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Vegetative behavior of hevéa plants on compost-based culture substrates

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Abstract
An agronomic test was conducted at the CNRA-Bimbresso research station in order to assess the vegetative behavior of rubber plants on compost-based growing media. To this end, after composting, four compost-based substrates and two soil-based controls were made and tested in a bag nursery. The follow-up of the experiment focused on the evaluation of the vegetative growth parameters and the rates of graftable plants, of grafting success and of transferable plants in the field. The results obtained reveal that the parameters of vegetative growth (diameter at the collar, height of the plants) and the rates of graftable plants and of success in grafting have been improved in rubber plants grown in compost-based substrates compared to control plants. The production of the rubber plant material was optimal with the dose of compost of 300 g or 27 $t.ha^{-1}$ which, under the conditions of this study, may be the dose recommended on rubber plants in bag nursery.

Keywords: growing medium, compost, vegetative growth, rubber plant material, cote d'ivoire

1. Introduction

Introduced by agro-industrial companies around the 1950 (Canh, 1999) [7] as part of crop diversification, rubber cultivation in Côte d'Ivoire, is of considerable economic interest which has aroused an ever-growing interest among many populations in recent years. Rubber cultivation in Côte d'Ivoire, is an important factor in rural poverty reduction policy, because of the monthly income it generates (Toguila *et al*., 2016) [20]. From 100 tonnes in 1960, Ivorian natural rubber production increased to 256,000 tonnes in 2013, then to 603,000 tonnes in 2017 (Kouassi, 2018) [16], over an area planted estimated at more than 534,000 hectares. This performance makes this country the 7th world producer and the 1st African producer of natural rubber. This prodigious development was boosted, on the one hand by the improvement in the purchase price of rubber on the field, and on the other hand, by the subsidization of the production of rubber plants by the Rubber Development Fund.

Unfortunately, several concerns, especially, land saturation in forest areas, parasite pressures, aging of the orchard and the low level of adoption of the technical routes recommended by the research, could hinder this performance. Also, it should be added that the national master plan for the development of the rubber sector, in its objective for 2025, plans to bring the production of natural rubber to 1 000 000 tonnes, which is far from being achieved if sustained efforts fail are not engaged. This objective of producing natural rubber can only be achieved by increasing the areas planted with efficient plant material, adapted to the soil and climatic conditions of the environment. The expansion of this rubber area necessarily starts from nurseries which, occupying a pivotal position in the production cycle of plant material is, at the origin of any project to create a rubber plantation. It remains the only effective means of obtaining quality planting material, capable of guaranteeing profitable and sustainable exploitation of rubber plantations. The high demand for planting material, linked to the enthusiasm aroused by rubber growing over the past decade, has shown the need for rubber growing nurserymen to shorten the production time of plant material in nurseries.

The lack of vigor of the plant material produced is one of the causes of high mortality after transfer to the field. These significant plant losses recorded translate into a heterogeneity in tree growth, induced by plant replacements and consequently, a significant reduction in the number of exploitable trees. Also, the work of Mougo (2012) [18] revealed that the loss of bagged hevea plants could reach more than 75 % before grafting, 53 % of which due to the type of plant material and the growing medium. In search of accessible materials that meet the requirements for plant growth, several studies have looked at the recycling of organic waste (Garny and Badiane, 1998 ; Compaoré *et al*., 2010; Abobi *et al*., 2014; Koulibaly *et al*., 2015; Essehi *et al*., 2016; Kitabala *et al*., 2016; Biekré *et al*., 2018) [14, 9, 2, 17, 12, 15, 4]. Indeed, the use of organic waste composting is a potential choice to develop for interesting agronomic and environmental reasons.

The general objective of the study is to improve, quantitatively and qualitatively, the production of rubber plant material, in a sustainable way, by using compost for the preparation of growing media. In order to achieve the general objective of this study, two specific objectives were proposed:

- Evaluate the effects of compost-based substrates on the aerial vegetative growth of rubber tree plants in the bag nursery;
- Evaluate the effects of compost-based growing substrates on the rates of graftable plants, successful grafting and plants transferable to the field.

