Contribution of cattle dung (organic fertilizer) as an alternative to mineral fertilization of soils in tomato (*Lycopersicom esculenta*) cultivation.

ABSTRACT

The use of chemical inputs, which in the long term constitutes a source of soil and environmental degradation, has led producers to use other sources of fertilizers such as cattle dung in order to reduce inputs ~~fertilizer~~ inorganic chemicals. However, these organic fertilizers alone do not restore the low level of soil fertility, hence the use of organo-mineral fertilization. The objective of the study was to improve soil fertility and tomato yield. The study was carried out using a Fisher block design, with three repetitions on sandy soil. Treatments T0 (control treatment), Tpp (500 kg/ha of NPK), T1 (40 kg/ha of cattle dung + 167 kg/ha of NPK), T2 (40 kg/ha of cattle dung + 250 kg /ha of NPK), T3 (40 kg/ha of cattle dung + 375 kg/ha of NPK), T4 (40 kg/ha of cattle dung + 500 kg/ha of NPK) and T5 (40 kg/ha of NPK of cattle dung) were applied to elementary plots of 20 m^2 (5 m x 4 m). Cattle dung was added as background fertilizer before transplanting and mineral fertilizer was applied at transplanting and at the start of flowering of the plants. The height of the plants, the circumference at the collar, the diameter of the fruits, the average number of fruits and the yield of the fruits were evaluated on 4 plants of the useful plot. The results obtained revealed that the addition of cattle dung to the soil made it possible to reduce the quantities of chemical fertilizer commonly used by tomato producers. Thus, the T3 treatment (40 kg/ha of cattle dung as a single contribution of basal fertilizer + 375 kg/ha of NPK), or C¾ of the dose of chemical fertilizer commonly applied by producers, made it possible to improve the agronomic parameters of the tomato and obtain the highest yield (16292.25 kg/ha). The cow dung combination at a dose of 40 kg/ha + 375 kg/ha of NPK 15 15 15 is therefore the optimum dose to provide for better tomato production.

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Keywords: Cattle dung, chemical fertilizer, tomato, Daoukro, Côte d'Ivoire.

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1. INTRODUCTION

In Côte d'Ivoire, tomatoes are grown in all regions for self-consumption or marketing with an average national production estimated at 32,364 tons [1]. However, its cultivation in Côte d'Ivoire faces many constraints. Indeed, tomato cultivation is practiced mainly by small rural farmers with low incomes [2] on small subsistence farms with low yields, causing a large importation of tomato paste to meet the needs of the population [3]. In addition, its cultivation is generally practiced near watercourses, which are generally sandy soils with very high water permeability and low natural fertility [4]. Faced with this situation, the use of chemical fertilizers which makes it possible to correct the deficit of the soil in mineral elements and to improve the production of crops [5] has been considered. However, in addition to their high cost which makes them almost inaccessible to small farmers, chemical fertilizers alone are not sufficient, in the long term, to maintain soil fertility or increase crop yields [6]. Indeed, the excessive use of chemical fertilizers pollutes the water tables, leads to an increase in acidity, a deterioration of the physical status and a drop in the organic matter of the soil [7]. Moreover, the sandy texture of these soils does not optimize the effects of mineral fertilizers. In such a context, the use of organic manures, which constitutes a good substitute for chemical fertilizers, is one of the solutions among many others to improve soil fertility and ensure the good development of plants [8]. In addition, organic fertilizers are able to reduce water consumption by plants [9]. Among these organic manures, livestock waste, in particular, cattle dung occupy an important place, especially in market gardening systems [10]. However, very few studies have been conducted with cattle dung, which is an organic fertilizer at a lower cost compared to chemical fertilizers, available and accessible to most tomato producers. This study therefore aims to improve soil fertility and tomato production by adding cattle dung to the soil.

