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Contribution of Cattle Dung as an Alternative to Mineral Fertilization of Soils in Tomato (*Lycopersicom esculenta*) Production

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Authors' contributions

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

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ABSTRACT

The use of chemical fertilizers, which in the long term constitutes a source of environmental degradation, has led farmers to use organic sources as alternative soil amendments. However, use of organic fertilizers alone may not restore the fertility of highly degraded soils, hence the need for the integration of organic and mineral fertilizers. The objective of the study was to improve soil fertility and tomato productivity. The study was carried out using a Fisher block design, with three replicates established on sandy soils. Treatments T_0 (control treatment), T_{pp} (500 kg $ha^{-1}$of NPK), T_1 (40 kg $ha^{-1}$of cattle dung + 167 kg $ha^{-1}$of NPK), T_2 (40 kg $ha^{-1}$of cattle dung + 250 kg $ha^{-1}$of NPK), T_3 (40 kg $ha^{-1}$of cattle dung + 375 kg $ha^{-1}$of NPK), T_4 (40 kg $ha^{-1}$of cattle dung + 500 kg ha-

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[1]of NPK) and T_5 (40 kg $ha^{-1}$of NPK of cattle dung) were applied to elementary plots of 20 m^2 (5 m x 4 m). Cattle dung was applied one week before transplanting was done. On the other hand, split application of mineral fertilizer was done at transplanting and at the start of flowering. The height of the plants, the circumference at the collar, the diameter of the fruits, the average number of fruits and weights of harvested fruits were evaluated on 4 plants of the effective 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, T_3 treatment (40 kg/ha of cattle dung as a single contribution of basal fertilizer + 375 kg/ha of NPK), or ¾ of the dose of chemical fertilizer commonly applied by producers, made it possible to improve the agronomic parameters of the tomato and obtained the highest tomato yields (16292.25 kg/ha). The cattle 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.

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

1. INTRODUCTION

In Côte d'Ivoire, tomatoes are grown in all regions for home-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 characterized by low household incomes [2] and subsistence farming. This has led to low tomato 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 with generally sandy soils characterized by 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 mineral soils and enhance tomato production and productivity [5] has been considered. However, in addition to their high cost which makes them almost inaccessible to small-scale farmers, use of chemical fertilizers alone is not sustainable in an effort to improve tomato productivity [6]. Excessive use of chemical fertilizers pollutes the environment. For instance, when wrongly applied, both surface and underground water bodies are prone to contamination. Further, excessive use of mineral fertilizers has been reported to destroy soil structure leading to changes in the physical soil characteristics [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 tomato plants [8]. In addition, organic fertilizers are able to reduce water consumption by plants [9]. Among these organic manures, livestock wastes, in particular, cattle dung plays an important role in crop production, especially in market gardening systems [10]. However, very few studies have been conducted with cattle dung as an organic fertilizer as an alternative and cheap source of soil amendment for tomato production. This study therefore aims to improve soil fertility and tomato productivity by using cattle dung as soil amendment.

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 rainy seasons separated by two 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 moderately 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, hydromorphic soils also exist that favor production of both perennial and annual crops, some of which are common in market gardening [12].

