International Journal of Agriculture and Environmental Research

ISSN: 2455-6939

Volume: 08, Issue: 05 "September-October 2022"

EFFECTS OF VERMICOMPOST FERTILISATION ON SOME GROWTH PARAMETERS AND YIELD OF TOMATO (*SOLANUM LYCOPERSICUM* L). IN DALOA, WEST-CENTRAL OF CÔTE D'IVOIRE

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DOI: https://doi.org/10.51193/IJAER.2022.8505

Received: 02 Sept. 2022 / Accepted: 12 Sept. 2022 / Published: 20 Oct. 2022

ABSTRACT

The production of tomato, a very important vegetable for human consumption and the most widely grown in Africa, remains low to meet the needs of the Ivorian population. Also, mineral fertilisation with its certain contributions to the crop, remains costly and inaccessible to small farmers. The present study aims to assess the effects of organic fertilisation based on vermicompost on the growth and yield of the tomato *Solanum lycopersicum* L. In a Fisher block design. Three vermicompost treatments T20 (20 t/ha), T40 (40 t/ha), T60 (60 t/ha) and a control T0 were set up with four replicates in Daloa, west-central of Côte d'Ivoire. The germination rate of the tomato seeds was determined during the three weeks of nursery. The height, crown diameter and vigour index of the tomato plants were measured regularly, as well as the yield at the end of the trial. The main results show that the germination rate was higher with the lowest dose of vermicompost (20 t/ha) while the height, crown diameter and vigour index of the tomato plants increased more rapidly with increasing doses of vermicompost. Thus, the highest height (146.76 cm), the largest crown diameter (38.13 mm) and the highest vigour index (4.22) were obtained with the highest dose. Similarly, yield was favourably affected with increasing doses of vermicompost. The highest being obtained with T60. Increasing doses of vermicompost favourably influence tomato growth and yield. Organic fertilisation with vermicompost could be recommended to farmers in order to sustainably increase agricultural production.

Keywords: Organic fertilisation, Vermicompost, Growth, Yield, Tomato, Côte d'Ivoire.

1. INTRODUCTION

Population growth in sub-Saharan Africa has led to an increase in food demand. The practice of long-term fallow is disappearing, giving way to short-term fallow and sedentary agriculture [1] [2], yet in most sub-Saharan African countries, soils have a low level of fertility and exported nutrients are not adequately replaced [2]. In Côte d'Ivoire, where agriculture plays a predominant role in the economy, annual production of tomatoes, which are a very important vegetable for human consumption and the most widely grown in Africa, as they are used in many traditional dishes [3], fluctuates between 22000 and 35000 t [4]. This production remains largely insufficient to cover the estimated needs of over 200000 t [5]. In the forest zone of Côte d'Ivoire, the expansion of perennial cash crops is restricting cultivable land and forcing farmers to shorten the duration of fallow periods [6].

In view of the growing needs engendered by the increasing population and the lack of arable land, the practice of intensive cultivation and the search for new fertile land result in agricultural pressure [7]. The consequence of this pressure is the decrease in fallow land which leads to soil degradation and low crop yields [8]. The problems of soil degradation have been the subject of much research, but it should be noted that these problems remain topical and unresolved [9].

Fertilisation is the most appropriate way to provide crops with the necessary complement to the soil supply [10]. Mineral fertilisation is certainly beneficial because it increases crop productivity and makes nutrients immediately available to plants; however, its polluting effect and high cost hinder its use by farmers [11]. This fertilisation increases the immediate yield but gradually destroy the soil, leading to an increase in acidity, a degradation of the physical status and a decrease in the organic matter content [12]. Thus, the alternative to restore soil fertility and improve yields would be organic fertilisation [13]. It consists of adding organic amendments which, when incorporated into the soil improve its physical chemical and biological properties [14]. Several studies have shown that composts applied to poor acidic tropical soils can provide the necessary nutrients for plant growth and development to increase crop yields [13]. The present study, which aims to evaluate the effects of vermicompost fertilisation on vegetable crops including tomato, was carried out in west-central Côte d'Ivoire.