2. MATERIALS AND METHODS

2.1. Characteristics of the experimental site

The study was carried out in Katimansou in the Ettrokro sub-prefecture in the Daoukro department (longitude 3°29' and 4°34' West and latitude 6°55' and 7°32' North) (Fig. 1) [11] with a humid tropical climate with two (2) rainy seasons and two (2) dry seasons. Average monthly precipitation varies between 11 mm and 198 mm with an average annual rainfall of 1103 mm. The vegetation is grassy savannah in the West and degraded forest in the East, North and South. In addition to this vegetation, there are patches of forest, gallery forests and savannah-crop mosaics [11]. The terrain is not very rugged with altitudes varying between 120m and 500m. The department is drained by the N'zi rivers to the west and Comoé to the east. The soils are ferralitic and brownish, moderately or slightly desaturated, with a saturation rate of between 20 and 70%. The pH of the soils is between 5 and 6. However, we find hydromorphic soils favorable to perennial crops, food crops and market gardening [12].

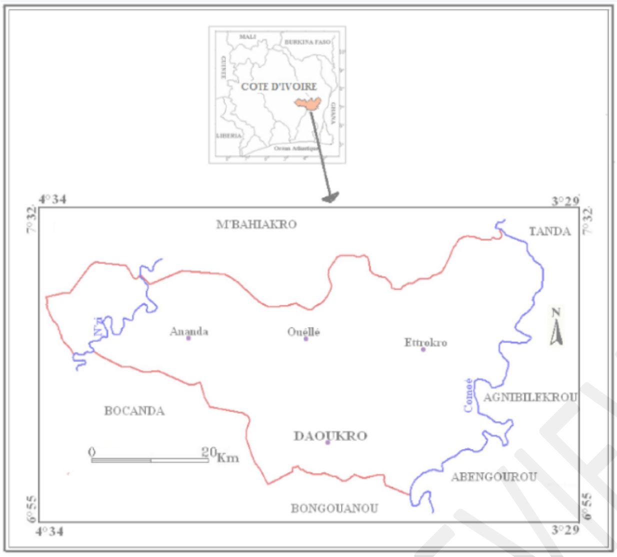

Fig. 1. Location map of the study area (Source: [12])

2.2. Plant material

The plant material used consisted of tomato seeds of the variety called 'Cobra'. This variety has a cycle of 120 days and an average potential yield of around 30 tons per hectare. It is used by market gardeners because it is resistant to diseases compared to most varieties of tomato. The tomato was used for this study because it is one of the main vegetable crops in the Ettrokro sub-prefecture.

2.3. Fertilizing material

The fertilizing material consists of cow dung and the chemical fertilizer NPK 15 15 15 + 0.3S + 4.5 MgO + 6.7 CaO (Fig. 2) which are fertilizers commonly used by market gardeners in the region to tomato fertilization. Cattle dung has been used because it is the subject of growing interest by most market gardeners who use it as an organic soil fertilizer. It was collected from pastures, then dried and put in bags before use.

A: Cattle dung B: Granular form of NPK fertilizer

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Fig. 2: Fertilizing equipment

2.4. Experimental apparatus

The test was carried out using a Fisher block experimental design (Fig. 3) on sandy soil with an area of 596 m^2 in a rural environment. The blocks were arranged parallel and spaced 1 m apart from each other. The treatments were repeated 3 times and distributed randomly in each block. Each block included 7 treatments or elementary plots, each with an area of 20 m^2 (5 m x 4 m). The useful plot consisted of 4 tomato plants on which the various readings were carried out.

