International Journal of Plant & Soil Science

Volume 36, Issue 9, Page 378-390, 2024; Article no.IJPSS.122134
ISSN: 2320-7035

Effect of Vermicompost and Vermicompost Tea on Vegetative Growth of Rubber Plants under Nurseries Conditions

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2024/v36i94987

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/122134

Original Research Article

Received: 28/06/2024
Accepted: 30/08/2024
Published: 05/09/2024

ABSTRACT

Success in rubber growing is linked to the production of vigorous plants in the nursery. However, this cruel stage faces difficulties related to the cost of chemical fertilizer and its availability. This work carried out in 4 localities (Bimbresso, Alépé, Abengourou and Daoukro) in Côte d'Ivoire aimed

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Cite as: *Essehi, Jean Lopez, Zokagon Sylvain Sehi, Antoine Koffi, Djézou Konan, and Samuel Obouayeba. 2024. "Effect of Vermicompost and Vermicompost Tea on Vegetative Growth of Rubber Plants under Nurseries Conditions". International Journal of Plant & Soil Science 36 (9):378-90. https://doi.org/10.9734/ijpss/2024/v36i94987.*

to improve the production of rubber plant material in nurseries in polyethylene bags using vermicompost and vermicompost tea. The experimental design used is a Fisher block with three treatments and two repetitions. The vermicompost, vermicompost tea and control factors were compared with each other. The addition of vermicompost tea and the control for three months while the addition of vermicompost was done only once. The results indicated that vermicompost tea is the most effective treatment for the vegetative development of plants regardless of the study site. In Bimbresso, the vermicompost tea and vermicompost treatments showed the highest increases with 1.23 and 1.21 mm.month^{-1}, compared to 1.13 mm.month^{-1} for the control and the highest average values of diameter at the collar. 10.1 mm was obtained with vermicompost tea. Also, the highest rate of graftable plants, grafting success and plants transferable to the field was obtained with vermicompost tea. Likewise, the mortality rate obtained with vermicompost and vermicompost tea was less than 20%. These treatments could be recommended in the production of rubber plant material.

Keywords: Vermicompost; vermicompost tea; nursery; Hevea brasiliensis; Côte d'Ivoire.

1. INTRODUCTION

Agriculture is the backbone of Côte d'Ivoire economy. This sector represents approximately 33% of GDP and 66% of the country's export earnings. It employs more than two thirds of the country's active population [1]. Côte d'Ivoire is the world's leading producer of cocoa, the leading producer of rubber in Africa and the third African producer of cotton and coffee [1]. Agriculture has contributed significantly to the growth of the Ivorian economy and continues to be its cornerstone. In addition to its economic role, agriculture makes Côte d'Ivoire a mosaic of agricultural lands, patiently shaped by human labour, each with its combination of different modes of production: cash crops, food crops, livestock, market gardening, fruit and horticultural production, forestry, etc. However, this important agricultural economy, dependent on its land resources and their potential, is subject to significant degradation and a decline in soil fertility [2]. Indeed, in Côte d'Ivoire, soils are subject to increasingly intensive agricultural exploitation due to the growing needs generated by demographic growth and the lack of arable land [3]. The major constraint famers mentioned is the gradual decline in the production capacity of cultivated land. This situation results from inadequate management of land fertility. However, agricultural by-products and other organic materials considered as waste are widely available and renewable. They can be recovered in the form of soil amendment products as they are or transformed by various techniques. Composting is one of the processing techniques, allowing for organic matter to be sufficiently developed to release nutrients into the soil-plant complex. However, the commonly used compost certainly enable an improvement in the physicochemical properties of the soil and soil fauna. Still, it could contain heavy metals that can deteriorate agricultural product's nutritional quality [4]. Considering all its disadvantages, biofertilizers (vermicompost and vermicompost tea) are credible alternatives for the farming community, particularly among rubber tree nurseries. These organic fertilizers are the products of a new technology called vermitechnology. This technology is a method of converting and recovering organic waste into organic fertilizers useful to plants by earthworms' contribution [5,6]. This natural, odourless aerobic process is different from conventional composting. This process produces a compost, which does not include a thermophilic phase (no heat) in its production, and a liquid, called "vermicompost tea or compost juice or tea" [7]. The effectiveness of vermicompost and vermicompost tea in soil fertilization and phytosanitary protection of plants has been proven by several studies [8,9]. However, the use of this innovative technology in rubber growing remains to be desired, particularly in Côte d'Ivoire, while Ivorian rubber growers are faced with the problem of fertilizing rubber plants. This study aims to improve the production of rubber plant material using organic fertilizers (vermicompost and vermicompost tea) of earthworm metabolic products.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted from September 2021 to July 2022 in four localities in Côte d'Ivoire, they are the Bimbresso Research Station of the CNRA, Alépé, Daoukro and Abengourou (Fig. 1).

The choice of these localities was based on the high representativeness of rubber cultivation. The experimental site of the CNRA Bimbresso Research Station (N 05° 18' 45.2" and W 004° 9' 18.9"), in the commune of Songon, in the South-East of Côte d'Ivoire, 24 kilometers from Abidjan, on the Abidjan – Dabou axis. The department of Alépé is in the South-East of Côte d'Ivoire between (N 05° 17' and 6° 70' and W 004° 66' and 3° 43'). The town of Alépé is located at 45 km northeast of Abidjan. The Abengourou department is in the East of Côte d'Ivoire, in the Indénié-Djuablin region, between latitudes (N 05° 45 and 7° 10 and W 003° 10 and 3° 50). Finally, the Daoukro department (N 06° 55' and 7° 32' and W 003° 29' and 4° 34') is in the N'zi Comoé region, in the Centre-East of Côte d'Ivoire. According to information from Sodexam [10], the experimental site of the CNRA Research Station of Bimbresso and the Department of Alépé is marked by a transitional humid subtropical climate with four seasons including a long dry season from January to February, a long rainy season from March to July, a short dry season in August and a short rainy season from October to December.