2. MATERIALS AND METHODS

2.1 Study site

The study was conducted in Daloa (6°84 and 6°91 North latitude, 6°41 and 6°48 West longitude), on the experimental site of the Jean Lorougnon Guédé University. Daloa, located in the centre-west of Côte d'Ivoire (Figure 1), is characterised by a Guinean climate regime with an equatorial and sub-equatorial regime with two rainfall maxima [15]. The relief is not very varied and is dominated by plateaus with an altitude of 200 to 400 m. Average rainfall is between 1400 and 1600 mm/year. The forest landscape varies progressively from semi-deciduous dense rainforest to mesophilic cleared forest [15]. The soils in this area are generally moderately desaturated ferrallitic on farmland and sandy hydromorphic on river terraces [16] [17]. The soil used was taken from the humus-bearing surface horizon (0 - 30 cm), characterised by a sandy-clay texture (10 to 15% A), a low pH (6.2), a low cation exchange capacity (6.13 cmol.kg-1) and a C/N ratio of about 10.75.

2.2 Fertilising material

The organic manure used is vermicompost. It was chosen because of its agronomic ability to improve soil fertility and boost plant growth. The vermicompost was made from earthworms and agricultural and household waste (Figure 2). The species of earthworm used *Eudrilus eugeniae* is a worm of African origin, mainly found in tropical and subtropical countries and frequently used in vermiculture and vermicomposting processes. The agricultural residues consist mainly of rice husks and household waste from cassava, banana, yam, cabbage, courgette, cucumber, onion and eggplant peelings, as well as grass clippings.

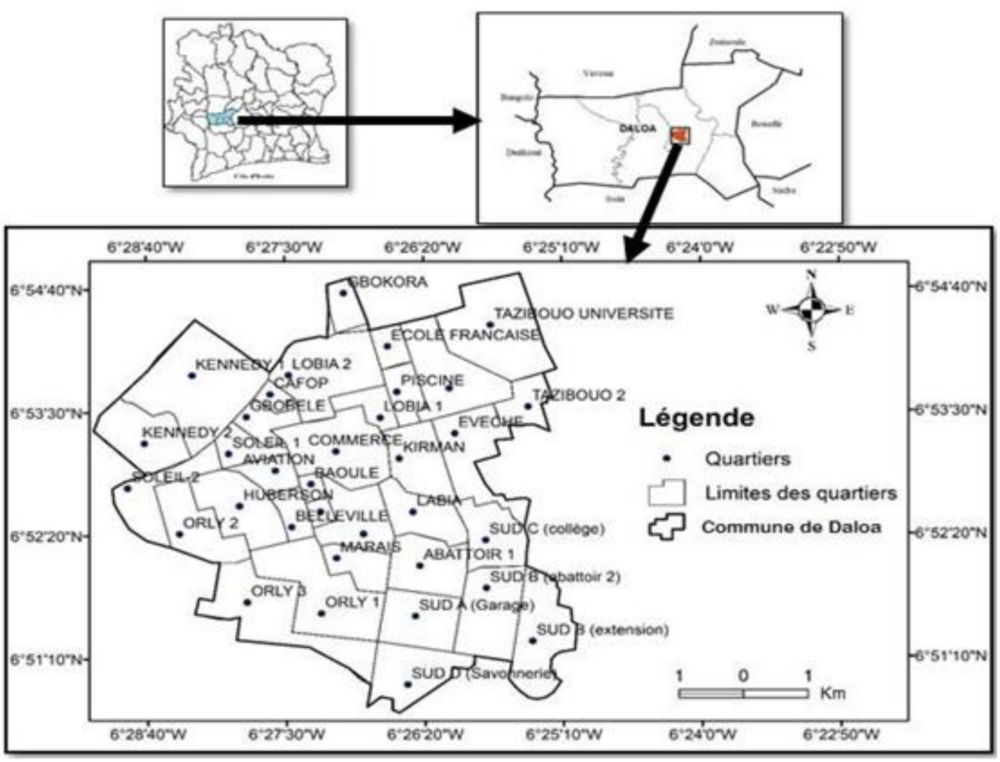

Figure 1: Location of Daloa commune

Figure 2: Fertiliser material: Earthworm Eudrilus eugenieae (A). grass clippings (B). household waste (C).

