities of the growthsubstratestested.*

*Meansfollowed by the sameletter do not differsignificantlyaccording to Duncan's test at the 5% threshold for the sameporosityparameter. Means for eachparameter (same-colored vertical bars) followed by differentlettersindicate the presence of significantdifferencesbetweensubstrates at the 5% thresholdaccording to Duncan's. test. S0 *: forest loam,SA : Substrate A, SB : Substrate B, SC : Substrate C, SD: Substrate D*

3.1.2. Chemical characteristics of growthsubstrates

3.1.2.1. Organicelement and phosphorus content.

The levels of organicmatter and phosphorusmeasured are shown in Table 2. The contents of carbon, organicmatter, nitrogen and the C/N ratio variedsignificantly ($p < 0.05$) between the differentsubstrates. The organicsubstrates SA, SB, SC and SD inducedhigher contents comparedwith the control substrate (S0). Cot (50.2±0.16%), Mo (90.3±0.65%) and N (5.76±0.04%) contents werehigher in the SC substratethan in the othersubstrates. The C/N ratio variedbetween 8 and 19. The mineralsubstrate (S0) had the highest ratio (19.8±0.19). On the other hand, the phosphorus content of the SD organicsubstrate (76.67±0.33 mg.kg-1) appeared to behigher. The phosphorus content of the control substrate (74.23±0.25 mg.kg-1) wasalsohigherthanthat of the organicsubstrates SA (64.47±0.02) and SB (74.01±0.19).

***Table 2**: Organicmatter and phosphorus content of composts*

Types of substrate	Compositions of organicelements 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 eachparameter (vertical bars of the samecolour) followed by differentlettersindicate the presence of significantdifferencesbetweensubstrates at the 5% thresholdaccording to Duncan's test. S0 *: forest loam, SA : Substrate A, SB : Substrate B, SC : Substrate C, SD: Substrate D*

3.1.2.2. Element content of the absorbent complex

The absorbent complexelement contents measured are shown in Table 3. It can beseenthat 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 variedsignificantly ($p < 0.05$) between the differentsubstrates. The organicsubstrates SA, SB, SC and SD inducedhigher contents comparedwith the mineralsubstrate (S0).

Table 3 : Absorbent complexelement 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 eachparameter (vertical bars of the samecolour) followed by differentlettersindicate the presence of significantdifferencesbetweensubstrates at the 5% thresholdaccording to Duncan'sTest. S0 *: forest loam, SA : Substrate A, SB : Substrate B, SC : Substrate C, SD: Substrate D*

3.2. Growth of *Gmelinaarborea* plants

3.2.1. Height of *Gmelinaarborea* plants

The growth in height of *Gmelinaarborea* plants duringtheirdevelopment cycle in the nursery isshown in figure 40A from the fourthweekaftersowing to the tenthweekaftersowing. It variedfrom 10.67 to 90.00 cm on average. Growthcurvesdifferedbetweensubstrates. The SA, SB, SC and SD substratesinducedgreatergrowththan the S0 control at all measurement times. Maximum growth in heightwasrecorded in plants on the SC substrate (H=90.00 cm) wherecowdung, chickendroppings, cocoapods and carbonisedsawdustwereadded to the sawdust (pterygotabequaertiigrindings and TerminaliaIvorensisgrindings). Individualsfromsubstrate S0 (forest loam) recorded the lowest values (H=58.50 cm) at the last data collection.

Figure 3B shows the averagedailyincreases in height per substrate. A rapiddeceleration phase wasobserved 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) betweendays 28 and 35. This wasfollowed by a cleargrowth phase for plants on the S0 and SC substrates and a rapidgrowth phase for plants on the SD substrates, withaveragedaily gains greaterthanthose for plants on the SA substrates (1.33 mm/d) on day 42. Then, on day 49, therewas a rapiddeceleration phase in SB and SC substrate plants and a slightdeceleration in S0 control substrate plants. Fromday 49 to day 56, with the exception of the SA substrate plants, therewas a rapidincrease in the plants of the othersubstrates. A reversal of the trend wasobserved on day 56.