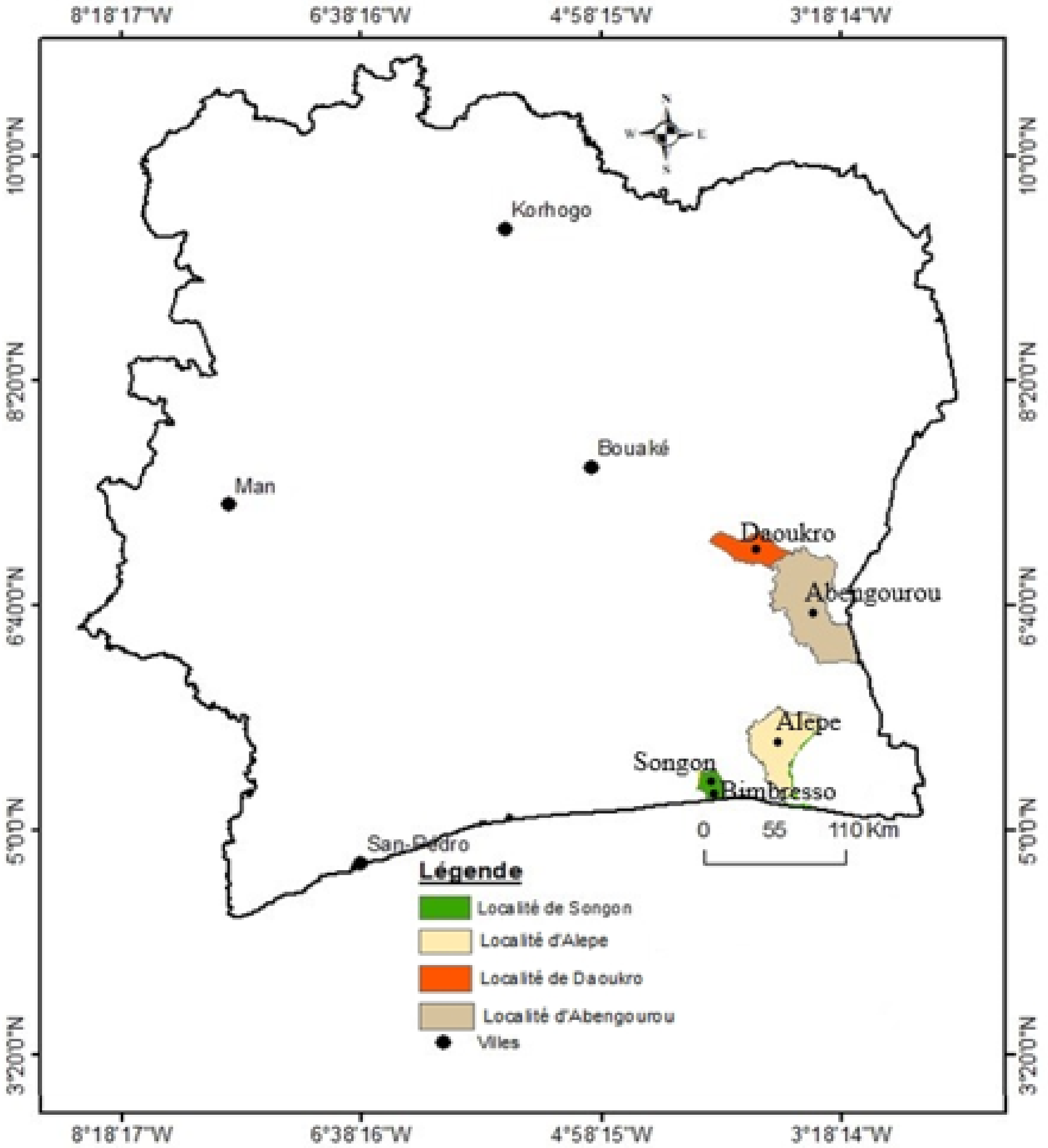


Fig. 1. Localisation of study sites

2.2 Vegetal Material

The GT1 clone of *Hevea Brasiliensis* was used as rootstock. This clone was selected for its high success rate in grafting plants [11]. The plant material used to graft the plants varies from one nurseryman to another. These grafts come from the five clones popularized in rural areas in Cote d'Ivoire. The clones are GT 1, PB 217, IRCA 41, IRCA 230 and IRCA 331.

2.3 Fertilizer Material

Vermicompost tea, vermicompost and mineral fertilizers were used for soil fertilization. Urea (46% N), Super-Gro (Biofertilizer used by rubber tree nurseryman producers), NPK and Fertimax are the mineral fertilizers used as controls in the experimental plots.

