Original Research Article

VEGETATIVE GROWTH RESPONSE OF EGGPLANT (*Solanum aethiopicum* L.) TO COMBINED EFFECTS OF FERTILIZER TYPES AND IRRIGATION REGIMES APPLIED ON LITTORAL TERTIARY SOIL IN CÔTE D'IVOIRE

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ABSTRACT

The use of manures and irrigation systems are essential ways to improve the fertility of coastline poor soils in Côte d'Ivoire and to optimize crop yields at any time of the year. The present study aims to identify the best manures and irrigation systems suitable for the vegetative growth of eggplant on the tertiary poor soils of the coast in Côte d'Ivoire. For this purpose, combinations of fertilizer (urea and organic manure from chicken droppings) and irrigation techniques (manual watering and drip irrigation system) were tested in Fisher block design. So, vegetative growth variables of Eggplant, Aub 21N / 06, grown on tertiary soil at the Marc Delorme research station of the Centre National de Recherche Agronomique (CNRA) in Southern Côte d'Ivoire were evaluated. The results showed that the growth dynamics of collar circumference, height and leaf production of eggplant irrigated by drip system and fertilized with organic manure from chicken droppings was significantly higher. The eggplants that received a treatment composed by organic or chemical manure without irrigation and those without manure and irrigation expressed lower vegetative growth. The organic manure from chicken droppings associated with the drip irrigation regime had a significant beneficial effect on the average growth rates of the collar circumference (0.0035 cm.day^{-1}), height (0.5669 cm.day^{-1}) and leaf production (3.12 leaves.day^{-1}) of eggplant. It appears that organic manure from chicken droppings associated with drip irrigation regime is an agricultural innovation to disseminate to market gardeners to cultivate the eggplant on littoral tertiary soil.

Keywords: eggplant, manure, irrigation regime, tertiary soil, Côte d'Ivoire.

1. INTRODUCTION

Eggplant (*Solanum aethiopicum* L.) is an herbaceous plant from *Solanaceae* family. It is generally grown for its globular berries, consumed as a vegetable. In the world, the area cultivated of eggplant in 2017 is estimated at 1 858 253 ha for a production of 52 309 119 t. In Africa, eggplant acreage covers 106 526 ha for an annual production of 1896091 t [1]. In Côte d'Ivoire, the yield of food crops in general and vegetables in particular is facing to a continuous decline in soil fertility. This depletion of soils is partly due to the climatic disturbances observed in recent years and has severely weakened agricultural production systems [2]. Vegetable production remains insufficient and very seasonal. It is generally provided by small producers who cultivate on small areas, often in urban and peri-urban areas [3,4,5].These market of garden crops constitute the occupation of a large section of the population of almost 60% women and young people. The main vegetable products grown are tomato, okra, onion, cucumber, squash, carrot and eggplant [6]. Since the 2000s, eggplant yields in Côte d'Ivoire has grown significantly [5]. In 2017, the national production on a cultivated area of 18,966 ha was estimated at 99000 t with an average yield of 5.22 $t.ha^{-1}$ [1].

Furthermore, the sandy soils of coastline Côte d’Ivoire are experiencing a real expansion of market gardening in order to satisfy the vegetable needs of large size of the populations living in coastal cities [7]. However, the sandy soils of Côte d'Ivoire's coastline are warming rapidly, are highly permeable to water and have very low fertility [8]. Also, for more than 30 years, precipitation patterns are disrupted and annual rainfall amounts are reduced. Less than 2000 mm of rain is recorded per year in the coastal zone. This has the effect of severe water deficits in agriculture [9]. To continually ensure people's food needs, the use of manure and irrigation systems is an appropriate farming technique. The use of manures, to improve and preserve the fertility of poor soils of Côte d’Ivoire, is an indispensable means to optimize crop yields. However, the use of organic manures from animals excretory (poultry droppings, cattle dung, pig droppings, *etc*.) or chemical enrich in nitrogen are good fertilization practices [10]. Irrigation also reduces the risks induced by climatic riskiness and leads to an efficient water supply for plants [11, 12]. Despite the economic and nutritional potential of eggplant, data on the doses of organic manure and urea as well as the appropriate irrigation systems for this crop on poor coastal soils are poorly available in Côte d'Ivoire. It is to solve this research problem that the present work is done to identify the best manure type and irrigation regime suitable for the vegetative growth of eggplant on littoral tertiary soil in Côte d’Ivoire.