2. Material and methods

3. Study material

3.1. Study site

The study was conducted on the CNRA-Bimbrésso experimental research site (N 05 18’45.2 "and W 004 9’18.9") in the south-east of the Ivory Coast. The climate, of humid subtropical type, comprises four seasons clearly differentiated by their bimodal rainfall regime (Brou, 2005) [6]. The average annual rainfall is 1,800 mm. The grounds, of iron type (ralitic strongly desaturated in base (CEC <15 cmol / kg), are deep and characterized by a sandy-clay texture. This soil has an acidic pH, a very low nitrogen content (N <0.5), a C / N ratio less than 15 characterizing a rapid rate of mineralization of organic matter, the nitrogen requirement of which This soil is also very poor in organic matter (OM).

3.3. Fertilizer material: compost and chemical fertilizer

The compost used was obtained by recycling chicken droppings and dry maximum panicum straw into a pit; wood ash and urea.

3.3.1 Technical field equipment

For the field work, we used the following technical equipment:

- tools (machetes, chisel, picks, files), for opening the trenches;
- a 50 meter decameter, for measuring distances;
- a caliper type "Stainless", for measuring the diameter at the collar of the stem and the pivot of the plants;
- a field notebook, to record all observations;
- a pencil, for taking notes;

3.4. Methodology of work

3.4.1. Site preparation, making trenches and filling sachets

This study was carried out on the experimental site of the Research Station of the National Center for Agronomic Research (CNRA) of Bimbresso. The plot has an area of 300 m2 (20 m × 15 m) and has been manually cleared and cleared of plant debris. It was then materialized by the placement of 8 trenches or gauges on the ground using stakes. These trenches were opened to the following dimensions: width 0.2 m; length: 4 m, depth: 0.2 m and distance between 2 trenches: 1 m. The earth, placed on the same side when digging the trenches, served as a growing medium, whether or not mixed with the compost produced, to fill the bags. These sachets, buried at 2/3 of the height, were placed in the trenches in discontinuous tetrads and a trench constitutes a micro-plot (Figures 1 and 2).

3.4.2. Filling and disposal of bags

By making a slight compaction over time, the polyethylene bags were filled with potting soil mixed with or without the compost produced. These bags, buried at 2/3 of their height, were placed in the trenches in discontinuous tetrads (Figure 2).

3.4.3. Seed collection and installation of the germinator

The establishment of a rubber tree nursery necessarily involves a germinator. It was made up of one (1) square meter flower beds that could contain up to 1000 seeds.

This strip was formed by a light medium about 5 to 10 centimeters thick in sand, and covered by a shade house made of oil palm stalks (Figure 3). The seeds used were those of clone GT 1. Transplanting into the sachets was carried out at the seedling stage of the seed, around 30 days after sowing.

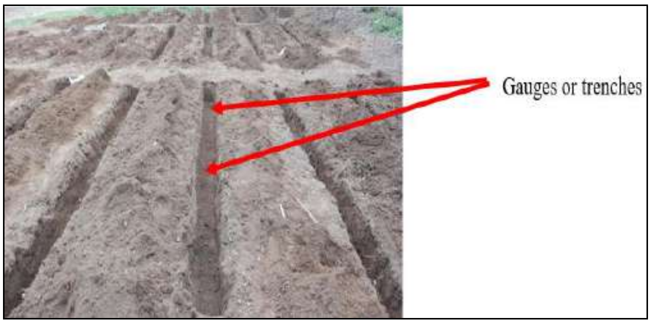

Fig 1: Staking and construction of the trenches (length: 4 m; width: 0.2 m; depth: 0.2 m and distance between two trenches: 1m)

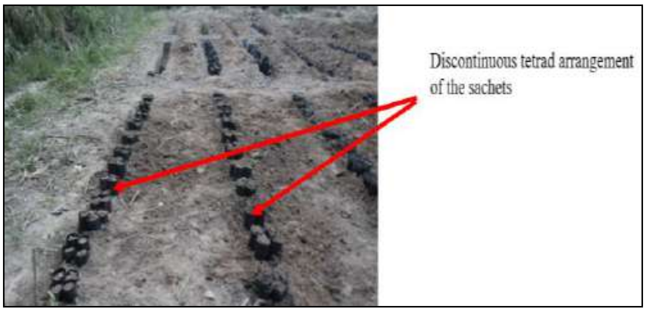

Fig 2: Filling and discontinuous tetrad arrangement of the sachets in the trenches (2/3 of the height of the sachet)