2.4 Production of Organic Fertilizer (Vermicompost and Vermicompost Tea)

The production of organic fertilizers (vermicompost and vermicompost tea) starts from a pre-decomposition of chicken droppings in black tarpaulins lasting approximately 1.5 to 2 months, depending on the number of turnings and watering on the site (Fig. 2 A). After the partial decomposition stage, the pre-decomposed organic matter is put into drums with a volume of 100 l fitted with a tap at the base. These drums are filled in successive layers from the base to the opening as follows:

- laying a layer of rubble or crushed granite 10 to 20 cm thick (Fig. 2 B).
- laying a layer of fine sand 5 to 10 cm thick (Fig. 2 B).
- laying a layer of mature compost (chicken droppings) 40 to 65 cm thick (Fig. 2 B)
- introduce of 50 to 60 individuals of mature earthworms per barrel, preferably of the Eisenia genus (Fig. 2 C).
- supply of water, with a volume of 2 l in a drainer suspended from the table above the barrels.

All these activities made it possible to produce vermicompost and vermicompost tea in the production device presented in Fig. 2D.

Fig. 2. Vermicompost and vermicompost tea production steps A: Pre-decomposing chicken droppings; B: Rubble, sea sand, pre-decomposed chicken droppings; C: Earthworms of the genus *Eisenia* introduced into the filled barrel; D: Complete assembly of a vermicompost and vermicompost tea production device with drainers, 100 l drums and 25 l cans to collect the vermicompost tea [12]

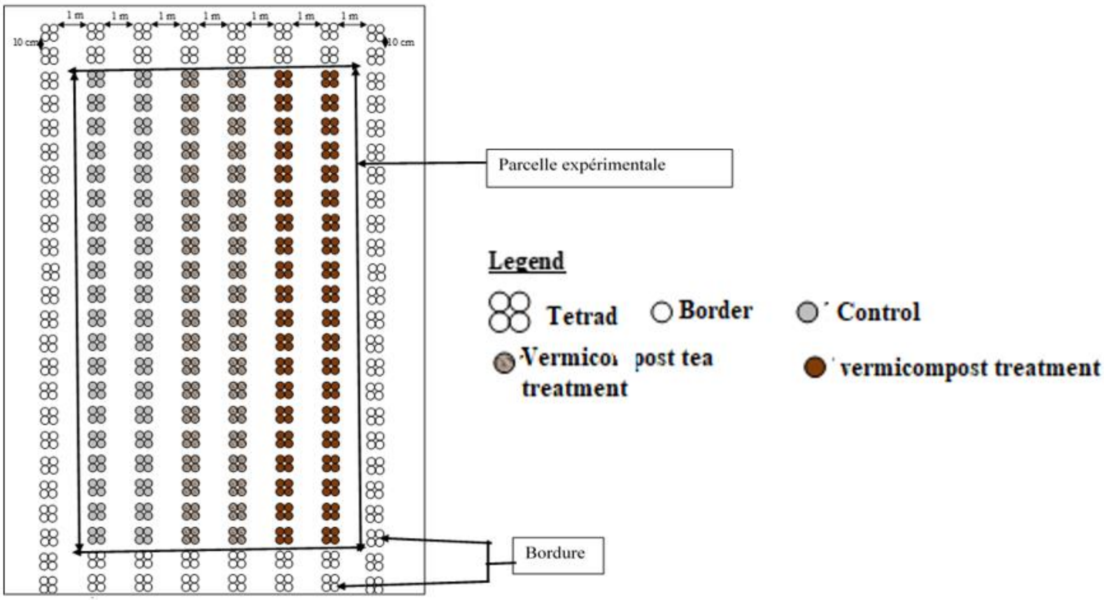


Fig. 3. Experimental design

2.5 Experimental Design

The experiment, on all study sites, was carried out using a Fisher block design with 3 treatments (control, vermicompost and vermicompost tea) and repeated twice (Fig. 3). The blocks, being separated by 1 m, are each made up of 80 tetrads spaced 20 cm. Each treatment contains 320 plants, or 960 plants for the three treatments. The vermicompost treatment bags were filled with 2/3 potting soil and 1/3 vermicompost. As for the vermicompost tea treatment consisted of applying the vermicompost tea in polyethylene bags, filled entirely with potting soil, at the foot of each plant, 3 times during the experiment (45th; 105th and 165th day after transplanting). Before application, the vermicompost tea was diluted to 50% with water. The control treatment was the usual practice of nurserymen for fertilizing plants in nurseries. This treatment was the application of urea (46% N) on the Bimbresso site, Fertimax on the Alépé site, Super-Gro on the Abengourou site and NPK at Daoukro site according to the recommended doses. Each plant receives 4 g of urea diluted in 50 ml of water.

2.6 Collection of Data

2.6.1 Monitoring vegetative growth parameters

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 1st to the 6th month after transplanting. These measurements are taken, based on the height (mm) and the diameter at the collar (mm). The measurement of these two parameters (height and diameter at the collar) made it possible to calculate the average monthly increase in height (ΔH) and diameter at the collar (ΔC), as well as the growth gain expressed as a percentage of the relationship with the control substrate taken as a reference.

$$\Delta C(\mathrm{mm.}mois^{-1}) = \frac{Mf - M_i}{\Delta t} \times 30 \qquad (1)$$

ΔC : Average monthly increase in collar diameter and height ;
Mf**:** Final measurement,
Mi: Final measurement.
Δt : Period between final measurement and initial measurement

2.6.2 Production of rubber plant of nursery

- **Rate of graft able rubber plants**

The rate of graft able rubber plants, determined from the 6th month after transplanting, was calculated according to the following formula:

$$T \times G\ (\%) = \frac{NbPt(9)}{NbPtT} \times 100 \qquad (2)$$

TxG (%): Rate of graftable rubber plants.
NbPt (9): Number of plants with a diameter ≥ 9 mm [13].
NbPtT: Total number of plants.