2.3 Plant material

The trial was conducted on one of the most important vegetable crops for human consumption, which is used in many traditional dishes [3]. This is the tomato *Solanum lycopersicum* L. an annual herbaceous plant of the Solanaceae family. The tomato plants derived from seeds of the F1 cobra 26 variety, constituted the plant material. This variety has a determined growth, very good vigour and productivity. The first harvest takes place 65 days after transplanting and produces tomatoes with good firmness and uniform colouring.

2.4 Technical equipment

The technical equipment consists of length measuring tools (tape measure, double decimetre, caliper), small field equipment (machetes, daba, plastic pots, honeycomb plates, diameter sieves. watering cans), and laboratory equipment (Roberval balance, OHAUS electronic precision balance).

2.5 Collection of earthworms and household waste

The worm species *Eudrilus eugeniae* was chosen for the study because of its high density in household waste piles. Individuals were collected in a place where household waste was dumped. The worms were collected by manual extraction three weeks before the start of the trial and then kept at room temperature in plastic waste buckets filled with soil of varying moisture content. Only adult or subadult individuals were collected for inoculation. Household waste was collected in different areas of the city of Daloa. It was also provided by the student catering service of the Jean Lorougnon Guede University. The characterisation of this household waste consisted essentially of a sorting to remove non-biological and non-fermentable material.

2.6 Vermicomposting

Vermicomposting consisted of inoculating natural composts with collected earthworms. To make the natural compost, a pit measuring 2 m x 1 m x 1 m, opened in a shady, non-floodable area was used as a compost bin. In this compost bin, the compostable fraction was laid out in successive alternating layers of grass clippings. household waste and rice husks to a height of one metre. The pile was then watered and the pit covered with a black tarpaulin. Two months later, earthworms were inoculated into the resulting natural compost, after the pre-composting period which allowed for the evacuation of any toxic volatile gases [18]. Earthworms were inoculated at a density of 3000 individuals per m^3. which corresponds to a rate of 3 earthworms per litre [19]. The inoculation was done in the morning. After 3.5 months, i.e. 105 days, the vermicompost was removed from the pit and air-dried for a fortnight on black tarpaulins. It was then sieved using a 2 mm mesh sieve. Three 0.5 kg composite samples of the vermicompost were made from the mixture of 9 samples taken at different locations and sent for chemical analysis to the Laboratory of Soil and Plant Analysis (LAVESO) of the Ecole Supérieure d'Agronomie (ESA), located at the Institut National Polytechnique Félix Houphouët Boigny (INP-HB) in Yamoussoukro.

2.7 Experimental design:

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The experimental design was based on the Fischer block with four treatments and four replications, a total of 16 substrates divided between four blocks. Each block consisted of four substrates made up of a mixture of soil and four doses of vermicompost, namely 0. 20. 40 and 60 t/ha. The four treatments were as follows:

- T0: soil + 0 t/ha of vermicompost (control).

- T20: soil + 20 t/ha of vermicompost (89.5 g of vermicompost for 6.5 kg of soil).

- T40: soil + 40 t/ha vermicompost (179 g vermicompost for 6.5 kg soil).

- T60: soil + 60 t/ha of vermicompost (268.5 g of vermicompost for 6.5 kg of soil).

The 16 substrates were transferred into 16 plastic pots, perforated at the base and closed with aluminium foil and spaced 0.5 m apart (Figure 3).

2.8 Conduct of the trial

A nursery was set up in a honeycomb plate in which 48 cells were used for the four treatments, 12 cells for each treatment, filled with the sieved constituted substrates. One tomato seed was sown in each well, at a depth of about one centimetre followed by watering. The tray was placed under a shade canopy. Watering was done twice a day (morning and evening). Three weeks after transplanting, four of the 12 tomato seedlings for each treatment the most developed at the stage of 4 to 5 true leaves were transplanted. Transplanting was done at the rate of one plant per substrate.