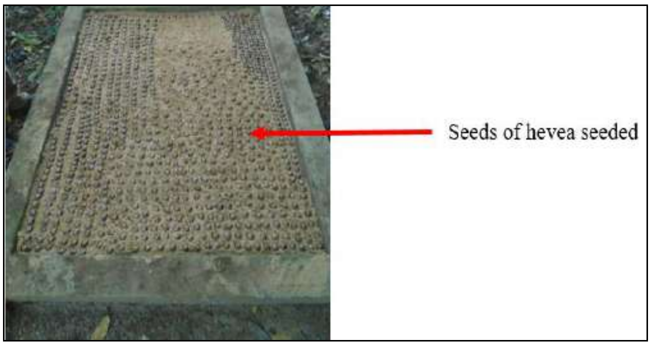

Fig 3: Making the germinator and sowing the seeds in sandboxes

3.4.4 Experimental setup and culture substrates

The trial was set up with a complete randomized block device (BCR). The manure was the main factor in the experiment, and the dose, the sub-factor, at 6 levels constitutes treatments or culture substrates (Table 1). Each treatment, repeated 3 times, consists of 40 plants. The number of useful plants was 720 out of a total of 1152 plants. Urea applications (46 % N) were made in three applications. The first was applied as background fertilizer. The second, from the second mature leaf stage and the last application, one month after the second pass. The urea was dissolved in water (50 ml of water per plant) and brought to the plants. However, the compost applications were made all at once (when the bags were filled).

Table 1: Composition of treatments

Growing media or Treatments	Mineral fertilizer (kg / ha)			Compost (t / ha)
	Background manure	2nd ripe leaf stage	3rd ripe leaf stage	
S1 (control)	0	0	0	0
S2	360 (4 g/plant)	630 (7 g/plant)	990 (11 g/plant)	0
S3	0	0	0	27 (300 g/plant)
S4	0	0	0	54 (600 g/plant)
S5	180 (2 g/plant)	315 (3.5 g/plant)	495 (5.5 g/plant)	27 (300 g/plant)
S6	90 (1 g/plant)	157,5 (1.75 g/plant)	247,5 (2.75 g/plant)	54 (600 g/plant)

NB: one hectare (1 ha) of sacked rubber tree nursery contains on average 90,000 plants (Compagnon, 1986) [8].

3.4.5. Nursery maintenance

Water supply

The water requirements of young rubber plants in the nursery are estimated at 120 mm of water per month, in the absence of rain. The plants were watered manually using a 15-liter watering can. The plants were watered three times a week at the rate of 15 liters of water per 100 plants, each time, in addition to the rainfall, at the hottest hours of the day: early morning or finally after- midday.

Weeding

After transplanting, weeding of the nurseries was done manually with a daba and a machete, each time weeds were regrown.

3.5 Data collection

3.5.1 Monitoring of aerial vegetative growth parameters

In order to assess the performance of the substrates produced, measurements of the vegetative growth parameters of the rubber plants were carried out monthly during and at the end of the nursery cycle, from the first to the sixth month after transplanting (JAR). These measurements related to the height (mm), the diameter at the collar (mm). The total height H (mm) of the plant was measured from the collar (at ground level) to the apical end of the plant using a graduated ruler. The diameter of the DC stem (mm) of the plant, was determined at 5 cm from the ground using a caliper type Stainless Hardened. Average monthly increases in height (ΔH) and in diameter at the collar (ΔC) were obtained according to the following formula:

$$\Delta\ (H, C)\ mm.month^{-1} = M_i - M_{i-1} \quad (1)$$

Where Mi and Mi^{-1} are two measurements made at successive observation stages.