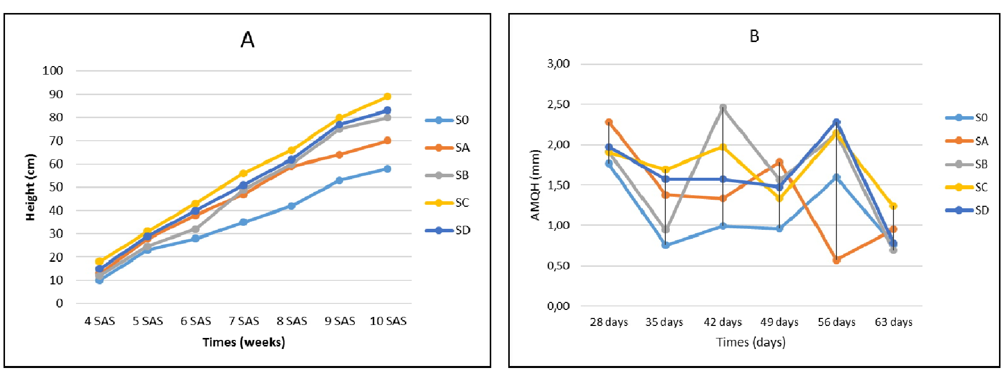

Figure 3 : Heightgrowth of *Gmelinaarborea* plants (A) ; Averagedailygrowth of plants per substrate (B)

*Test. S0 *: forest loam, SA : Substrate A, SB : Substrate B, SC : Substrate C, SD: Substrate D*

3.2.2. *Growth in diameter*

The Figure 4 shows that the growth in thickness of the *Gmelina* stem evolvedcontinuouslyfrom the 4th week to the 10th weekaftersowing. It variedfrom 2.96 to 15.05 mm.Thicknessgrowthcurvesdifferedbetweensubstrates. The SA, SB, SC and SD substratesinducedgreatergrowththan the control (S0). At the last measurement, maximum growth in thicknesswasrecorded in plants on the SC substrate (D=15.05 mm) where a combination of cowdung, chickendroppings, cocoapods and sawdustcarbonisedwithsawdust (pterygotabequaertiigrindings and TerminaliaIvorensisgrindings) wasused. At this date, the individuals in substrate S0 (D=9.00 mm), whichisforest loam, recorded the lowestthickness values. The SB and SD substratesshowed the samethickness at the 10th SAS (D= 13.62 mm).

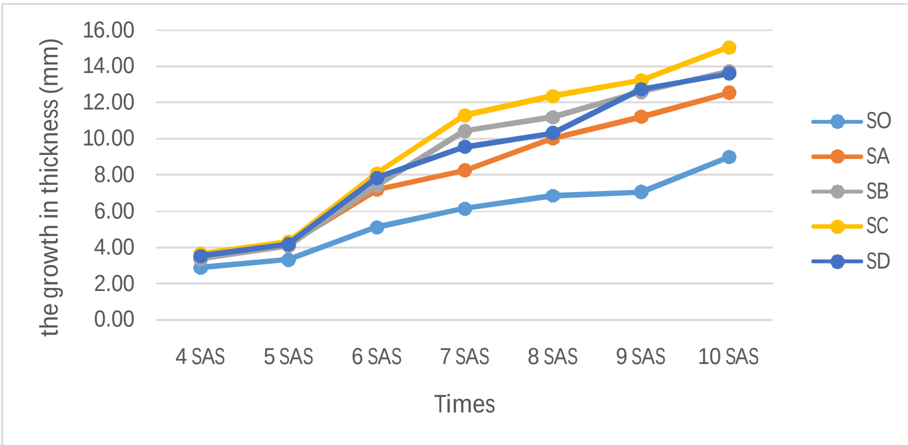

Figure 4 : the growth in thickness of the stems of *Gmelinaarborea*

*Test. S0 *: forest loam, SA : Substrate A, SB : Substrate B, SC : Substrate C, SD: Substrate D*
SAS: weeksafterplanting

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

The resultsrelating to thisparameter are shown in Figure 5. The robustness ratio of Gmelinaarboreaseedlingsproduced on each cultivation substratestudiedduring the growthsurveyscarried out. At the first measurement, i.e. 5 weeksaftersowing, all the substratesshowed a robustness ratio of robustness index of lessthan 7, except for substrate S0. However, at the first measurement, only the SA substratehad a robustness index of lessthan 7.