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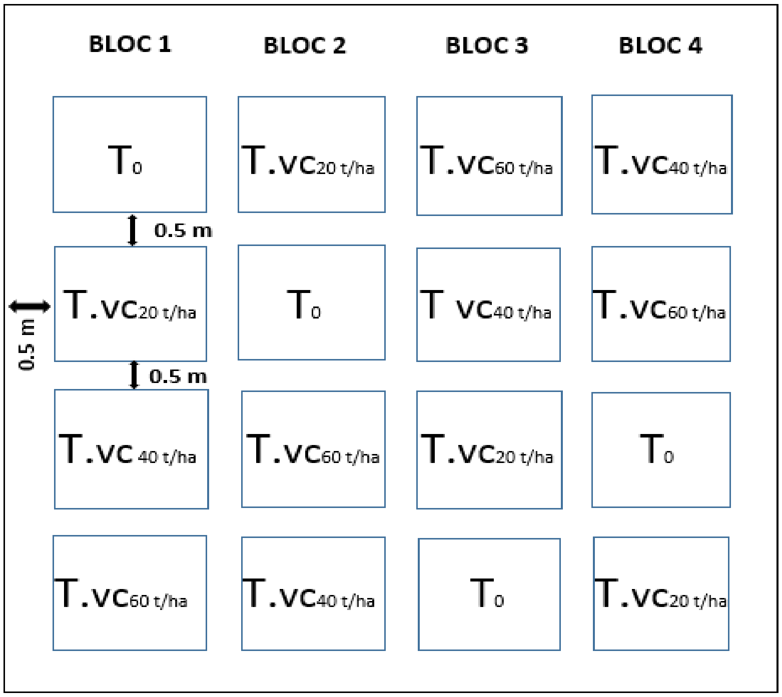

Figure 3: Experimental set-up of the study
(T.VC: Vermicompost treatment. T0 Control treatment).

2.9 Measurement of growth and yield parameters

The germination rate, an important parameter in agronomy, makes it possible to assess the percentage of seed germination after sowing. The emerged seedlings were counted in the 12 cells allocated to each treatment per block. The rate was determined each week from the 1st to the 3rd week after sowing, according to the following formula:

$TG = ng/NG \times 100$

With:

TG: Germination rate (%).

ng: Number of germinated seeds per treatment.

NG: Total number of seeds sown per treatment.

The height crown diameter and vigour index of the tomato plants were determined every fortnight from the date of transplanting to the 12th week. Four plants were measured for each treatment. The height of the plants corresponding to the length of the stem was measured with a tape measure attached to a wooden rod and the diameter at the neck with a caliper. The plant

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vigour index is an important character of plant development [20] was determined using the following formula:

$IV = \log (C^2 \times H) / 4\pi$; $C = \pi \times D$

With:

IV: Vigour index.

C: Circumference at the neck of the plants (cm).

D: Diameter at plant collar (cm).

H: Plant height (cm).

Fruit counts per plant were made on all four plants for each treatment at harvest, which took place at 12 weeks after transplanting. Each harvested fruit was weighed and yields were determined according to the following formula:

Yields (t/ha) = (Harvested fruit mass per plant (kg) / Area per plant) x 10

With:

Fruit yield (t/ha).

Fruit mass (kg).

Area occupied by the plant (m2).

2.10 Statistical analysis

The data were subjected to a one-factor analysis of variance (ANOVA 1), after checking the homogeneity of the variances. Then, the post Anova LSD Fischer test, at the 5% threshold, was performed to compare the means and deduce the homogeneous groups. These analyses were carried out using Statistica 7.1 software.