- **Grafting success rate**

The grafting success rate, expressed as a percentage, is equal to the ratio of the number of successful grafts to the total number of grafts placed.

$$T \times R\ (\%) = \frac{NbPtR)}{NbPtP} \times 100 \qquad (3)$$

TxR (%): Grafting success rate.
NbPtR: Number of plants successfully grafted,
NbPtP: Number of plants planted.

- **Rate of plants transferable to the field**

The diameter measurements at the collar taken 60 days after grafting made determining the rate of plants transferable to the field possible. A rubber plant in the nursery, successfully grafted, can be transferred to the field when it reaches a collar diameter greater than or equal to 15 mm [13,14]. The rate of plants transferable to the field is formulated as follows:

$$T \times T\ (\%) = \frac{NbPt\ (15)}{NbPtT} \times 100 \qquad (4)$$

TxT (%): Rate of plants transferable to the field after grafting;
NbPt (15): Number of grafted plants with a diameter greater than or equal to 15 mm
NbPtT: Total number of plants received at grafting.

2.6.3 Plant mortality rate in the field

The mortality rate of rubber plants was determined according to the following formula:

$$TM\ (\%) = \frac{NbPtM}{NbPtT} \times 100 \qquad (5)$$

TM (%): Mortality rate.
NbPtM: Number of dead plants
NbPtT: Total number of plants per treatment

2.7 Statistical Data Analysis

Tests for comparing the means of a variable are widely discussed [13-15]. The choice of a method depends on several parameters. In this study, where it was often a matter of comparing the means of variables tested on more than two treatments, one-way analysis of variance (ANOVA 1) was used. The degree of freedom is (n – k) where n and k are the numbers of observations and groups respectively. The significance level chosen for this analysis is 5% (*p-value* ≤ *0.05*). When the difference is significant, a post-hoc test (*Tukey test*) was carried out to classify and find out which of the determine which treatment were different. This analysis was carried out with XLSTAT software version 12.0.

3. RESULTS

3.1 Vegetative Growth Parameters of Rubber Plants

- **Diameter at the collar of rubber plants**

The analysis of variance of the diameter at the collar of the rubber plants carried out at 1st measurement (50 day after transplanting) showed that there is a significant difference between the different treatments (*p-value = 0.019*) at Bimbresso (Fig. 4A). A statistical difference was observed at the 2nd measurement (79 days after transplanting) (p-value = 0.0001). The control treatment presented the highest mean diameter values (6 mm). This was followed by vermicompost (5.7 mm) and vermicompost tea (4.2 mm) treatments. The average diameter values at the collar at the 3rd measurement (167 day after transplanting) of the rubber plants of the three treatments indicated statistically similar values (8.9 to 9 mm). In Alépé, at the 1st measurement, no significant difference was observed between the average values of plant diameter (*p-value = 0.301*). The diameter varied from 4 to 4.2 mm (Fig. 4B). However, significant differences were noted in the 2nd and 3rd measurements (*p-value = 0.023 and 0.005*). The vermicompost tea treatment is the one that recorded the highest average diameter values of around 5.7 mm (2nd measurement) and 10.3 mm (3rd measurement). At Abengourou, no significant difference was observed whatever the stage of the measurements (*p-value = 0.052*) (Fig. 4C). The average values of plant diameters were 4.3 mm, 6.3 mm and 10.33 mm, respectively, at the 1st, 2nd and 3rd observations for all treatments. At Daoukro, significant differences were observed between the diameters of the plants of the different treatments at all observations (*p-value = 0.0001*, Fig. 4D). At the 1st observation, the plants of the control treatment displayed the highest average values of diameter at the collar (4.3 mm), followed by those treated with vermicompost tea (3.9 mm) and vermicompost (3.4 mm). At the 2nd and 3rd measurements, the vermicompost tea treatment presented the highest average values of 5.4 to 10.1 mm respectively at the 2nd and the 3rd measurement.