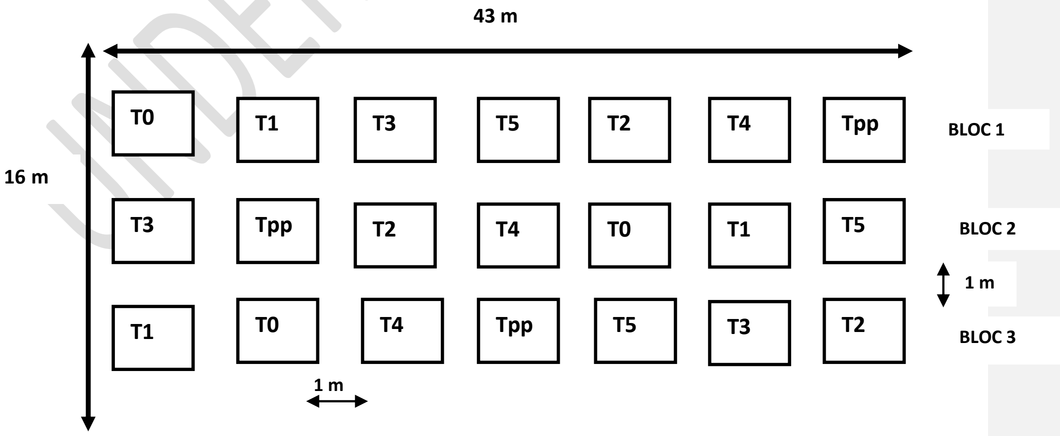

Fig. 3. Diagram of the experimental design of the study showing the distribution of treatments.

2.5. Treatments

The treatments consisted of cattle dung applied as basal fertilizer one week before transplanting and chemical fertilizer divided into two equal doses (one week after transplanting and at the start of flowering):

- **T0** (control): Without fertilizer input;

- **Tpp** (full dose commonly used by producers): 500 kg/ha of NPK, or 20 g/plant;

- **T1**: 40 t/ha of cattle dung + 167 kg/ha-1 of NPK (6.7 g/plant), or ¼ of the dose of NPK commonly applied;

- **T2**: 40 t/ha of cattle dung + 250 kg/ha of NPK (10 g/plant), or half the dose of NPK commonly applied;

- **T3**: 40 t/ha of cattle dung + 375 kg/ha of NPK (15 g/plant), or ¾ of the dose commonly applied;

- **T4**: 40 t/ha of cattle dung + 500 kg/ha of NPK (20 g/plant), or the full dose commonly applied;

- **T5**: 40 t/ha of cattle dung.

2.6. Land preparation

The preparation of the land consisted of clearing and weeding of the plots which were carried out manually. The plant mass was placed outside the plot. The burning of plots, as well as herbicide treatments, has been prohibited, to avoid any uncontrollable interaction. The cattle dung was buried in the soil after plowing with a hoe as a background fertilizer one week before transplanting the plants.

2.7. Setting up the nursery

Setting up the nursery consisted of sowing tomato seeds on a 2 m^2 bed. After sowing, the bed is covered with palm leaves. One week before transplanting, the shadehouse is lightened, by reducing the amount of palm. The nursery is regularly watered in the absence of any rain.

Phytosanitary treatments have been carried out to control pests. Two days before transplanting, which occurs at 21 days, the shadehouse is completely removed.

2.8. Transplanting and caring for tomato plants

The 21-day-old plants were transplanted with a spacing of 40 cm between plants on the same row and 1 m between rows (Fig. 4). Only vigorous seedlings with 4 and 5 blooming leaves were transplanted. Sanitary treatments based on Azadirachta Indica extract were carried out on the plants against pests every two weeks until flowering.

Two week old tomato plants

Fig. 4: Plants transplanted on beds

2.9. Crop fertilization

Cattle dung was applied as basal fertilizer at the rate of 40 tons per hectare (recommended dose per hectare for organic waste). The NPK fertilizer was brought to the feet of the tomato plants according to different fractions. The first supply of NPK was made one week after transplanting and the second, at the start of flowering.

2.10. Sampling, conservation and evaluation of soil chemical parameters

The chemical potential of the soil was determined on the composite samples of soil taken before the establishment of the test in the first 20 centimeters of the soil using an auger. The samples taken were dried and sieved and a composite sample of approximately 500g was made up for chemical analyzes in the plant and soil laboratory of the National Polytechnic

Institute Houphouët-Boigny in Yamoussoukro. These chemical analyzes concerned the following parameters:

- the pH, determined by the ~~electrometric~~ pH meter method [13];
- ~~measurements~~Measurements of total nitrogen (N), organic carbon, phosphorus and exchangeable bases (K, Mg, Na and Ca), carried out respectively, by the methods of Kjeldhal, Walkley and Black, modified Olsen and ammonium acetate at pH 7 [13];
- the organic matter (OM) content was determined by multiplying the carbon content by 1.72.