3. RESULTS AND DISCUSSION

3.1 Chemical characteristics of vermicompost

The results of the laboratory analysis of the vermicompost used are given in Table 1. These results show that the compost is well supplied with organic matter (8.9%) with a C/N ratio of 9.04 with average contents of calcium (8.4 cmol.kg-1). magnesium (3.4 cmol.kg-1) and potassium (3.1 cmol.kg-1) and phosphorus (27.17 mg.kg-1). The pH (7.5) shows that the vermicompost is relatively basic. The contents of trace metal elements (TME) are 98.3 g/kg for zinc. 12.2 g/kg for copper and 23.8 g/kg for lead.

Table 1: Chemical characteristics of vermicompost

Organic status (%)			Acidity	Phosphorus (mg/kg)	Mineral content (cmol/kg)			Metal trace element (mg/kg)		
MO	N	C/N	pHeau	P.ass	Ca^{2+}	Mg^{2+}	K^{+}	Zn^{2+}	Cu^{2+}	Pb^{2+}
8.9	0.63	9.04	7.5	27.17	8.4	3.4	3.1	98.3	12.2	23.8

3.2 Tomato seed germination rates

The germination rates of tomato seeds obtained from the different treatments are shown in Figure 4. These rates were significantly different under the effect of vermicompost (P = 0.03) at 2 and 3 weeks after transplanting. One week after sowing, the germination rates of seeds in each substrate, except T60 are above 50%. A strong improvement of these rates is observed with T0 and T20 where the values vary. Respectively, from 54 to 75% and from 62 to 83.33% but with T20, the values recorded are the highest and 3/4 of the sown tomato seeds have germinated two weeks after sowing. On the other hand treatments T40 and T60 showed the lowest rates, which showed little improvement over the three weeks of nursery, especially T60. These rates increased from 50 to 58.33% with T40 and from 41.67% to 58.33% with T60. It can be seen that the higher the dose of vermicompost, the lower the germination rates.

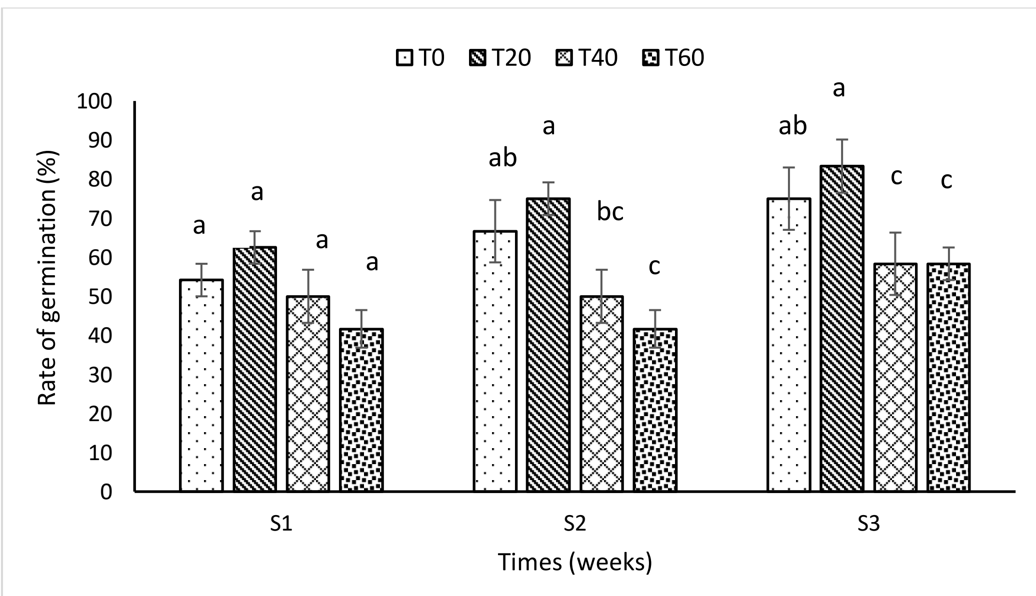

Figure 4: Germination rate (%) of tomato seeds according to treatments over time.