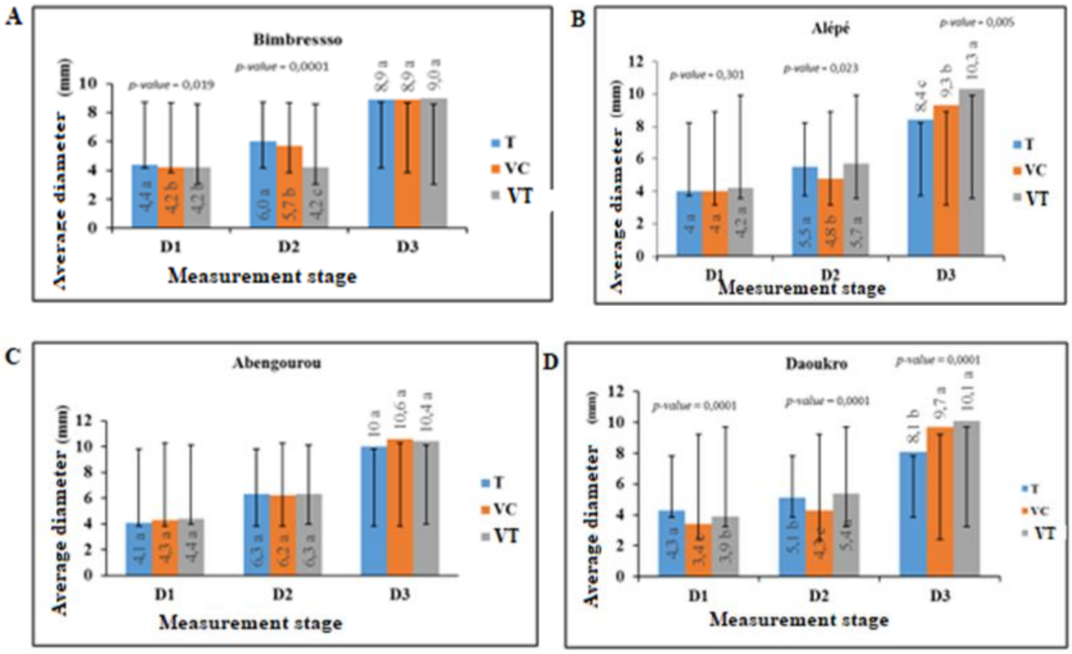


Fig. 4 (A, B, C et D). Evolution of the diameter at the collar during the 03 measurement stages in Bimbresso, Alépé, Abdennour and Daoukro. The average values followed by the same letter *a, b, c,* in the same column are not significantly different at the 5% threshold, p: Probability. T: Control, VC: Vermicompost, VT: Vermicompost tea)

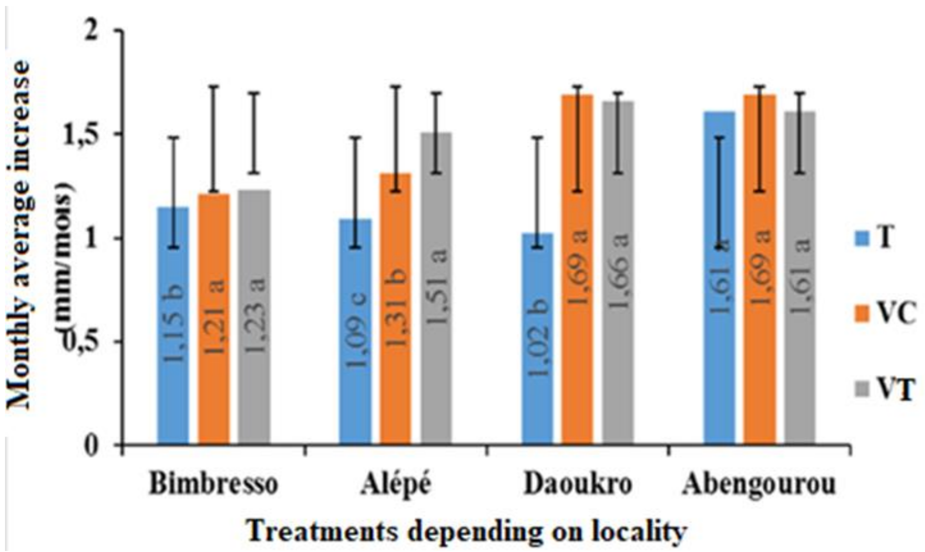


Fig. 5. The collar diameter increasing average by month with the different treatments according to the different localities (Mean values followed by the same letter in the same column are not significantly different at the 5% threshold. T: Witness; VC: Vermicompost; VT: Vermicompost tea)

- **Average monthly growth of rubber plants**

The analysis of variance of the average monthly growth of rubber plants showed that on the Bimbresso site, the vermicompost tea and vermicompost treatments favoured the highest average monthly growth for respective values of 1.23 and 1. 21 mm. month^{-1} (Fig. 5). In Alépé, statistical differences were observed (*p-value* < 0.05). The vermicompost tea treatment presented the highest average monthly increase of around 1.51 mm. month^{-1} (Fig. 5). It was followed by vermicompost treatments (1.3 mm. month^{-1}) and the control (1.09 mm. month-1). At the Daoukro site, the average monthly increase presented high values for the vermicompost (1.69 mm. month^{-1}) and vermicompost tea (1.66 mm. month^{-1}, Fig. 5) treatments. The plants in the control treatment had the lowest values (1.02 mm. month^{-1}). At Abengourou, no statistical difference was observed between the different treatments. The average monthly increase is between 1.61 and 1.69-mm. month^{-1} (Fig. 5).

3.2 Weight Dimensional Parameters

- **Rate of graftable plants**

The evaluation of the rate of graftable plants (TxG) indicated significant differences between the treatments on the four sites. In Bimpresso (Fig. 6B), this rate was higher with the control treatment (74%). It was followed by vermicompost tea treatment (71%). The vermicompost treatment recorded the lowest rate of graftable plants (69%). In Alépé (Fig. 6 B), the rate of graftable plants was high for the vermicompost tea treatment with a proportion of (71.25%). On the Abengourou experimental site (Fig. 6 C), the rate of graftable plants was high for the vermicompost tea treatment with (76.25%) and the control treatments, vermicompost showed rates of 70 and 64% respectively. Finally, in Daoukro (Fig. 6 D), the vermicompost tea treatment presented the highest rate of graftable plants (44%).

- **Success rate of plants at grafting**

The evaluation of the grafting success rate of the plants showed a good expression of the vermicompost tea (VT) treatment between the treatments on the four sites. At Bimpresso, the proportion of plants successfully grafted was higher for the vermicompost tea treatment, at 79% (Fig. 7A). It was 75% for the control treatment and 66% for the vermicompost treatment. In Alépé, the vermicompost tea and control treatments presented rates of (71.87%) and 70% of plants successfully grafted (Fig. 7B). The success rate for grafting plants from the vermicompost treatment was 53.75%. At Abengourou site (Fig. 7C), the plants from the vermicompost tea and control treatments had respective grafting success rates of 78.12 and 76.87% for the control. This rate was 65.62% for the vermicompost treatment. In Daoukro (Fig. 7D), plants treated with vermicompost tea had a grafting success rate of 45.62%, compared to 40% for the control treatment and 35.62% for vermicompost.