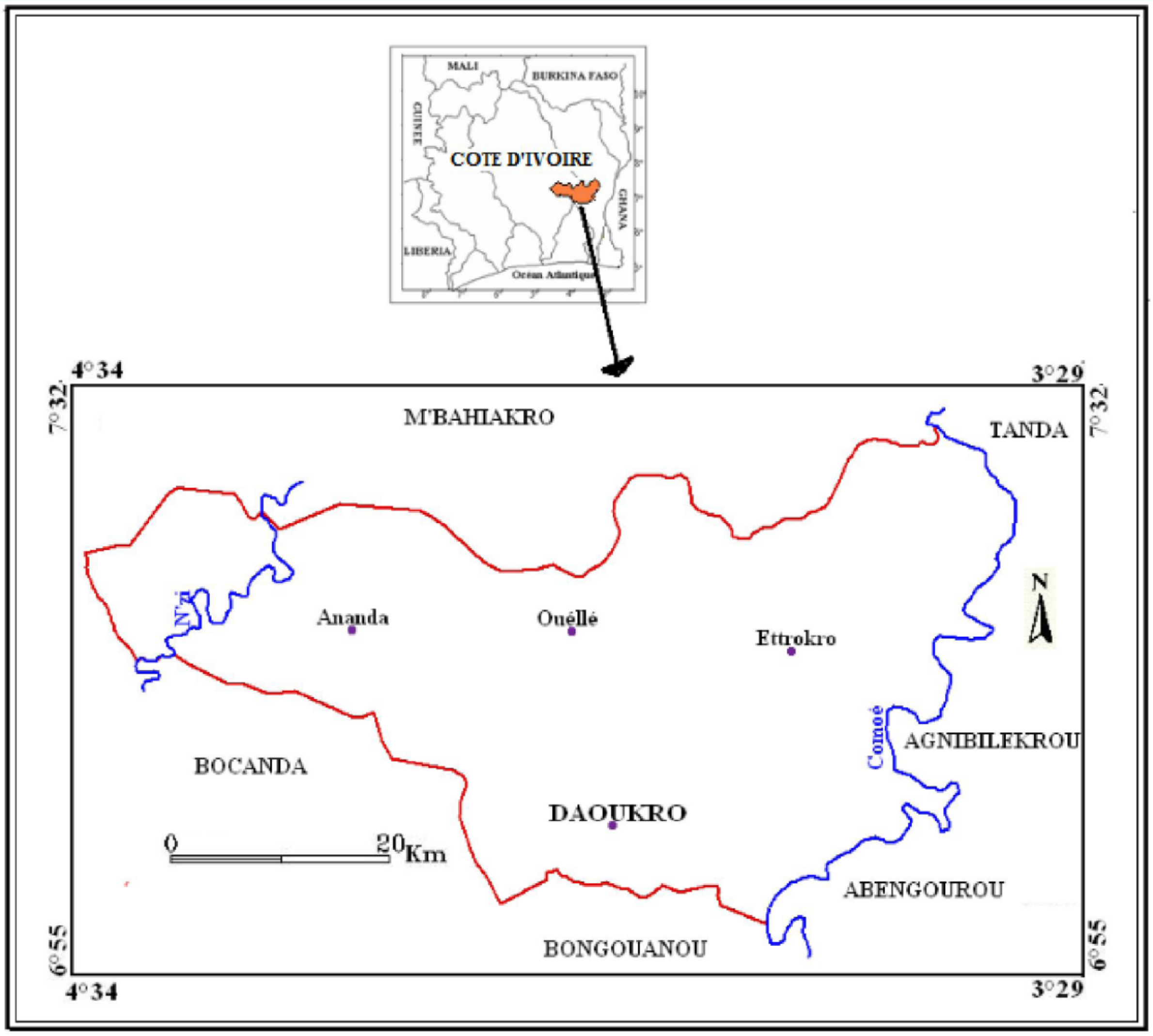

Fig. 1. Location map of the study area (Source: [12])

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 t ha^{-1}. It is used by market gardeners because it is tolerant to most 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 cattle 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 was used because it had become popular market gardeners who use it as an organic soil fertilizer. It was collected from grazing pastures, then dried and put in bags before use.

2.4 Experimental Design

The experiment was set up using a Fisher block experimental design (Fig. 3) on sandy soil with an area of 596 m^2. The blocks were arranged parallel and spaced 1 m apart from each other. The treatments were replicated 3 times and distributed randomly in each block. Therefore, each block had 7 treatments each in a plot size 5 m x 4 m. The effective plot consisted of 4 tomato plants on which the various plant parameters were carried out.