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3.3 Plant height

The T20, T40 and T60 treatments positively influenced tomato plant heights with increasing doses of vermicompost (Table 2). The differences between heights were highly significant for all measurement dates (P <0.001). Tomato plants grew faster on the vermicompost substrates from the 2nd to the 12th week of cultivation from 6.39 to 135.41 cm with T20 from 6.44 to 125.80 cm with T40 and from 8.93 to 146.76 cm with T60. i.e. significant gains of 129.03 cm. 119.36 cm and 137.84 cm respectively. In contrast, in the control substrates growth was slowest from 3.88 to 44.66 cm, a small gain of 40.79 cm. At the end of the trial, compared to the height of the plants in the control substrates, increases of 203.19% with T20, 181.69% with T40 and 228.63% with T60 were noted. The higher the dose of vermicompost applied, the faster the growth and the greater the increase in plant height compared to the control.

3.4 Diameter at the crown

The influence of vermicompost doses on the crown diameter of tomato plants was positive with significantly different means (< 0.001). The diameter at the crown increased more rapidly in the 12 weeks of cultivation in the vermicompost substrates, the higher the dose applied, from 9.5 to 30 mm, 12.13 to 35.38 mm and 10.50 to 38.13 mm with T20, T40 and T60, respectively. Increases of 20.5, 23.25 and 27.63 mm were noted with T20, T40 and T60 respectively. The T0 treatment showed the smallest increase in crown diameter, from 5.75 to 12.88 mm, a small gain of 7.13 mm. Compared to the crown diameter of plants on control substrates, those obtained at week 12 with T20, T40 and T60 showed increases of 133.01, 174.76 and 196.12% respectively. These increases were higher the higher the dose of vermicompost (Table 3).

3.5 Vigour index

Table 4 shows the mean values of the vigour indices of tomato plants for the different treatments. The determined vigour indices are very significantly different under the effect of vermicompost doses (< 0.001). The highest indices are presented by T60 and the lowest by T0 at all measurement dates. Their evolution, from the 2nd to the 12th week, was low with T0, from 0.99 to 2.75, while it was high with the vermicompost substrates and this according to the doses, from 1.65 to 3.97 with T20, from 1.85 to 4.09 with T40 and from 1.87 to 4.22 with T60. The growth rates obtained at the end of the trial, in relation to the vigour indices presented by the control, were 44.38% with T20, 48.44% with T40 and 53.24% with T60. The growth of the vigour index is faster with the addition of vermicompost, depending on the doses applied.

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Table 2: Evolution of the height (cm) of tomato plants according to the treatments. over time.

Treatments	Time (weeks)					
	S2	S4	S6	S8	S10	S12
T0	3.88 a ±0.09	4.31 a ±0.23	5.65 a ±1.69	13.55 a ±2.06	26.44 a ±5.69	44.66 a ±4.34
T20	6.39 b ±0.43	9.63 b ±0.90	31.25 b ±4.74	73.19 b ±4.92	102.85 ±6.53	135.41 b ±5.5
T40	6.44 b ±1.49	13.98 c ±0.65	49.74 c ±4.11	75.00 b ±4.81	107.94 b ±6.68	125.80 b ±6.59
T60	8.93 c ±0.42	16.71 d ±1.61	55.40 c ±2.86	97.10 c ±5.65	126.54 c ±5.60	146.76 c ±4.78c
Mean	6.41	11.16	35.51	64.71	90.94	113.16
Probability	0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Significance	***	***	***	***	***	***

Values with the same letter are not significantly different at the 5% level. *** = very highly significant difference.

Table 3: Evolution of the diameter at the neck (mm) of tomato plants according to the treatments, over time.