2. MATERIALS AND METHODS

2. 1. DESCRIPTION OF EXPERIMENTAL SITE

The experiment was conducted in larger dry season at Station Marc Delorme (SMD) located Southern Côte d’Ivoire. SDM is located on littoral, Southern Abidjan city, between 03°54' - 03°55W latitude and 05°14'- 05°15' N longitude (Figure 1). The natural forest on the littoral tertiary soil at the station Marc Delorme is dense and the trees carry some leaves in all period of the year. The soil type is tertiary with pH of 5.7, carbon of 0.52%, nitrogen of 0.05%, CEC of 0.25 cmol $(+).kg^{-1}$ and assimilable P of 42.20 $mg.kg^{-1}$ (Brou, 2005). The climate is characterized by four seasons, including two dry seasons and two rainy seasons. The larger dry season starts from December to March and the small one from July to August. The larger rainy season covers the months of March to June and the small season runs from September to November. Over the decade from 2006 to 2015, mean monthly temperatures ranged from 24.5 to 27.7 ° C and average annual rainfall was 1840.1 mm (Figure 2). The sunshine was of the order of 2000 $h.year^{-1}$ and the relative humidity of about 80 to 90%.

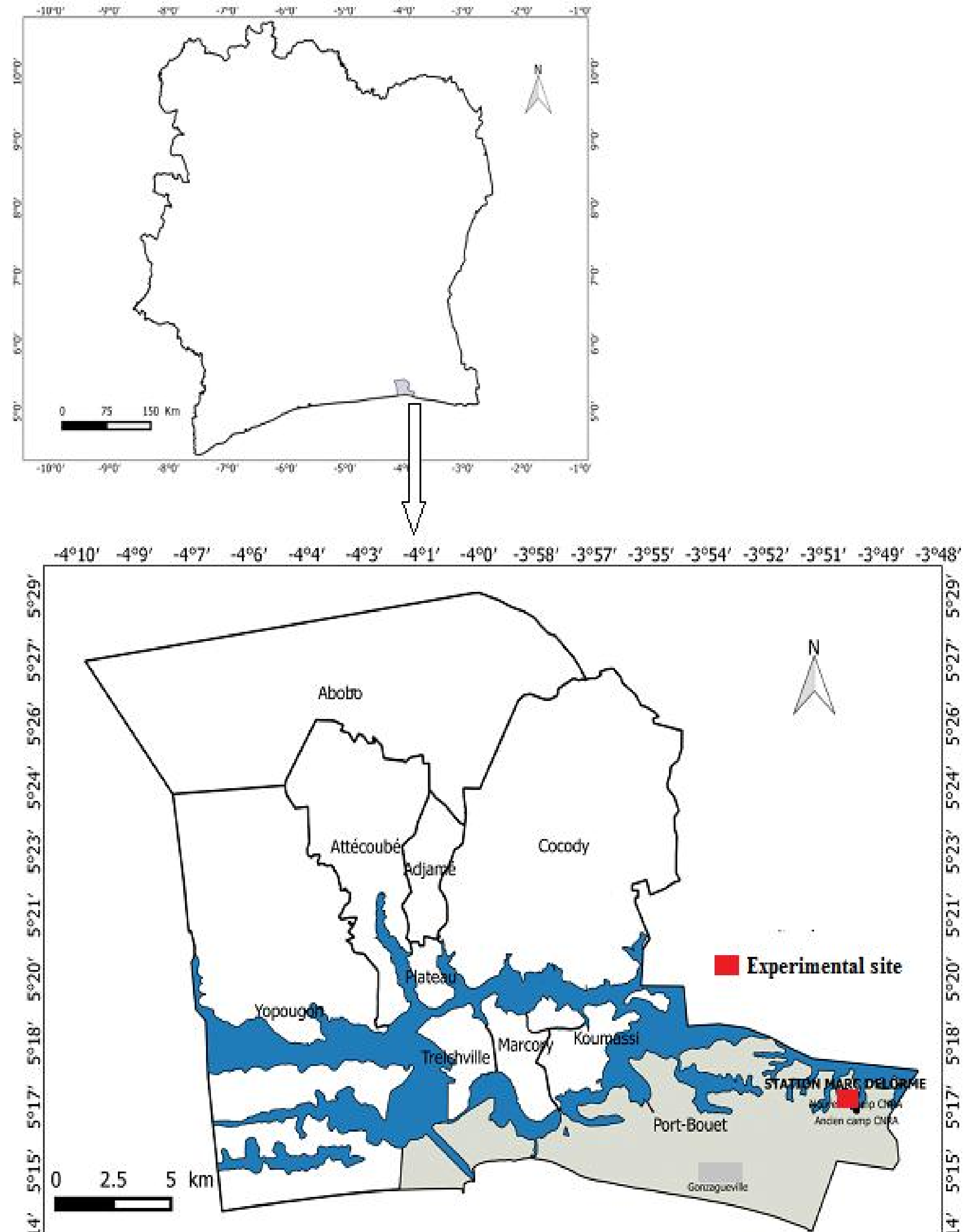

Figure 1. Location of experimental site in Southern Abidjan city, Côte d'Ivoire

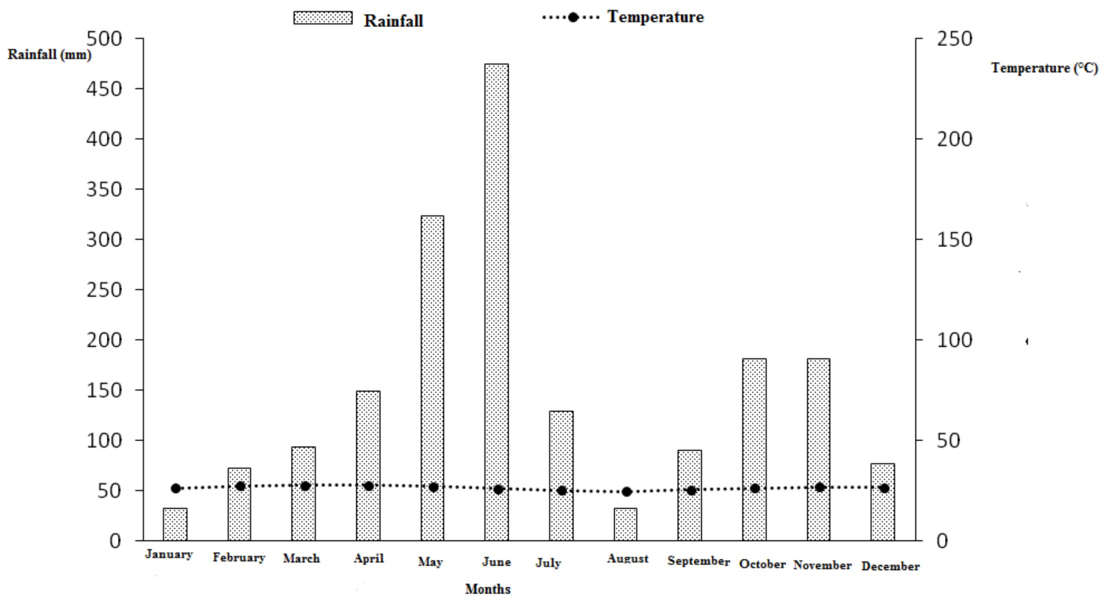

Figure 2. Ombrothermal curve covering the decade from January 2006 to December 2015 at Station Marc Delorme (SMD)