The determination of the average monthly increase made it possible to determine the growth gain expressed as a percentage of the ratio with the control substrate S1, taken as a reference.

$$Gain\ (\%) = \Delta\ (H, C)_{substrate} \times 100 / \Delta\ (H, C)_{control} \quad (2)$$

Δ (H, C) substrate: Average increase (H, C) of the substrate (2, 3, 4, 5 and 6)

Δ (H, C) witness: Average increase (H, C) of witness (S1)

3.5.2 Production of rubber plant material

To assess the performance of the cultured substrates on the time taken to produce rubber tree plant material (time for grafting), we opted for "green" grafting, which is generally carried out with very young plants, 4 to 6 months (Compagnon, 1986) [8]. However, the Hévéa Development Fund (FDH) requires the practice of grafting so-called "vigorous" plants, which have a caliber greater than or equal to 10 mm in diameter (Compagnon, 1986; Elabo *et al*., 2014) [8, 11]. The rate of graftable plants (TxG), determined from the 4th to the 6th month after transplanting and the success rate of grafting (TxR), determined by carrying out a success check of the grafting operation (42 days after grafting) were calculated according to the following formula:

$$\mathbf{TxG}(p.c.) = \frac{NbPt\,(10)}{NbPtT} \times 100 \quad (3)$$

TxG (%): Rate of graftable plants;
NbPt (10): Number of Plants with a diameter greater than or equal to 10 mm;
NbPtT: Total Number of Plants.

$$\mathbf{TxR}(p.c.) = \frac{NbPtR}{NbPtP} \times 100 \quad (4)$$

TxR (%): Graft Success Rate
NbPtR: Number of plants actually successfully grafted;
NbPtP: Number of Plants Placed.

In the rubber tree, a graft is considered to be definitively successful, if 42 days after grafting, the graft is alive (Compagnon, 1986) [8]. In addition, the uprooting of plants begins 60 days after grafting provided that the plants have a dimension of 20 to 40 mm in diameter at the neck (Elabo *et al*., 2014) [11]. The diameter measurements at the collar (D) made two months (60 days) after grafting, therefore, made it possible to determine the rate of plants transferable to the TxT field (grafted plants having a diameter greater than 20 mm) after the operation. To check the success of plants that have successfully grafted.

$$\mathbf{TxT(p.c.)} = \frac{NbPt(20)}{NbPtT} \times 100 \quad (5)$$

TxT (%): Rate of plants Transferable to the field after grafting
NbPt (20): Number of grafted Plants with a diameter greater than or equal to 20 mm;
NbPtT: Total Number of Plants received at grafting.

3.6 Data processing
Vegetative growth data for seedlings in the nursery was captured and processed using the Excel spreadsheet. One-factor analysis of variance (ANOVA) was used to assess the effects of applying the compost produced on the vegetative growth parameters of the plants. The mean values were classified using the Fisher's smallest significant difference (ppds = Lsd) method. The probabilities were assessed at the threshold of α = 0.05.

Results and discussion
4. Results
4.1 Vegetative behavior of rubber plants as a function of growing media
4.1.1. Aerial vegetative growth (H and DC) of rubber plants
Figures 4 and 5 show the evolution of the vegetative growth parameters (H and DC) of rubber tree plants in the nursery, over an observation period of 165 JAR (days after transplanting) at the Bimbresso site. The results obtained allow the following observations to be made:
- the analysis of the first two measurements (15th and 45th JAR) carried out showed no significant difference (*p*> 0.05) between the culture substrates or treatments tested for all the vegetative growth parameters combined (H, DC). The mean values at these observation stages range from 256.39 to 481.22 mm, for the height, from 3.73 to 5.33 mm, for the diameter at the collar;
- from the 3rd to the 6th stage of observations (from 75th to 165th JAR), highly significant differences (*p* <0.01) between the culture substrates were observed, in particular, in terms of height (H) and the diameter at the collar (DC);
- in general, compost-based substrates S3 (27 $t.ha^{-1}$, dose of 300 g of compost per plant), S4 (54 $t.ha^{-1}$ of compost per plant) and S5 (27 $t.ha^{-1}$ compost per plant combined with a fractionated supply of urea) are more efficient than the control substrate S1 (without compost), with statistically significant differences for the vegetative growth parameters studied throughout the duration of the experiment.