Treatments	Time (weeks)					
	S2	S4	S2	S8	S2	S12
T0	5,75 a ±0,50	9,88 a ±0,63	10,25 a ±1,04	10,63 a ±1,03	12,13 a ± 1,49	12,88 a ±1,49
T20	9,5 b ±1,00	19,25 b ±2,87	20,75 b ±0,87	26,63 b ±1,11	28,25 b ±1,56	30,00 b ±1,41
T40	12,13 c ±1,11	22,13 b ±2,69	28,88 c ±1,65	32,13 c ±0,25	33,88 c ±0,63	35,38 c ±0,63
T60	10,50 bc ±1,92	21,25 b ±3,50	32,00 d ±0,71	34,00 d ±0,71	36,00 d ±0,41	38,13 d ±0,63
Mean	9,47	18,13	22,97	25,84	27,56	29,09
Probability	0,007	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001
Significance	***	***	***	***	***	***

Values with the same letter are not significantly different at the 5% level. *** = very highly significant difference

Table 4: Evolution of the vigour index of tomato plants according to the treatments, over time.

Treatments	Time (weeks)					
	S2	S4	S2	S8	S2	S12
T0	0,99 a ±0,09	1,51 a ±0,07	1,65 a ±0,19	2,07 a ±0,14	2,47 a ±0,12	2,75 a ±0,13
T20	1,65 b ±0,10	2,43 b ±0,16	3,01 b ±0,08	3,60 b ±0,06	3,80 b ±0,06	3,97 b ±0,06
T40	1,85 c ±0,14	2,72 c ±0,13	3,50 c ±0,06	3,78 c ±0,03	3,98 c ±0,02	4,09 c ±0,02
T60	1,87 d ±0,17	2,76 d ±0,17	3,64 c ±0,02	3,94 d ±0,01	4,10 d ±0,01	4,22 d ±0,01
Mean	1,59	2,35	2,95	3,35	3,59	3,76
Probability	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001	< 0,001
Significance	***	***	***	***	***	***

Values with the same letter are not significantly different at the 5% level. *** = very highly significant difference

3.6 Yields

The addition of vermicompost to the soil induced highly significant differences (P = 0.0021) between the yields of the different treatments (P = 0.01). The yields obtained with T60, T40 and T20 were, respectively, 5, 3 and 2 times higher than the T0 control. The higher the doses of vermicompost, the higher the yields.