A: Cattle dung **B: Granular form of NPK fertilizer**

Fig. 2. Types of soil amendments used

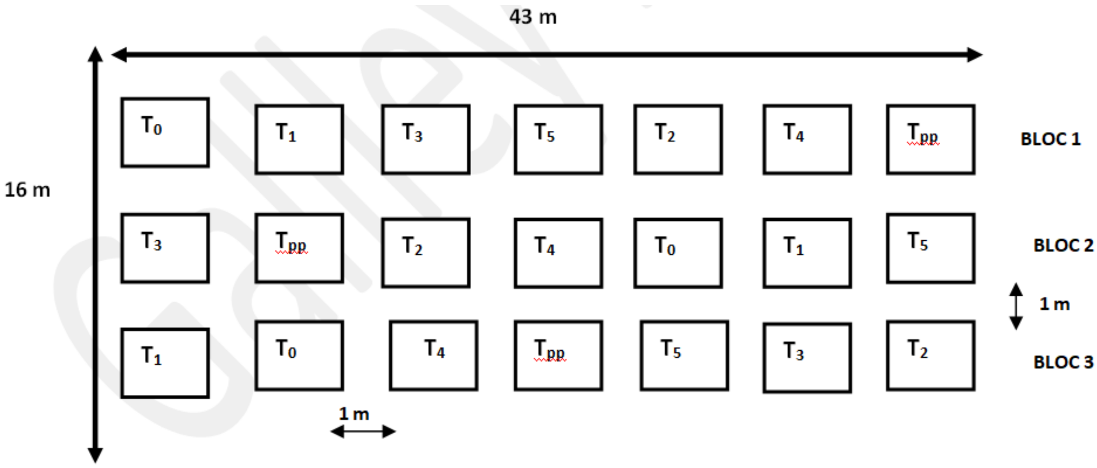

Fig. 3. Diagram of the experimental design of the study showing the distribution of applied soil amendments

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):

- T_0 (control): Without fertilizer input;
- T_{pp} (full dose commonly used by producers): 500 kg ha^{-1} of NPK;
- T_1: 40 t ha^{-1} of cattle dung + 167 kg ha^{-1} of NPK, or ¼ of the dose of NPK commonly applied;
- T_2: 40 t ha^{-1} of cattle dung + 250 kg ha^{-1} of NPK, or half the dose of NPK commonly applied;
- T_3: 40 t ha^{-1} of cattle dung + 375 kg ha^{-1} of NPK , or ¾ of the dose commonly applied;
- T_4: 40 t ha^{-1} of cattle dung + 500 kg ha^{-1} of NPK , or the full dose commonly applied;
- T_5: 40 t ha^{-1} of cattle dung.

2.6 Land Preparation

The preparation of the land and experimental management consisted of field clearing and weeding of the plots, which were carried out manually. The weeds were removed and placed outside the experimental field. The bush burning and application of herbicide treatments were not used to avoid any uncontrollable interaction. The cattle dung was incorporated into the soil with a hand hoe one week before transplanting tomato seedlings.

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 was covered with palm leaves using raised support stands. One week before transplanting, the shade-house was lightened, by reducing the amount of palm leaves to allow plant hardening. The nursery was regularly watered in the absence of any rain. Phytosanitary treatments were carried out to control insect pests. Two days before transplanting, which occurred at 21 days after sowing, the shade-house was is completely removed.

2.8 Transplanting and Caring for Tomato Seedlings

The 21-day-old tomato seedlings 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.

2.9 Crop Fertilization

Cattle dung was applied as basal fertilizer at the rate of 40 t ha^{-1} (recommended application rate for organic waste). The NPK fertilizer was applied and mixed with the soil in planting holes. The first and second fertilizer dozes of NPK were made one week after transplanting and at the start of flowering.

2.10 Sampling, Conservation and Evaluation of Soil Chemical Parameters

A composite soil sample was obtained at 0-20 cm depth from the experimental field. The soil sample was air-dried, crushed and screened through a stainless sieve. The soil sample was later analyzed for chemical parameters as described by [13] from the Plant and Soil Laboratory of the National Polytechnic Institute Houphouët-Boigny in Yamoussoukro [13].

2.11 Evaluation of Soil Morphological Parameters

The description of the morphological characteristics of the soil was made following Manichon procedure. The different horizons were described accordingly based on thickness, texture, rate of coarse elements and the presence of humus.

2.12 Evaluation of Agronomic Parameters of Tomato

The agronomic parameters of tomato plants assessed were height of the plants, collar circumference, fruit diameter, number of fruits on each sampled plants and yield. Yield was determined by:

$$RDT = (D \times PPu) / NPPu \quad \text{eqn (i)}$$

Where,

RDT= Yield;
PPu = Production from effective plot;
NPPu = number of plants in the effective plot
D = Density (number of plants ha^{-1}).

2.13 StatisticalAnalysis 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 performance 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 had four horizons (Fig. 5). The first horizon, which was horizon A_{11}, was 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 was sandy-loamy with approximately 20% coarse elements. The second horizon A_{12}, just below the first horizon, was not very humus, not very thick (12 cm) and brown in color (2.5YR 4/3). This horizon was sandy-silty with approximately 35% coarse elements. The third horizon B_{11} was non-humus, thin (10 cm) and reddish brown in color (2.5YR 5/3). It was a sandy horizon with approximately 40-45% coarse elements. The last B_{12} horizon was also non-humus, thick (10-12 cm), reddish brown in color (2.5YR 5/4). It was sandy with approximately 45-50% coarse elements. Waterlogged layer, composed mainly of coarse sand was also observed in this horizon. The soil of the study site was therefore, sandy gleysol.