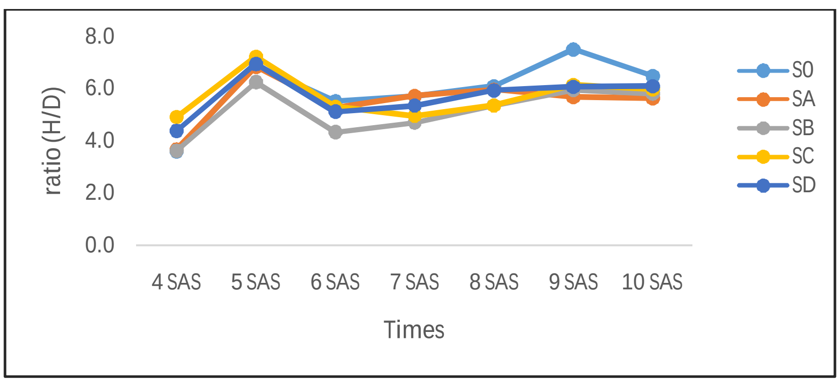

Figure 5 *:* Robustness ratio of*Gmelina arbore* plants

*Test. S0 *: forest loam, SA : Substrate A, SB : Substrate B, SC : Substrate C, SD: Substrate D*
SAS: weeksafterplanting

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

The figure 6 shows that the MFA/MFR ratio varies between the differentsubstrates, with the highest value recorded for the SB treatment (1.56). The lowest value wasrecorded for the S0 substrate (0.82). For the othersubstrates, the values of thisparameter lie withinthis range with a ratio of far from the equilibriumthatwasestablishedbetween the twosystems for the SA substrate (1.20). Finally, the SC and SD substratesappear to generateequal ratios. This findingwasconfirmed by the statistical test, whichproved to behighlysignificant.

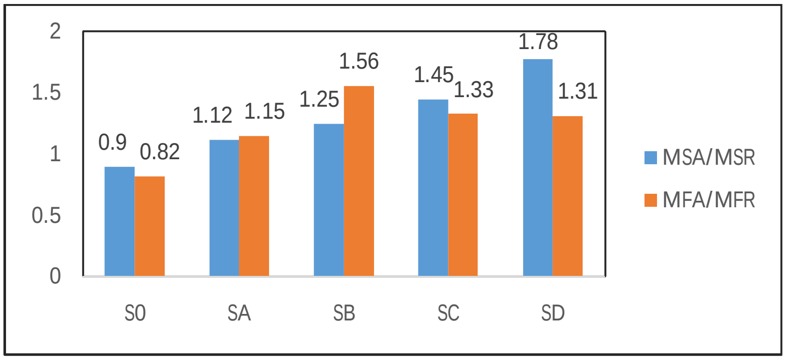

Figure 6 : stem/root biomass ratio

*Test. S0 *: forest loam, SA : Substrate A, SB : Substrate B, SC : Substrate C, SD: Substrate D. MFA: aerialfresh mass, MFR: root fresh mass, MSA: aerial dry mass, MSR: root dry mass.*

3.3. Study of root regenerationcapacity and recoveryaftertransplanting

3.3.1. Root regenerationcapacity

Table 4 shows the resultsobtainedconcerning the emission of new roots in *Gmelinaarborea* plants from the five substratesaftertransplantinginto local soil. Evaluation of the root regenerationcapacityshowedthat all the plants emitted new rootsoutside the initial root ball. The number of new rootsemittedvariedbetween 22 and 38 (Table 3). Among the five substrates, the highestnumber of new rootsemittedwasrecorded in the SC substrates (sawdust + cowdung + chickendung + cocoapod), i.e. 38.67±1.53. The best elongationswereobtained in the plants on the organicsubstratescomparedwith the forest loam control, withaveragesrangingfrom 32.33 to 82.33 cm comparedwith 28.33 cm in the control plants. The new root dry matterproducedwas 3.03 to 5.17 g for plants raised in organicsubstrates, comparedwith 1.35 g for control plants. Statisticalanalysis of the data (ANOVA) revealed a highlysignificantdifferencebetween the substrates in terms of both the number of new rootsproduced and root elongation. The samewastrue for total root biomass (P-value < 0.05). Plants grown on the SC substrateperformedbetter in assessing the root regenerationcapacity of *Gmelinaarborea* plants.