Thus, the average values of the growth in height, at the end of the experiment, were 1344.36 mm, 1281.10 mm and 1248.04 mm, respectively, for the substrates S3, S4 and S5 against 1126, 81 for the control substrate S1 (without addition of fertilizer). Furthermore, these same trends were observed in the diameter at the collar (DC) of the plants. The highest mean values observed were 13.84 mm, 13.41 mm, and 13.00 mm, respectively, for the substrates S3, S4 and S5 against 11.54 mm for the control substrate S1.

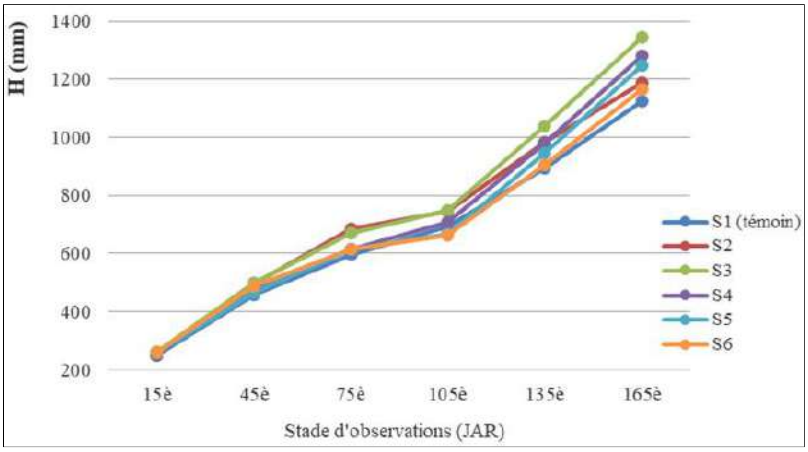

Fig 4: Evolution of growth in height (H) of rubber tree plants in the nursery as a function of growing substrates

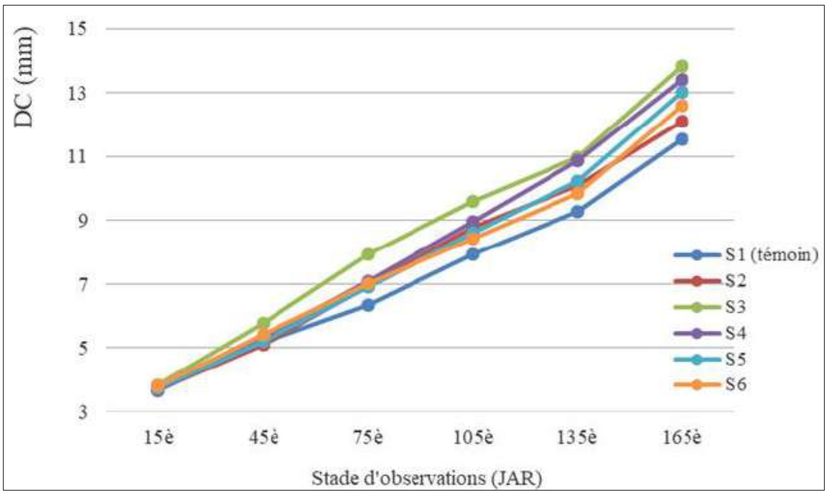

Fig 5: Evolution of the diameter growth at the collar (DC) of rubber tree plants in the nursery according to the culture substrates.

4.1.2. Average monthly increase in height, collar diameter and growth gain (%) compared to the control substrate

In response to the different growing media used, the average monthly increase (mm.month^{-1}) in height (ΔH) and in diameter (ΔD) varied throughout the vegetative stage of the plants (Tables 2 and 3). The analysis of variance carried out at the end of the observation on the average monthly increases did not reveal any significant difference ($p > 0.05$) between the growing media, although the vegetative growth was influenced by the growing media to compost base. Average values varied from 175.04 to 216.73 mm.mont^{-1} (height) and from 1.57 to 2.00 mm.mont^{-1} (diameter), respectively, for substrates S1 (control) and S3 (27 t.ha^{-1}, dose of 300 g of compost per plant).