2. 2. TYPES OF MANURES APPLIED AND APPLICATION METHODS

Two types of fertilizers were used in the study. Chemical fertilization with urea constituted of 46% of nitrogen and, organic manure from chicken dejections. Each eggplant plant received 20 g of urea over a period of 4 weeks at a frequency of 5 $g.plant^{-1}.week^{-1}$. The organic manure consists of chicken dejections. The chickens were aged of 17 months and fed with industrial feeds from IVOGRAIN in Côte d'Ivoire. The organic manure (Figure 3) consisted of 86.10% dry matter and 0.69% nitrogen. Eggplant plants received 202 g of organic manure only once, corresponding to the dose of urea applied. Fertilization was done 30 days after sowing.

Figure 3. Appearance of organic manure from chicken dejection used to fertilize eggplants

2. 3. TYPES OF IRRIGATION AND APPLICATION MODES

Two types of irrigation, manual watering and drip irrigation system, were tested. A watering which can contain until 16 l was used for daily manual watering. The drip irrigation system with John Deere Water equipment was installed. It consists of two tanks of 1000 l, the ramps longer were 25 m on which we find drippers every 50 cm of stop valves, filters (Figure 4). Ramps were erected on ridges. The tanks were suspended on towers of 2 m high, built with coconut stems to have sufficient water pressure. The flow rate of manually irrigated and drip-fed plants was 5.6 $l.j^{-1}.plant^{-1}$.