Table 4 *:* Root regenerationcapacity of *Gmelinaarborea* plants in relation to substrates

Substrats	▪ **Root regenerationcapacity**		
	New root number	Meanlength (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 eachparameter (vertical bars of the samecolour) followed by differentlettersindicate the presence of significantdifferencesbetweensubstrates at the 5% thresholdaccording to Duncan'sTest. S0 *: forest loam, SA : Substrate A, SB : Substrate B, SC : Substrate C, SD: Substrate D*

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

The resultsconcerning the recovery rates of *Gmelinaarborea* plants subsequentlymeasuredafter six months of transplanting in the fieldvariedaccording to the substrates (Figure 7). Withrecovery rates rangingfrom 52% to 85%, the recovery of plants on compost-basedsubstrateswasmuchhigherthanthat of plants on the control substrate (S0) without compost (forest loam), whichhad a recovery rate of 52%. The substrate (SC) wasfavourable to seedlingrecovery, with a rate of 85%, followed by the SD substrate (81%). The substrate (S0) wasdetrimental to recovery, with a mortality rate of 48%. The SA and SD substrates, on the other hand, hadrecovery rates of 66% and 76% respectively.

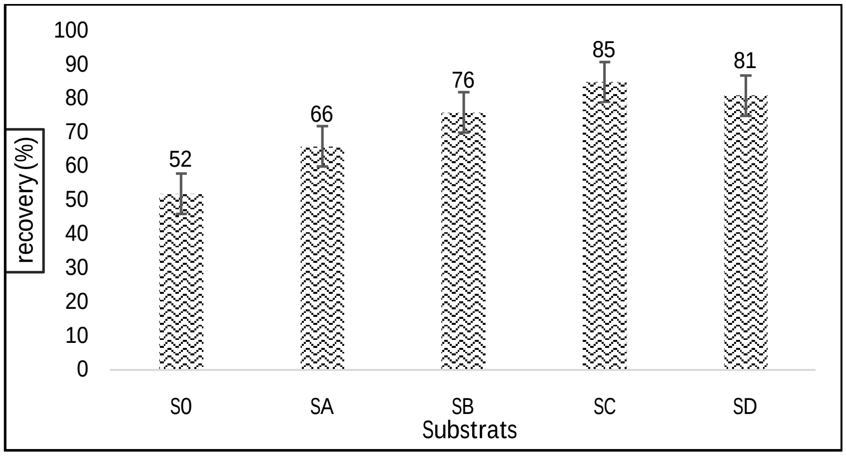

Figure 7 *: Recovery rate of Gmelinaarborea plants from five substratesafter six months of transplanting*

*Test. S0 *: forest loam, SA : Substrate A, SB : Substrate B, SC : Substrate C, SD: Substrate D*

4.DISCUSSION

In the first phase of the project, composts wereproducedfromcrushed*Pterygotabequaertii* and crushed*TerminaliaIvorensis*, with inputs includingcow'spurse, poultrydroppings, cocoahusks, coffee husks and carbonisedsawdust.