2.11. Evaluation of soil morphological parameters

The description of the morphological characteristics of the soil was made from an open pit on the test site and the different horizons described according to the following parameters: depth, texture, rate of coarse elements and the presence of humus.

2.12. Evaluation of agronomic parameters of tomato

The agronomic parameters to be assessed concerned:

- the height of the plant (from the collar to the ligule of the last leaf well deployed by the plant) was evaluated on 4 tomato plants previously identified at random in the center of the elementary plot. To do this, stakes were placed next to each plant and a rope is unwound around the plant to keep it straight and the height is determined with a graduated ruler every week, one week after transplanting until flowering;
- the collar circumference is determined using a vernier caliper;
- the diameter of the fruits was determined by dividing the measurement of the circumference of the fruits, evaluated by a caliper by 3.14;
- the average number of fruits of each plant was determined by counting the number of fruits of each useful plot during the different harvests;
- the yield (RDT) was determined from the production of each useful plot (PPu) using the following formula: RDT = (D x PPu) / NPPu.

Where, RDT= Yield; PPu = Production of the useful plot; NPPu = number of plants in the useful plot and D = Density (number of plants per hectare).

2.13. Statistical analysis of data

The data collected was subjected to an analysis of variance (ANOVA) using SAS 9.4 software. The means were separated using the Newman and Keuls test at the 5% threshold between the different treatments in order to evaluate the contributions of the different fertilizers on the evolution of the agronomic parameters of the tomato.

3. RESULTS

3.1. Physical characteristics of the soil of the study site

The profile of the open pit on the study site has four horizons (Fig. 5). The first horizon, which is surface horizon A_{11}, is humus-rich, not very thick (10 to 12 cm) and made up of a layer of brown-colored organic matter debris (2.5YR 4/1). It is sandy-loamy with approximately 20% coarse elements. The second horizon A_{12}, just below the first horizon, is not very humus, not very thick (12 cm) and brown in color (2.5YR 4/3). This horizon is sandy-silty with approximately 35% coarse elements. The third horizon B_{11} is non-humus, thin (10 cm) and reddish brown in color (2.5YR 5/3). It is a sandy horizon with approximately 40 to 45% coarse elements. The last B_{12} horizon is also non-humus, thick (10 to 12 cm), reddish brown in color (2.5YR 5/4). It is sandy with approximately 45 to 50% coarse elements. We also observe in this last horizon, a waterlogged layer, composed mainly of coarse sand. The soil of the study site is therefore sandy gleysol.

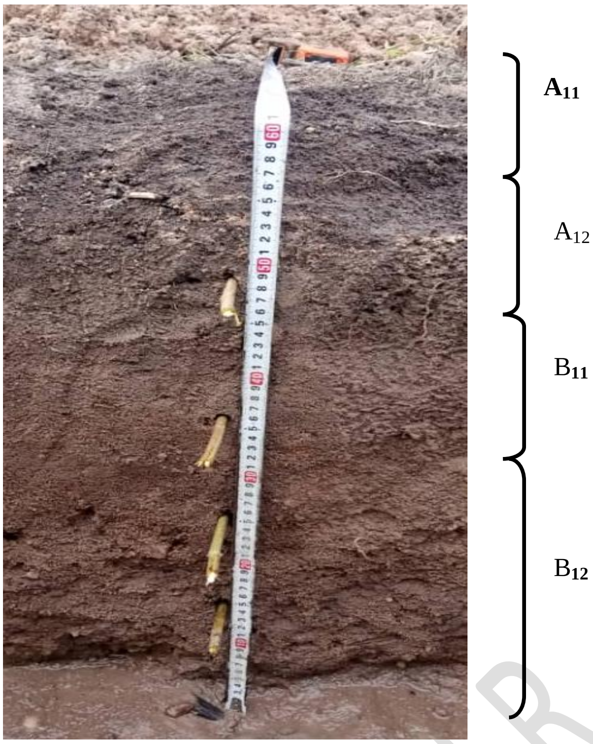

Fig. 5: Soil profile of the study site.