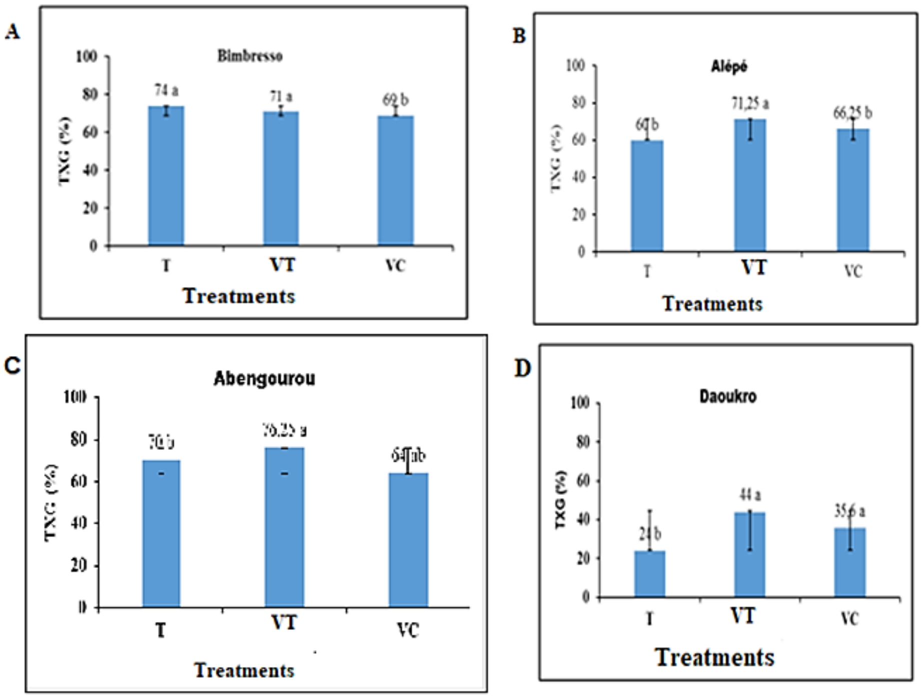


Fig. 6 (A, B, C et D). Rate of graftable plants by treatment by locality (T: Control; VC: Vermicompost; VT: Vermicompost tea)

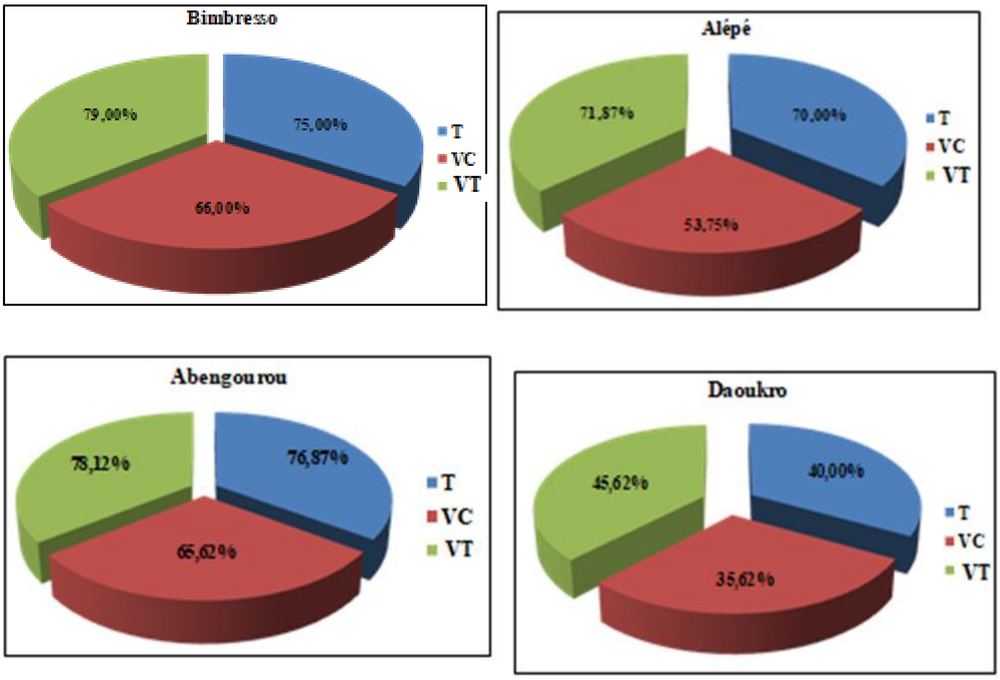


Fig. 7 (A, B, C et D). Success rate (TxR) for grafting by treatment and by locality (T: Control; VC: Vermicompost; VT: Vermicompost tea)