Compost-based substrates allow significant growth gains in height and diameter at the collar compared to the plants of the control substrate (S1). The growth gains were 13.10 to 23.82 %, respectively, for the substrates S5, S4 and S3 as regards the height growth of the plants, and from 12.34 to 27.88 %, respectively, for S6, S4, S5 and S3 substrates at the collar diameter. However, the addition of compost based on chicken droppings certainly induced better vegetative growth of the plants, but, at high doses (in particular, the substrate S6), a depressive state of growth delays in height and diameter at the collar were observed in relation to the plants of the substrate S2 (fractional supply of urea).

Table 2: Average monthly height increase (H) and growth gain compared to the control substrate (S1) at the Bimbresso site.

Substrate of culture	ΔH1	ΔH2	ΔH3	ΔH4	ΔH5	ΔHmoy	Gain (%)
S1 (control)	208.29 b	136.25 bc	98.47 a	201.14 b	231.03 b	175.04 a	0.00
S2	243.63 a	189.72 a	60.54 abc	237.47 ab	207.25 b	187.72 a	7.25
S3	239.45 a	172.00 ab	75.05 abc	291.04 a	306.12 a	216.73 a	23.82
S4	224.92 ab	135.53 bc	90.81 ab	274.57 a	300.40 a	205.24 a	17.26
S5	206.67 b	149.09 bc	51.26 bc	281.86 a	301.00 a	197.97 a	13.10
S6	226.04 ab	126.24 c	48.41 c	241.68 ab	260.54 ab	180.58 a	3.17
MG	224.83	151.47	70.76	254.63	267.72	193.88	
p	0.02	0.01	0.03	0.04	0.02	0.97	

The letters a, b and c indicate significantly different mean values in the column at the threshold α = 0.05; p: Probability, MG: General Average ΔH: Average height increase (mm.month^{-1}) for two stages of observations ΔHmoy: Average monthly increase in height (mm.month^{-1}) during the test Gain (%): Height gain gain compared to the control substrate (S1)

Table 3: Average monthly increase in collar diameter (DC) and growth gain compared to the control substrate (S1) at the Bimbresso site

Substrate of culture	ΔC1	ΔC2	ΔC3	ΔC4	ΔC5	ΔCmoy	Gain (%)
S1 (control)	1.46 b	1.17 c	1.60 a	1.33 a	2.27 bc	1.57 a	0.00
S2	1.40 b	1.84 ab	1.86 a	1.29 a	2.04 c	1.69 a	7.63
S3	1.96 a	2.17 a	1.65 a	1.38 a	2.86 a	2.00 a	27.88
S4	1.69 ab	1.76 ab	1.88 a	1.88 a	2.55 ab	1.95 a	24.71
S5	1.48 b	1.71 b	1.70 a	1.60 a	2.80 a	1.86 a	18.50
S6	1.60 ab	1.60 bc	1.41 a	1.43 a	2.76 ab	1.76 a	12.34
MG	1.60	1.71	1.68	1.49	2.55	1.80	
p	0.00	0.01	0.91	0.77	0.02	0.68	

The letters a, b and c indicate significantly different mean values in the column at the threshold α = 0.05; p: Probability, MG: General Average ΔC: Average increase in diameter (mm.month^{-1}) for two stages of observations ΔCmoy: Average monthly increase in diameter (mm.month^{-1}) during the test Gain (%): Growth gain in diameter at the collar compared to the control substrate (S1)

4.2. Evolution of the rate of graftable plants (TxG)

The evolution of the rate of graftable plants was influenced by compost-based substrates from the 75 th JAR with clear significant differences ($p < 0.05$) between treatments (Figures 6). The S3 substrate favored an important vegetative development of the plants throughout the duration of the experiment. The rate of graftable plants varied from 27.93 to 99.02 % from 75th to 165 th JAR for S3 culture substrates. By comparison between the treatments applied, the low-dose compost substrate (S3) made it possible to obtain the highest levels of graftable plants, reaching 90.20 % from the 135 th JAR and 81.57 % at 165th JAR.