Fig. 4. Tomato plants under different soil treatments applied in experimental field

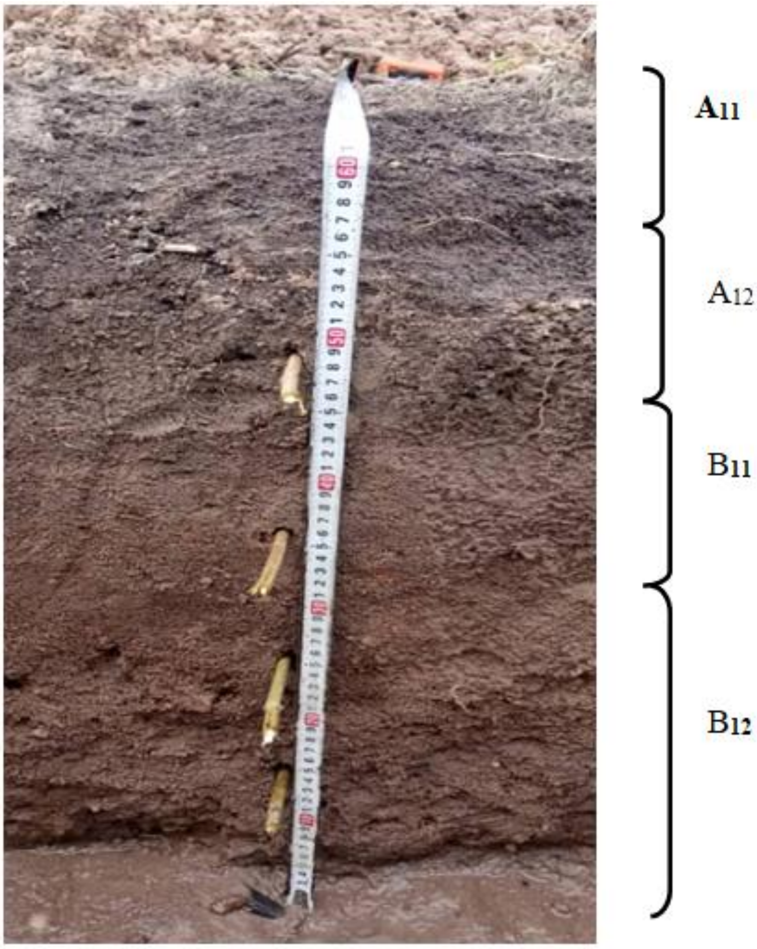

Fig. 5. Soil profile of the study site

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 was acidic with a value of 5.1, lower than the normative reference values of 6.6-7.3 (Table 1). The levels of organic matter, carbon, nitrogen and phosphorus also indicated very low values compared to the normative reference values (MO = 3.15; C = 0.61%; N = 0.05%; P = 22 ppm). The cation exchange capacity was also very low (CEC= 5.97 cmol kg^{-1}). The same was true for potassium (K^+ = 0.05 cmol kg^{-1}), magnesium (Mg^{2+} = 0.18 cmol kg^{-1}), calcium (Ca^{2+} = 0.22 cmol kg^{-1}) and sodium (Na^+ = 0.10 cmol kg^{-1}) that were very low compared to the normative reference values.

3.3 Physical and Chemical Parameters of Cattle Dung

It emerged from chemical analyzes (Table 2) that the pH of cattle dung is basic (pH = 8.1). These chemical analysis results also indicate rates of 3.64% and 0.35%, respectively for total carbon and total nitrogen. As for exchangeable cations, respective contents of 6.741, 2.839, 5.583 and 0.718 cmol.kg-1 were obtained for calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+) and sodium (Na^+). Regarding the C/N ratio, the organic matter content and the cation exchange capacity (CEC), respective values of 10, 6.26% and 17.60 cmol.kg-1 were obtained. The assimilable phosphorus content is high with a value of 368 ppm. In terms of trace elements, average contents of 108.4 and 48.5 ppm were noted for iron (Fe^{2+}) and zinc (Zn^{2+}). On the other hand, for lead, no trace was decelerated. Referring to the FAO standard, the organic matter levels and nitrogen contents of cattle dung are not satisfactory.