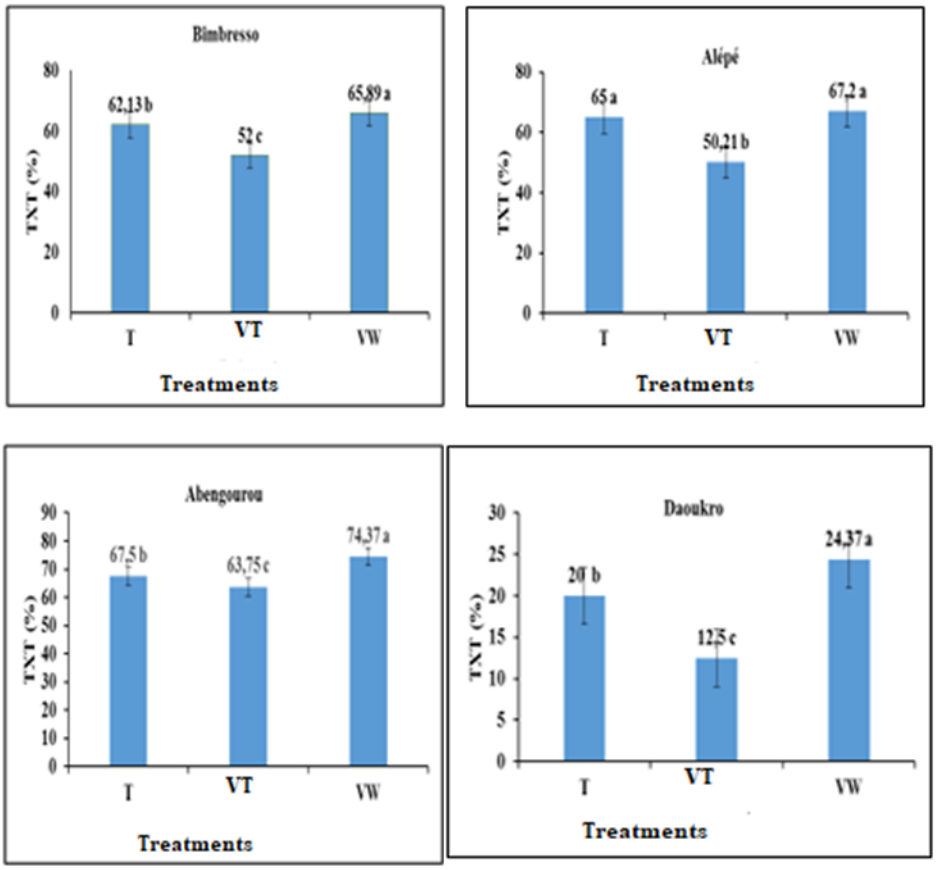
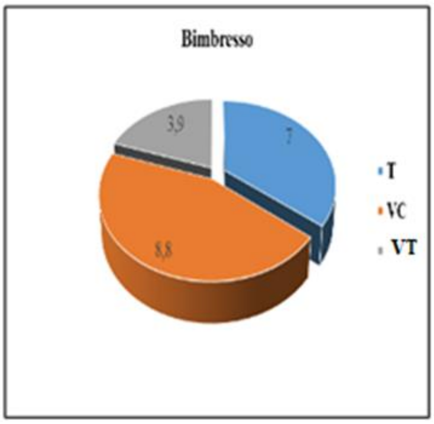
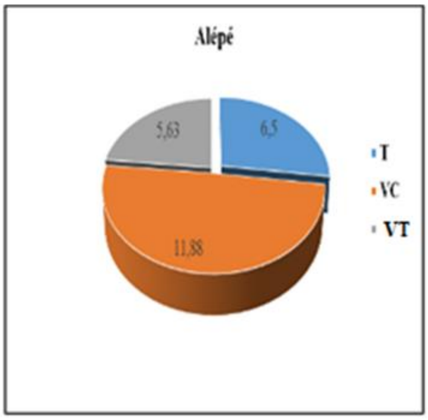


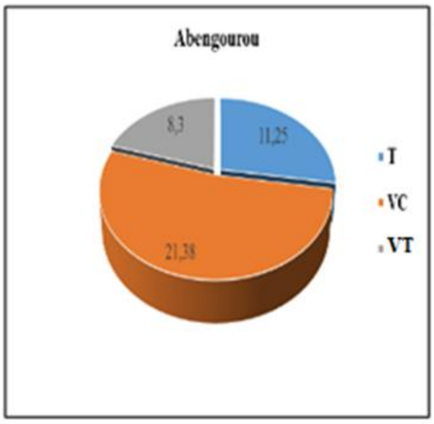
Fig. 8. Rate of plants transferable to the field at 6 months depending on the treatments on the different study sites (T: Control; VC: Vermicompost; VT: Vermicompost tea)



(A)



(B)



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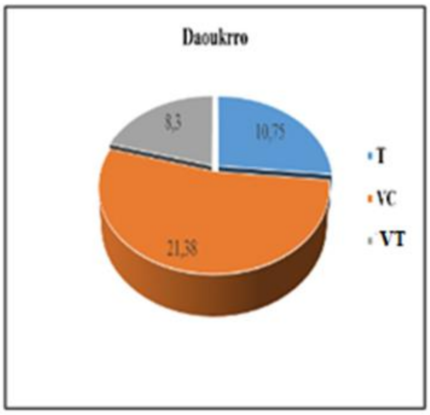

(d)

Fig. 9. Average mortality rate of rubber nesury by locality

Table 1. Mortality rate by treatment for all localities

Treatments	Mortality average rate
T	8,87 ± 2,51 b
VC	15,36 ± 3,15 a
VT	6,48 ± 2,21 b
p-value	0,301

Mean values followed by the same letter in the same column are not significantly different at the 5% threshold. T: Witness; VC: Vermicompost; VT: Vermicompost tea

- **Rate of plants transferable to the field 60 days after grafting**

The evaluation of the rate of plants transferable to the field on the Bimpresso experimental site indicated significant differences between the three treatments (*p-value = 0.030*). This rate was 65.89% for the vermicompost tea treatment. The control and vermicompost treatments have a rate of 62.13% and 52% respectively (Fig. 8). Alépé's, the rate of plants transferable to the field was higher with the vermicompost tea (67.20%) and control (65%) treatments. This rate was low for the vermicompost treatment (50.21%). At the Abengourou site, a significant difference was observed between the treatments (*p-value = 0.001*). The rate of plants transferable to the field was higher for vermicompost tea treatments with 74.37% (Fig. 8). The control treatment followed with 67.50% and the vermicompost treatment 63.75%, the lowest rate. In Daoukro, a significant difference was also observed (*p-value = 0.021*).