3.2. Chemical parameters of the soil of the study site

The physico-chemical properties of the soils, compared to the normative reference values show that the pH of the soil of the study site is acidic with a value of 5.1, lower than the normative reference values which are between 6.6 and 7.3 (Table I). The levels of organic matter, carbon, nitrogen and phosphorus also indicate very low values compared to the normative reference values (MO = 3.15 < 9.6-68.8 ; C = 0.61% < 5.6 % ; N = 0.05% < 0.3% ; P = 22 < 50 ppm). The cation exchange capacity is also very low (CEC= 5.97 cmol/kg < 10 cmol/kg). The same is true for potassium (K^+ = 0.05 cmol/kg < 0.3 cmol/kg), magnesium (Mg^{2+} = 0.18 cmol/kg < 1.5 cmol/kg), calcium (Ca^{2+} = 0.22 cmol/kg < 5 cmol/kg) and sodium (Na^+ = 0.10 cmol/kg < 0.3 cmol/kg) very low compared to the normative reference values.

Table I: Chemical parameters of the soil of the study site compared to the normative reference values

Parameters	Composants	Element contents in the 0-20 cm horizon	*Normative reference value*
Acidity	pH	5.1	6.6 -7.3
Organic mater	MO (%)	3.15	9.6-68.8
	C (%)	0.61	5.6-10
	N (%)	0.05	0.3-0.6
	C/N	13.5	9-12
Phosphorus	Pass (ppm)	22	50-100
Exchangeable cations	Ca^{2+} (cmol/kg)	0.22	5-8
	Mg^{2+} (cmol/kg)	0.18	1.5-3
	K^+ (cmol/kg)	0.05	0.3-0.6
	Na^+ (cmol/kg)	0.10	0.3-0.7
	CEC (cmol/kg)	5.97	10-15

*Normatives reference values [14], [15].

3.3. Evolution of tomato growth parameters depending on the treatments

3.3.1. Diameter at collar

The analysis of variances showed a very highly significant difference ($P < 0.0001$) between the different treatments in terms of the evolution of the collar diameter of the tomato plants (Table II). The highest collar diameters were obtained at the T3 (13.54 mm), T4 (14.37 mm) and T5 (11.14 mm) treatments and the lowest at the T0 control treatments (10.20 mm) and Tpp (10.95 mm). Intermediate values are obtained by treatments T1 (11.75 mm) and T2 (12 mm).

3.3.2. Plant height

It emerged from the analysis of variances that there is a very highly significant difference ($P < 0.0001$) between the different treatments in terms of changes in the heights of tomato plants (Table II). Treatments that received cattle dung as basal manure recorded higher height measurements than those that did not receive dung. Indeed, treatments T3 (61.41 cm) and T4 (66.48 cm) recorded the highest plant heights. The control treatment T0 (41.19 cm) recorded, on the other hand, the lowest height. The intermediate height values were obtained by the treatments Tpp (49.31 cm), T1 (50.02 cm), T2 (51.66 cm) and T5 (51.77 cm).

3.3.3. Fruit circumference

The different treatments had a very highly significant effect ($P < 0.0001$) in terms of the evolution of the circumference of the tomato fruits (Table II). Treatments T3 and T4 with values of 15.29 and 15.79 cm, respectively, recorded the highest fruit circumferences. The low values were obtained with the control treatment T0 (12.31 cm); the intermediate values being obtained with the treatments Tpp (13.76 cm), T1 (14 cm) and T2 (14.41 cm).