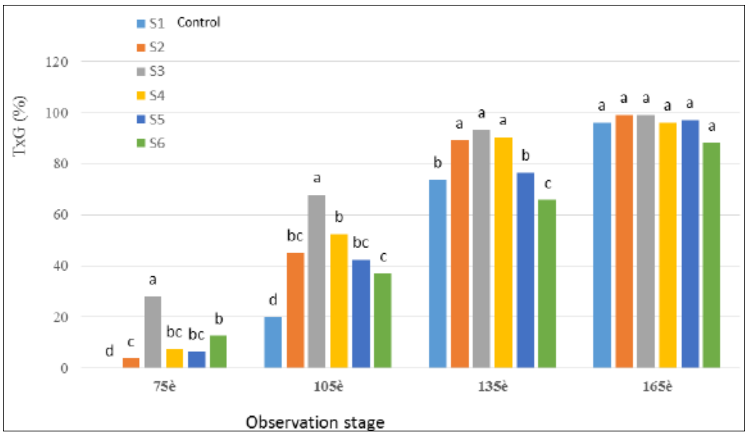

Fig 6: Evolution of the rate of TxG graftable plants (φ ≥ 10 mm) as a function of the culture substrate over time (observation stage) at Bimbresso

4.3. Graft success rate (TxR)

Forty-two (42) days after grafting, the success rates for grafting varied from 92.61 to 100 % respectively for the substrates S2 and S4. The lowest success rates for grafting were observed with the culture substrates S2 (92.61 %) and S4 (81.86 %) (Figure 7). Whereas the success rates for grafting the culture substrates S1, S3, S4, S5 and S6 were statistically equivalent ($p \geq 0.05$).

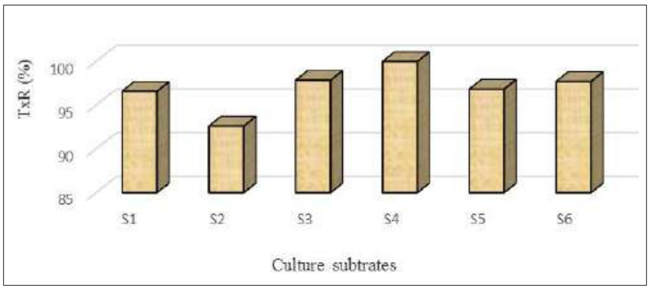

Fig 7: Success rate (TxR) for grafting as a function of culture substrates

4.4. Rate of plants transferable to the field (TxT) after the period of 60 days after grafting (JAG)

Compost-based growing media had an effect on the rate of plants transferable to the field ($20 \leq \varphi \leq 40$ mm) 60 days after grafting. The highest average rates of field transferable plants were obtained with S3 substrates (71.13 %) compared to the rate of control substrate S1, which was around 25.42 % (Figure 8). Furthermore, the average rate of plants transferable to the field for all compost-based substrates (71.17 %) was significantly higher than that of the control substrates S1 (25.42 %) and fractionated supply of urea S2 (30.46 %).

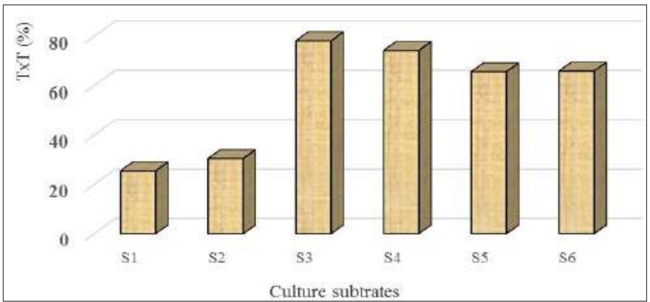

Fig 8: Rate of TxT transferable plants ($\varphi \geq 20$ mm) in the field at 10 months

5. Discussion

In terms of growth of rubber tree plants in the nursery, compost-based substrates performed better than the control substrate (S1), with statistically significant differences for the dimensional (height and diameter) and weight (plant rate) parameters. Graftable TxG and rate of plants transferable to the TxT field). The average values of the monthly increase in diameter at the collar (ΔC), the most important parameter in the management of a rubber tree nursery, were significantly greater for the plants of compost-based substrates: 1.76; 1.86; 1.95 and 2 $mm.month^{-1}$, respectively, for the substrates S6, S5, S4 and S3, against 1.57 $mm.month^{-1}$ for the plants of the control substrate (S1), and even greater than that observed by Compagnon (1986) [8], which is around 1.5 $mm.month^{-1}$ on average. In addition, compost-based substrates made it possible to achieve significant growth gains ranging from 3.17 to 23.82 % in height and from 12.34 to 27.88 % in diameter, compared to the plants of the control substrate S1. This difference in growth observed with compost-based substrates is linked on the one hand, to the maturity of the compost obtained and, on the other hand, to its richness in nutrients. The nutrients from the mineralization of chicken droppings (Biekré *et al*., 2018) [4] and dry straw from Panicum must have enriched the soil and contributed favorably to the development of rubber plants, compared to plants from the substrate. Witness (S1).