The rate of plants transferable to the field was consistently high for the vermicompost tea treatment (24.37%). It was 20% for the control treatment. As for vermicompost treatment, this proportion was very low (12.50%).

- **Average mortality rate of nursery of rubber tree**

On the Bimbresso experimental site (Fig. 9), the mortality rate was 8.80% for the vermicompost treatment, 7% for the control treatment and 3.90% for the vermicompost tea treatment. In Alépé, the vermicompost tea and control treatments presented mortality rates of 5.63% and 6.50% respectively. The vermicompost treatment showed a rate of 11.88%. On the Abengourou site, the highest plant mortality rate, of 21.38%, was recorded with the vermicompost treatment. Those of the vermicompost tea and control treatments were around 8.3% and 11.25% respectively. This rate was for treatment. In Daoukro, plants treated with vermicompost tea showed a mortality rate of 8.30%, those of the control (10.75%) and vermicompost (21.38%) treatments. The average mortality rate of rubber plants is presented in Table 1. The average mortality rate of plants was greater for the vermicompost (15.36%) and control (8.87%) treatments. This rate was low for the vermicompost tea treatment (6.48%).

4. DISCUSSION

The evaluation of the effect of vermicompost and vermicompost tea on the vegetative development of rubber plants in bag nurseries showed that vermicompost tea and vermicompost promote good isodiametric development of the plants with significant monthly increases. This optimal development of rubber plants in nurseries under the effect of these organic fertilizers could be explained, on the other hand, by the fact that the organic matter contained in these fertilizers improves the structure of the soil because of its bonds with the particles. Minerals and adhesive materials produced by microorganisms. Mineral elements become easily assimilated by the plant. These results are similar to those of Coulibaly [16] who showed that compost, particularly vermicompost, promotes stem development and leaf growth of *Largenaria siceraria*. On the other hand, earthworm droppings are an intimate mixture of plant and mineral particles, and the nutrients are present there in higher concentration and in a form easily assimilated by plants [14]. Additionally, the mucus secreted by earthworms during vermicomposting would increase the nitrogen content, as shown by [16, 14,15], in their work. According to these authors, earthworms have nitrogenous substances in their mucus and growth hormones such as auxins, gibberelins, cytokinins and enzymes that promote plant growth. The investigations of Abdullah [9], carried out in India, also showed that vermicompost tea and vermicompost promote good stem development as well as good foliar growth of spinach (*Spinacia oleracea*) and potato (*Solanum tuberosum*). According to Steffen [17], the nutrients in compost are slowly released into the soil at levels that strictly meet the needs of the plant and are easily assimilated. The high rates of graftable plants observed with vermicompost tea could be explained by the nutritional value of this liquid biofertilizer, which results in the rapid provision of the nutrients essential to the plant's development. Indeed, Fadhil [7] and Ndegwa [18] showed that during vermicomposting, the most important nutrients such as nitrogen (N), potassium (K), phosphorus (P) and calcium (Ca) are quickly released and become easily absorbable by the plants. These nutritional values of vermicompost tea have enabled several rubber plants to reach a significant rate of graftable plants in record time. This study also indicated that the probability of successful grafting of rubber plants in nurseries is higher with vermicompost tea on all sites. This could be explained by the good mineral element content of this organic fertilizer. Indeed, vermicompost tea, which is an aqueous extract of vermicompost, collected in the presence of an affluent population of earthworms, contains several enzymes, plant growth hormones, vitamins as well as macro and micronutrients which quickly provide nutrients to the plant during its development cycle [19]. This good availability of nutrients must have strengthened the vigour of the rootstocks by allowing them good adhesion with the scion, which favoured the resumption of the physiological process [13,20]. Vermicompost tea applied to plants was less harmful with low plant mortality rates. However, vermicompost caused more mortality of rubber plants. These plant mortality rates observed with vermicompost could be explained by the high dose of vermicompost given to the plants. Our work agrees with Essehi [12]. Indeed, these authors showed that increasing doses of organic manure, particularly compost in bags intended for nurseries, could increase the mortality rate, making these doses harmful to the plants [21].

5. CONCLUSION

The results obtained in this study showed that the use of organic fertilizers (vermicompost and vermicompost tea) promotes good radial development with optimal monthly growth of rubber plants. The nutritional values of these two have enabled many rubber plants to reach the diameter required for grafting in record time. Furthermore, the probability of success in grafting rubber plants in bag nurseries was good for vermicompost tea, with mortality rates of less than 20%. The good expression of vermicompost tea in this study indicates that this biofertilizer could be used as a substitute or in combination with mineral fertilizer, commonly applied in rubber tree nurseries in Côte d'Ivoire. Adoption of vermicompost tea in rural areas could also contribute to reducing environmental degradation. However, before any popularization of vermicompost tea and even vermicompost which was the best organic fertilizer in this study, economic research must be carried out on production costs and gains after the sale of the nursery plants.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

ACKNOWLEDGEMENTS

The authors acknowledge the Fund for Agricultural Research and Advice (FIRCA) and the Association of Rubber Professionals and Manufacturers (APROMAC) of Côte d'Ivoire for their contributions to this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
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