3.4 Growth Response of Tomato Based on Applied Soil Amendments

3.4.1 Diameter at collar

The analysis of variances showed a very highly significant difference ($p < 0.0001$) between the different treatments in terms of the expansion of the collar diameter of the tomato plants (Table 3). The highest collar diameters were obtained at the T_3 (13.54 mm), T_4 (14.37 mm) and T_5 (11.14 mm) treatments and the lowest at the T_0 (10.20 mm) and T_{pp} (10.95 mm). Intermediate values were obtained under treatments T_1 (11.75 mm) and T_2 (12 mm).

3.4.2 Plant height

It emerged from the analysis of variances that there was a very highly significant difference ($p<0.0001$) between the different treatments in terms of changes in plant heights of tomato (Table 3). Tomato plants that received cattle dung as basal manure recorded higher heights than those that did not receive the cattle dung. Indeed, treatments T_3 (61.41 cm) and T_4 (66.48 cm) recorded the highest plant heights. The control treatment T_0 (41.19 cm) recorded, on the other hand, the lowest height. The intermediate height values were obtained under the treatments T_{pp} (49.31 cm), T_1 (50.02 cm), T_2 (51.66 cm) and T_5 (51.77 cm).

3.4.3 Fruit circumference

The circumferences of tomato fruits varied significantly with the applied soil treatments ($p<0.0001$) (Table 3). Treatments T_3 and T_4 with values of 15.29 and 15.79 cm, respectively, recorded the highest fruit circumferences. The low values were obtained with the control treatment T_0 (12.31 cm); the intermediate values being obtained with the treatments T_{pp} (13.76 cm), T_1 (14 cm) and T_2 (14.41 cm).

3.5 Variation of Tomato Plant Growth under the Different Soil Treatments

3.5.1 Average number of fruits on a tomato plant

Number of tomato fruits on plants varied significant with the applied soil treatments ($p<0.0001$) (Table 4). The low number of fruits $plant^{-1}$ (11.16 fruits) was obtained under the control treatment T_0. The average intermediate numbers of fruits $plant^{-1}$ were obtained with the treatments T_{pp} (12.23 fruits), T_1 (12.75 fruits), T_2 (12.75 fruits) and T_5 (13.41 fruits). Treatments T_3 and T_4 with average numbers of fruits per plant respectively of 15.75 and 16.79 showed the highest number tomato fruits $plant^{-1}$.

3.5.2 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 4). The highest yields were obtained with treatments

T_3(16292.25 kg ha^{-1}) and T_4 (16850.75 kg ha^{-1}). Intermediate average yields were observed with the T_{pp} (10285 kg ha^{-1}), T_1 (11018 kg ha^{-1}) and T_2(11949.75 kg ha^{-1}) and T_5 (10863.5 kg ha^{-1}) treatments; the lowest yield being obtained with the control treatment T_0 (6513.5 kg ha^{-1}).

Table 1. 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].*

Table 2. Chemical and organic compositions of cattle dung

Matières organique					**P.ass. (ppm)**	**CEC (cmol.kg^{-1})**	**Oligo-éléments (ppm)**		
pH	**C%**	**Nt%**	**M.O%**	**C/Nt**			**Fe^{2+}**	**Zn^{2+}**	**Pb^{+}**
8,1	3,64	0,35	6,26	10	368	17,60	108,4	48,5	0,00

Table 3. Variations stem diameter, fruit size and plant heights with applied soil amendments

	Growthparameters		
Treatments	**Diameter at the collar of the plants (mm)**	**Fruit circumference (cm)**	**Plant height (cm)**
T_0	10.20 ± 0.17 d	12.31 ± 0.19 c	41.19 ± 0.41 d
T_{pp}	10.95 ± 0.20 d	13.76 ± 0.17 b	49.31 ± 0.35 c
T_1	11.75 ± 0.24 c	14 ± 0.21 b	50.02 ± 1.10 c
T_2	12 ± 0.33 c	14.41 ± 0.31 b	51.66 ± 0.95 c
T_3	13.54 ± 0.31 a	15.29 ± 0.27 a	61.41 ± 1.28 a
T_4	14.37 ± 0.36 a	15.79 ± 0.35 a	66.48 ± 1.29 a
T_5	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