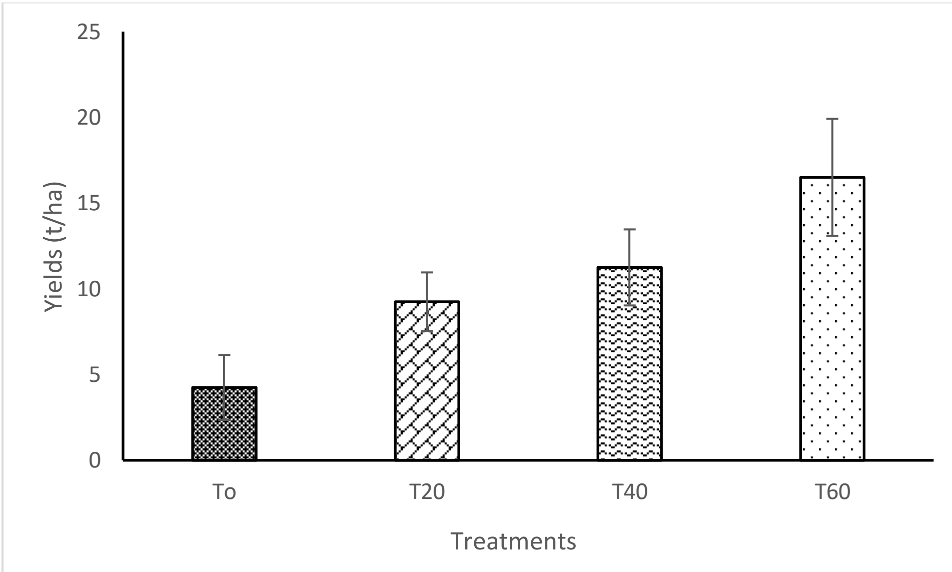

Figure 4: Tomato yields according to treatments

The results of the study show that no significant difference was observed between the means of germination rates at the first week after sowing, and that the rates differed when moving away from the sowing period. This would mean that the first germination would come from the nutrient reserves of the seeds placed in the soil and that from the second week onwards, the germination of the seeds would be dependent on the condition of the substrate in which the seedlings were placed. Seed germination rates from this date onwards were high for T0 and T20, especially for T20, and low for T40 and T60, especially for T60. These results could be explained by the fact that the addition of vermicompost would have modified the environmental conditions and the high doses would have negatively influenced germination. This corroborates the work of [21] and [22]. [21] showed that the germination rate of tomato seeds was high (62.42%) with the addition of 25% household waste compost to the soil and low with the addition of 75 and 100% compost. The work of [22], on the other hand, showed that germination rates above 50% are obtained for composts at low doses. Thus, the higher the dose of vermicompost, the lower the germination rates. According to the results of the work of [23], a compost is considered non-toxic when the germination rate it induces exceeds 50%. However, the germination rates obtained with T0 and T20 increased from 54.17 to 75% and from 62.50 to 83.33%, respectively. The T0 and T20 treatments with the low dose of vermicompost would be non-toxic to tomato seeds and therefore favourable to their germination. On the other hand, those obtained with T40 and T60 varied, respectively, from 50 to 54.17% and 41.67 to 54.17%, lower or slightly higher than 50%, hence the low germination rates. As a result, [24], and [25], recommend the use of small amounts of composts for vegetable crops during the nursery phase.

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The vermicompost applied to the soil produced significantly positive effects on tomato growth parameters, including height, crown diameter and plant vigour index over the 12 weeks of cultivation. This is certainly related to the improvement of soil fertility with the addition of vermicompost. This improvement would be due to the release of minerals contained in the vermicompost. Indeed, vermicompost is made up of nutrients such as (N, P, K, Ca, Mg...) which contribute to the improvement of soil fertility and plant growth [26]. Vermicompost, having directly assimilable mineral elements, would have favoured the rapid growth of tomato plants. Its efficiency may be due to its decomposition to make nutrients available to plants. These results corroborate numerous studies that have shown the beneficial effects of organic amendments on crop growth. This is the case of the work of [27] and [28] who showed that organic fertilizers had positive effects on height, crown diameter, length and width of maize plant leaves. The results obtained for the vigour of tomato plants with increasing doses of vermicompost can be explained by the fact that the nutrients promote the rigidity of plant tissues and, consequently, the vigour of the plants. The higher the dose, the greater the improvement in growth parameters. The average values of height, crown diameter and vigour index of tomato plants were greater with the T60 treatment. These very significant results obtained with T60 would mean that a high input of vermicompost to the soil accelerates the growth in height, thickness and rigidity of tomato plants. This rapid growth could be explained by a high activity of microorganisms following the addition of vermicompost, which would favour the decomposition of these products to make nutrients available in the soil [10].Indeed, a high dose of vermicompost releases, during its decomposition in the soil, more nutrients available for the tomato plant. According to [29], the compatibility of vermicompost with plant growth increases with the amount of dose applied. [30] states that the nutrients that can be supplied are variable and depend on the dose of compost used to fertilise the soil. The results obtained show that high doses, especially 60t/ha of vermicompost, improved the vegetative parameters of the tomato more. The vermicompost, applied to the soil in different doses, provided nutrients necessary for the feeding and growth of tomato plants.

4. CONCLUSION

This study, carried out on the experimental site of the Jean Lorougnon Guédé University in Daloa, in the central-western part of Côte d'Ivoire, showed that soil fertilization with vermicompost produced significantly beneficial effects on the growth parameters and yield of tomato, with increasing doses. Thus, the results show that the 60 t/ha vermicompost application achieves the best performance with faster growth of height, crown diameter and vigour index as well as yield of tomato plants. However, tomato seed germination rates obtained with this rate are the lowest but rise above 50% at the end of the nursery. The addition of organic matter to the soil in the form of vermicompost is both a soil improver and a plant food. Subsequently, the valorisation of vermicompost made from *Eudrilus eugeniae* worms, agricultural residues and rubbish deserves to be further explored as their use could be a solution in soil fertility management for a sustainable improvement of agricultural production.

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