Table II: Evolution of the diameter at the collar, circumference of the fruits and the height of the plants depending on the treatments

	Growth parameters		
Treatments	Diameter at the collar of the plants (mm)	Fruit circumference (cm)	Plant height (cm)
T0	10.20 ± 0.17 d	12.31 ± 0.19 c	41.19 ± 0.41 d
Tpp	10.95 ± 0.20 d	13.76 ± 0.17 b	49.31 ± 0.35 c
T1	11.75 ± 0.24 c	14 ± 0.21 b	50.02 ± 1.10 c
T2	12 ± 0.33 c	14.41 ± 0.31 b	51.66 ± 0.95 c
T3	13.54 ± 0.31 a	15.29 ± 0.27 a	61.41 ± 1.28 a
T4	14.37 ± 0.36 a	15.79 ± 0.35 a	66.48 ± 1.29 a
T5	11.14 ± 0.13 c	11.91 ± 0.38c	51.77 ± 1.02 c
CV	10.41	9.04	6.35
P	< 0.0001	< 0.0001	< 0.0001

3.4. Evolution of tomato production parameters according to treatments

3.4.1. Average number of fruits per tomato plant

The different treatments had a very highly significant effect ($P < 0.0001$) on the average number of fruits per tomato plant (Table III). The low number of fruits per plant (11.16 fruits) was obtained by the control treatment T0. The average intermediate numbers of fruits per plant were obtained with the treatments Tpp (12.23 fruits), T1 (12.75 fruits), T2 (12.75 fruits) and T5 (13.41 fruits). Treatments T3 and T4 with average numbers of fruits per plant respectively of 15.75 and 16.79 obtained the highest numbers.

3.4.2. Average tomato yield

The analysis of variances showed a very highly significant difference ($P < 0.0001$) between the different treatments in terms of the average tomato yield per hectare (Table III). The highest yields were obtained with treatments T3 (16292.25 kg/ha) and T4 (16850.75 kg/ha). Intermediate average yields were observed with the Tpp (10285 kg/ha), T1 (11018 kg/ha) and T2 (11949.75 kg/ha) and T5 (10863.5 kg/ha) treatments; the lowest yield being obtained with the control treatment T0 (6513.5 kg/ha).

Table III: Evolution of the average number of fruits per plant and of the yield according to the treatments.

	Production parameters	
Treatments	Number of fruits	Yield (kg/ha)
T0	11.16 ± 0.39 c	6513.5 ± 21.13 e
Tpp	12.23 ± 0.41 b	10285 ± 21.02 d
T1	12.75 ± 0.37 b	11018 ± 21.45 d
T2	12.75 ± 0.36 b	11949.75 ± 21.03 c
T3	15.75 ± 0.33 a	16292.25 ± 25.93 a
T4	16.79 ± 0,41 a	16850.75 ± 25.27 a
T5	13.41 ± 0.25 b	10863.5 ± 20.17 d
CV	11.98	13.75
P	< 0.0001	< 0.0001

4. DISCUSSION

4.1. Physical and chemical characteristics of the soil of the study site

The pH value which is 5.1 indicates that the soil of the study site is acidic. It therefore has a low chemical fertility which could be explained by the sandy nature of the soil of the site. Indeed, according to [4], sandy soils generally have a very high water permeability and have a very low natural fertility. This low soil fertility would also be linked to the acidity of hyperdystric ferralsols, which is the basis of many phenomena harmful to plant growth, such as the reduction in nitrification, the phosphorus deficiency and the high availability of certain heavy metals [16]. These results agree with those of [17] which showed that tropical soils are characterized by a low level of organic matter, high acidity, high desaturation in exchangeable cations and slow mineralization of organic matter.

4.2. Effect of fertilizers on agronomic parameters of tomato

The values of the agronomic parameters at the level of the control treatment T0 (without the addition of fertilizers) are low compared to those of the treatments having received fertilizers. These low values at the level of the control treatment would be linked to the low fertility of the soils due to their sandy texture [18]. Indeed, according to [19], sandy soils limit the growth and yields of cultivated plants. These low values therefore explain the effect of the law of the minimum or limiting factors or Liebig's law which stipulates that: "the yield obtained is determined by the assimilable fertilizing element which is found in the lowest quantity in the soil relative to the needs crops”.