The four substratesproduced by compostingwerethenused to rear*Gmelinaarborea*seedlingsaboveground. The results of the physical and chemicalcharacterisation of the five substratestestedwere, on the whole, in favour of the substratescontaining compost comparedwith the control without compost (local soil). The pH of the various composts shiftedslightlytowardsalkalinity, rangingfrom 7.33 for SD compost, 7.38 for SC compost and 7.58 for SA and SB composts. This trend towardsalkalinity in composts is due to the production of CO_2 and organicacids by microbialmetabolismduring the decomposition process by microorganisms[18]. The pH defines the state of the absorbent complex. Indeed, thesealkalinepHsofferfavourable conditions for improvingbiologicalproperties and the availability of soil cations [19]. The chemicalcharacteristics of the 4 composts and the forestrytopsoil (S0 control) showedthat agricultural and forestryresidues are rich in certain primarymineralelementssuch as potassium and phosphorus. All the composts hadhigherlevels of fertilisingelementsthan the forestrytopsoil. Furthermore, the SC compost (sawdust+ cowdung+ ; chickendung+ cocoapod+ carbonisedsawdust) had the highestlevels of fertilisingelements (N, P, K, Ca, Mg). This couldbeexplained by the combined contribution of chickendroppings and cowpurse. In fact, chickendroppings are the mostnitrogen-rich of all livestock effluents. Measurementsshowed an averagenitrogen content of 5.76% with a C/N ratio of 8.7. The high levels of potassium (K) in SB, SC and SD compost couldalsobeexplained by the woodash (carbonisedsawdust) inputs. The ashes of Wood isboth a basic residueagainstsoilacidity and a source of essential mineralssuch as Ca, P, K and Mg ([20]; [21]).

From the point of view of total porosity, the SA and SB substratespresented the highest values, i.e. 77% and 75% respectively. With regard to retentionporosity, the SA (48%) and SC (37%) substratesshowed the highest values. Finally, with regard to aerationporosity, the SD (38%) and S0 (53%) substratesshowed the highest values. Furthermore, according to [22], (2017) the normal values of porosities in a compost are Pt ≥ 50%, Pa ≥ 20% and Pr ≥ 30%. Thusrelatively to ourresults It is possible to concludethat SA, SC and SD substrates have the best porositiescompared to the othersubstrates by combining the threeporositiesstudied. This couldbeexplained in part by the composition of the SC and SD composts. Thesesubstratescontaincowdungcomparedwith the other composts and the S0 control. This enabled more efficient retention of water and nutrients, thusminimisingsubstrateleaching and providingbetter conditions for off-soil plant growth[23]. Regarding the aggregate composition of the different types of compost, small-sizedparticles (< 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, fairlyhomogeneousparticles. The high proportion of fine elements in SA compost (80%) isexplained by the presence of rice bran. From the point of view of root ballconsistency, the sawdust-basedsubstratesprovidedbetter root ballcohesionthan the control substrate. The bulk densities of the compost-basedsubstrateswerelogicallylowerthanthose of the control substrate (forest compost). The control substratewas the densest (0.46 g/cm^3). From a practical point of view, the lowdensity of the compost-basedsubstrates, and consequentlytheirlightness, makesiteasier to handle the boxes in the nursery and when travelling to the reforestation site, comparedwith the heavier control substrate. A plastic cratecontaining 20 polyethylenebagsfilledwith compost weighslessthan 10 kg, whereasitweighed 16 kg with the control substrate (forest compost). In terms of growth, the SA, SC and SD organicsubstratesshowed good plant developmentcomparedwith the S0 control substrate. The SC substratewashighlysignificant, followed by the SD substrate, in terms of height, number of leaves, length and width of the thirdleaves and diameter at the crown, comparedwith the S0 control treatment (forest compost). The differences in plant growthobservedbetween the composts themselves and betweenthem and the S0 control are thought to be a function of the properties of the composts. Thesepropertiesconstitute the anchoring and exploration support for the roots of the seedlings, in whichthey must findsufficientquantities of the nutritionalresources (water, nutrients, mineralelements) necessary for theirgrowth and development. Theseproperties are physical (aerationporosity, water content, wettability), chemical (pH, salinity, levels of mineralelementssuch as nitrogen, phosphorus and potassium) and biological. In addition, the high organicmatter content of SA, SB, SC and SD composts (82.1%, 83.8%, 90.3% and 85.2% respectively) comparedwith the S0 control (41.3%) couldgivethem an appreciableamending value [24]. According to [25],2008, EC is a good indicator of the nutrient content of composts. Indeed, higher values mean more mineralelements. According to [25], 2008 and [26], compost isconsidered to have good electricalconductivitywhen the EC islessthan 400 (mmoh/cm3). SC and SD composts, whichcontainchickendroppings and cowdung and are thereforericher in nitrogenthanothersubstrates, are said to stimulatevegetation by accelerating the formation and growth of plant vegetativeorgans. Severalauthors ([27],[28]) claim thatusing composts producedfromorganicwastemakesnutrientsavailable and promotes plant growth. The poordevelopment of the plants in the control substrate can beattributed to the unsuitablephysical and chemicalproperties and to the competitionexerted by the weedscolonisingthissubstratecomparedwith compost-basedsubstrates. Composting has a negativeeffect on weed germination [29]and the development of severalpathogenic fungi.whichadversely affect plant quality[30].