Table 4. Variations in number of fruits on tomato plant and yield with the applied soil amendments

	Production parameters	
Treatments	**Number of fruits**	**Yield (kg ha^{-1})**
T_0	11.16 ± 0.39 c	6513.5 ± 21.13 e
T_{pp}	12.23 ± 0.41 b	10285 ± 21.02 d
T_1	12.75 ± 0.37 b	11018 ± 21.45 d
T_2	12.75 ± 0.36 b	11949.75 ± 21.03 c
T_3	15.75 ± 0.33 a	16292.25 ± 25.93 a
T_4	16.79 ± 0,41 a	16850.75 ± 25.27 a
T_5	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 was 5.1 indicated that the soil of the study site was acidic. It therefore had 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 hyperdystricferralsols, which was the basis of many phenomena harmful to plant growth, such as the reduction in nitrification, the phosphorus deficiency and the high availability of heavy metals [16]. These results were similar with those of [17], which showed that tropical soils were characterized by a low level of organic matter, high acidity and high desaturation in exchangeable cations.

4.2 Effect of Fertilizers on Agronomic Parameters of Tomato

The values of the agronomic parameters at the level of the control treatment T_0 (without the addition of fertilizers) were low compared to those of the treatments with 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 T_{pp} treatment (treatment based on NPK only) compared to the values observed for the cattle dung only and the combination of the NPK fertilizer and the cattle dung, would be linked to the sandy texture of the experimental soils. Sandy soils were low in clay and organic matter, and had a low retention capacity for mineral elements. Under these conditions, the mineral elements provided by the chemical fertilizer would not be retained on the adsorbent complex to ensure the nutrition and development of tomato plants. These results were similar with those of [4] which showed that sandy soils generally had low natural fertility and very high water permeability. On the contrary, these elements provided by chemical fertilizer further acidify the soil and degrade its fertility. According to [20], continuous application of chemical fertilizer increases 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 T_5 (application of only cattle dung) compared to the other treatments would be linked to the fact that the mineral elements contained in the cattle 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 cattle dung) were higher than those sole application of fertilizers (NPK alone at the Tpp level or cattle dung alone at the T_5 level). These results obtained could be explained by the synergy of the combined effects of chemical fertilizer and cattle dung. The combined action of cattle dung and NPK fertilizer was a good combination that improves soil fertility in the long term. The NPK chemical fertilizer provided nutrients that were directly used by the tomato plants to satisfy their initial needs. On the other hand, organic matter gradually underwent mineralization subsequently to providing other additional soil nutrients. Combination of mineral NPK fertilizer and cattle dung provided higher amounts of available nutrients and improved soil physical conditions that favored proper growth of tomato plants [22]. These results confirm those of [10] who specified that cattle dung was a quality fertilizer, particularly due to its high nitrogen content. The work of [23] had shown that the potassium (K) contained in the NPK fertilizer allowed optimum crop growth. In addition, the work of [23] showed that the phosphorus contained in NPK fertilizer and cattle dung was a nutrient that stimulates flowering and fruiting. The combination of these nutrients therefore, improved tomato yields. According to [2], the combination of organic and mineral fertilizers creates the optimum growing conditions for crops. The high values of the growth parameters of the tomato plants at the level of treatments T_3 (40 t/ha of cattle dung as a single contribution of basal fertilizer + 375 kg $ha^{-1}$of NPK) and T_4 (40 t/ha of cattle dung cattle with a single input of basal fertilizer + 500 kg $ha^{-1}$of NPK) compared to the other treatments, could be explained by the optimum soil conditions provided by these treatments. However, the non-significant differences observed in tomato agronomic parameters between treatments T3 (40 t/ha of cattle dung + 375 kg $ha^{-1}$of NPK) and T_4 (40 t/ha of cattle dung + 500 kg $ha^{-1}$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 T_3, or the dose of 375 kg of NPK, was the optimal dose of NPK fertilizer to combine with cattle dung at a dose of 40 t/ha to obtain the highest tomato plant responses. This dose of NPK provided allowed 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 T_3 treatment (40 t/ha of cattle dung + 375 kg $ha^{-1}$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^{-1}, the combination of cattle dung at a dose of 40 t/ha + 375 kg $ha^{-1}$of NPK 15 15 15 is the optimum dose to bring to the soil for enhanced tomato production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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