The low values of the agronomic parameters obtained at the level of the Tpp treatment (treatment based on NPK only) compared to the values observed for the dung only and the combination of the NPK fertilizer and the dung, would be linked to the sandy texture of the study site. Indeed, sandy soils are poor in clay and organic matter and have a low retention capacity for mineral elements. Under these conditions, the mineral elements provided by the chemical fertilizer will not be retained on the adsorbent complex to ensure the nutrition and development of tomato plants. These results agree with those of [4] which showed that sandy soils generally have low natural fertility and very high water permeability, which does not make it possible to make the action of mineral fertilizers profitable brought. On the contrary, these elements provided by chemical fertilizer acidify the soil and degrade its fertility. Indeed, according to [20], the use of chemical fertilizer promotes, in the long term, an increase in soil acidity. The work of [21] also showed in market gardening that the exclusive application of chemical fertilizer acidified the soil.

The low values of the agronomic parameters of the tomato at the level of treatment T5 (supply only of cattle dung) compared to the other treatments would be linked to the fact that the mineral elements contained in the dung could not be released in time or are not sufficient to satisfy the effective needs of tomato plants during their development [19].

The values of tomato growth parameters obtained with the combination of fertilizers (NPK and dung) were higher than those recorded at the level of fertilizers used alone (NPK alone at the Tpp level or dung alone at the T5 level). These results obtained could be explained by the combined effects of chemical fertilizer and dung. The combined action of cattle dung and NPK fertilizer is a good combination that improves soil fertility in the long term. In fact, the NPK chemical fertilizer provides nutrients which can be directly used by the plants to satisfy their initial needs and the organic matter, for its part, gradually mineralizes subsequently to provide other additional nutrients to the soil. The dung provided, which is an additional source of nutrients, reinforces the effectiveness of the mineral fertilizer, making it possible to improve soil fertility and plant growth. Furthermore, these results could also be explained by the nature of the fertilizers which are NPK fertilizer and cattle dung which have high contents of nitrogen and potassium, essential factors of plant growth especially at the level of the leaves, stems and plant height [22]. These results confirm those of [10] who specify that cattle dung is a quality fertilizer, particularly due to its high nitrogen content. The work of [23] has shown that the potassium (K) contained in the NPK fertilizer allows good plant growth. In addition, the work of [23] has shown that the phosphorus contained in NPK fertilizer and cattle dung is a nutrient that stimulates flowering and fruiting. The combination of these nutrients brought to the soil will therefore improve plant yields. According to [2], the combination of organic and mineral fertilizers creates the best growing conditions for crops. The high values of the growth parameters of the tomato plants at the level of treatments T3 (40 t/ha of cattle dung as a single contribution of basal fertilizer + 375 kg/ha of NPK) and T4 (40 t/ha of cattle dung cattle with a single input of basal fertilizer + 500 kg/ha of NPK) compared to the other treatments, could be explained by the fact that these treatments have the optimum that tomato plants need for their growth. However, the non-significant differences observed in tomato agronomic parameters between treatments T3 (40 t/ha of dung + 375 kg/ha of NPK) and T4 (40 t/ha of dung + 500 kg/ha of NPK) confirm the law of surpluses or Mitscherlich's law, which states that: "when increasing doses of fertilizer are applied to a crop, equal increases in the quantities of fertilizer correspond to increasingly smaller increases in yield, at as fertilizer doses increase. Treatment T3, or the dose of 375 kg of NPK, is the optimal dose of NPK fertilizer to combine with cattle dung at a dose of 40 t/ha to obtain the best results. This dose of NPK provided allows the cattle dung to be more effective in improving the agronomic parameters of the tomato.

5. CONCLUSION

The development of sustainable agriculture requires the development of new farming practices that make it possible to limit the recourse to the heavy use of chemical fertilizers. This study aimed to improve soil fertility and tomato (Lycopersicom esculenta) production in the Daoukro region. The results obtained showed that the T3 treatment (40 t/ha of cattle dung + 375 kg/ha of NPK 15 15 15), or ¾ of the NPK dose commonly used by producers, allowed better expression of all the parameters agro-morphology of tomato. With the highest average yield of 16292.25 kg/ha, the combination of cattle dung at a dose of 40 t/ha + 375 kg/ha of NPK 15 15 15 is the optimum dose to bring to the soil for a better tomato production.

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