The emission of new rootsis a good indicator of plant performance aftertransplanting[31]. It is one of the mostwidelyused performance tests [32]. The root system is a crucial attribute for the success of reforestation. The resultsobtained in this trial showedthat All the plants of the targetspeciesgrown on the organicsubstrates, comparedwith the S0 control (forest loam), developed new rootsfrom the root apicesthatweresurrounded by air. The new rootsdeveloped more deeply, confirming the pivotal nature of the roots of thesespecies. According to [33] (1990), the mostcommonthreat to the survival of newlyplantedseedlingsisdesiccation. Theirability to extract water rapidlyfromtheirenvironmentistherefore the mostsought-aftersurvivalattribute in aridregions. The survival rate recorded for plants of the threetargetspecies on organicsubstratescouldthereforebejustified by theirrapiddeepgrowth. This rapiddeepgrowthallows the roots to quicklyreach the lower, wetter horizons, increasing the survivalpotentialunder 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 rapidlyestablishfunctional connections with the soil and restore the soil-plant-atmosphere continuum ([34], [35], [36]). The performance of plants grown on thissubstratecomparedwithothersubstrates (compost) and with the control reallyconfirmed the superiority of root regenerationobserved in the nursery phase.

5.CONCLUSION

The aim of thisworkwas to evaluate the possibilities of introducing compost into the forestseedling production process by producing a compost of *Pterygotabequaertii* and *TerminaliaIvorensis* A Chev, characterisingit and evaluatingitseffect on the quality of *Gmelinaarborea*seedlings in the nursery and aftertransplanting to experimental plots.The composting process based on pterygotabequaertiigrindings and *TerminaliaIvorensis* A Chevgrindingshad a significant influence on the maturity index and the physico-chemicalcharacteristics of oursubstrates. Based on the direct evaluation (maturity ; total, aeration and retentionporosities ;chemicalparameters) of the composts, according to the formulations. Indirect evaluation (germination behaviour of Gmelinaarboreaseeds and vegetativebehaviour of nursery plants). In addition, at the end of the three phases of thisstudy, significant qualitative improvementswererecorded in the Gmelinaarborea plants reared in compost-basedsubstratescomparedwith the control plants. Plants raised in compost wereclearlybetterdeveloped in the nursery and performedbetter in the field. The four composts produced can thereforebeused to raise good qualityGmelinaarboreaseedlings. However, given the performance of the SC composts used in thisstudy, withchickendroppings and cowdung as inputs, and theiravailability in the study, and for purelyeconomicreasons, we can besatisfiedwiththis one. In addition to the bettergrowing conditions offered to *Gmelinaarborea*seedlings by the compost of pterygotabequaertiishred and TerminaliaIvorensis A Chevshredcomparedwithconventionalsubstrate, compost rearing minimises the costsassociatedwithcontrollingweeds and pathogensassociatedwithrearing in forest humus. In addition, givenits invasive nature and the areas recentlyplantedwith*Pterygotabequaertii* and *TerminaliaIvorensis* A Chev, the supply of green matter for compostingdoes not pose aproblem. This studyshowedthatcompostingPterygotabequaertiishreds and TerminaliaIvorensis A Chevshredscouldprovide a real alternative for the production of qualityseedlings, thuscontributing to the success of reforestation operations. It is all the more interesting in that the adoption of compost based on forestry and agricultural wastecouldallowboth a sustainableincrease in forestry production (in the case of *Gmelinaarborea*) and a reduction in environmental pollution and the degradation of forestsoils. In thisway, the forestrysectorwillbe able to playits part in environmentally-friendly agriculture.

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