This confirms the observations made by Amadji *et al*., (2009) [3] after using the compost enriched with chicken droppings for the production of cabbage on sandy soil, and Essehi *et al*., (2016) [12] on the impact of organic fertilization on some characteristics of the soil and on the growth parameters of the rubber tree in the installation phase at Bonoua, in the south of Côte d'Ivoire. These results indicate that the nutrients, in this case nitrogen, phosphorus and potassium, were more available in compost-based growing substrates than in the other substrates (S1 and S2). However, the addition of compost based on chicken droppings induces, admittedly, better vegetative growth of the plants, but, in high doses (2D: 600 g of compost per plant or 54 $t.ha^{-1}$), a depressed state and growth delays in height and diameter at the collar are observed with respect to the plants of the 1D substrate (300 g of compost or 27 $t.ha^{-1}$). This suggests that the transfer of nutrients from the soil to the rubber plants was less important with the dose of 600 g of compost per plant. The opposite would have been logical, since Dorn *et al*., (1985) [10] reported that the higher doses provide more plant nutrients.

These observed delays could also be the result of the alkalizing action of the compost on the soil, which would obviously have reduced the acidity of the soil (Bray and Weil, 2002) [5]. According to the results of container growing, Compagnon (1986) [8] indicates that the rubber tree is a very hardy acidophilic plant capable of adapting to variations in soil pH. However, in the nursery, hevea growth is hindered on soils with a pH above 6.0. This phenomenon has been clearly demonstrated in experiments on container cultures where chlorosis and growth defect manifested themselves from pH 6.5 (Rhines *et al*., 1952) [19]. Furthermore, Ferrand (1944) [13], making this same observation, declined the methods using the practice of burning in the development of forest soils intended for the rubber tree nursery. According to this author, the pile of ash left, after burning stumps of wood, locally alkalizes the earth and makes spots on which the young rubber trees refuse to grow. This depressive effect of the compost is not linked to the immaturity of the compost but to the doses of compost provided (Abad *et al*., 1997; Compaoré *et al*., 2010) [1, 9]. There would therefore be a threshold beyond which any additional contribution could hinder the development of plants. A reasonable application of chicken droppings compost at a dose of 300 g per plant or 27 $t.ha^{-1}$ would be wise for the sustainable production of rubber tree plants in bag nurseries on sandy clay soil. The higher rates of graftable plants (TxG) and field transferable plants (TxT) observed with compost-based substrates could be a good performance indicator for the use of compost for making growing substrates.

Conclusion

The results obtained, at the end of the study on the vegetative behavior of rubber plants (*Hevea brasiliensis* Muel Arg.), Showed that significant qualitative improvements were recorded in rubber plants grown in substrates based on compost compared to the plants of the control substrates. The rubber trees grown in compost-based substrates were significantly better developed and more efficient. The use of compost as an organic soil fertilizer has proven to be useful for improving soil fertility. However, at high doses (600 g of compost per plant or 54 $t.ha^{-1}$), growth retardation is observed. There would therefore be a threshold beyond which any additional input could hinder the development of rubber plants. A reasonable application of chicken droppings compost at a dose of 300 g per plant or 27 $t.ha^{-1}$ would be wise for the sustainable production of rubber tree plants in bag nurseries on sandy clay soil.

Conflict of interest

The authors do not declare any conflict of interest.

Author contributions

For this work, BMM and BEK carried out the entire sampling and took an active part in the data processing and the preparation of the document. As for AK and BEK, they were very present in the data processing and the preparation of the final document. KYJ made its research laboratory available to the team and provided the working equipment.

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