Figure 4. Drip irrigation system consisting of (a) tanks of 1000 l, mounted on supports made of coconut stems 2 m high, (b) filter, (c) ramps and (d) drippers on a ramp.

2. 4. EXPERIMENTAL DESIGN OF FERTILIZING AND IRRIGATION

The soil was plowed to a depth of 20 to 30 cm. Ridges of 25 m long, 1 m wide and 30 cm high were made. The ridges were treated with an insecticide with Chlorpyrifos (480 $g.l^{-1}$) as an active ingredient at 1 $l.ha^{-1}$ to neutralize termites. Similarly, a glyphosate herbicide treatment (300 $g.l^{-1}$) was applied around the experimental plot to control weeds. The equivalent of 150 kg of $urea.ha^{-1}$ in manure from chicken dejections, or 3.03 $kg.m^{-2}$, was mixed with soil as a basic fertilizer. The test was conducted in Fisher blocks design with 9 treatments and three replicates (Figure 5). The elementary plot consisted of 4 ridges of 4 m wide and 5 m long equal to 20 m^2 (5 m x 4 m) of surface. On each ridge of the basic parcel, 10 irrigation booms were installed with 0.5 m between them. Each dripper is slightly offset from the foot of the eggplant plant (Aub 21N / 06) that it irrigates. Each elementary plot has 40 plants and the treatments are disposed as follows:

T0: without fertilizer, without irrigation
T1: without fertilizer with drip irrigation
T1am: without fertilizer with manual watering
T2: urea, with drip irrigation
T2am: urea with manual watering
T3: urea without irrigation
T4: organic manure, without irrigation
T5: organic manure with drip irrigation
T5am: organic manure with manual watering

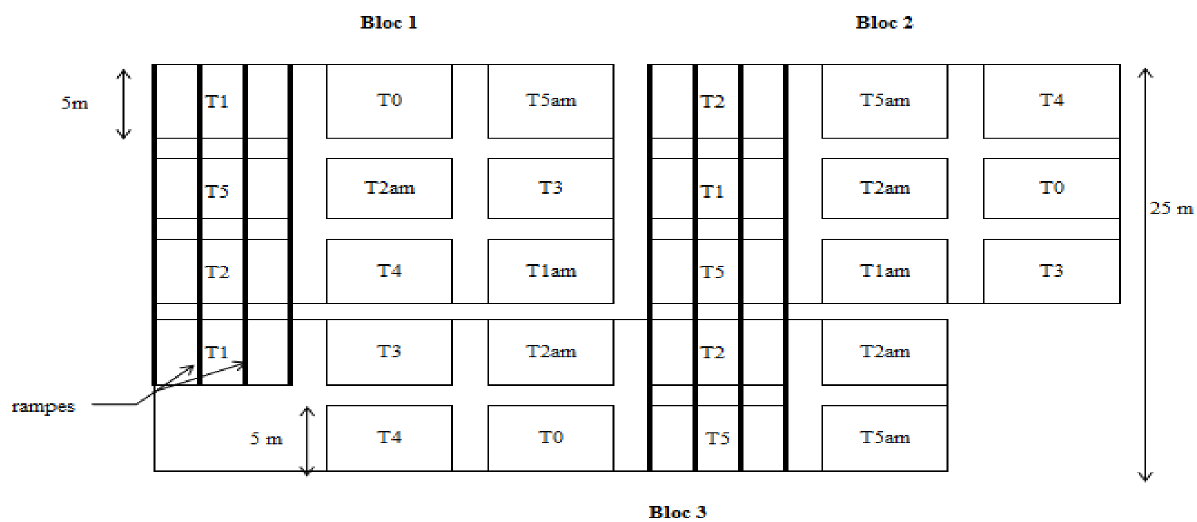

Figure 5. Experimental design used for eggplant fertilization and irrigation

2. 5. DATA COLLECTION AND STATISTICAL ANALYSIS

Observations included 20 plants located on two central ramps per elementary plot. Three vegetative characters that are collar circumference, height and number of leaves were determined. The collar circumference was measured using a sliding caliper. The height was measured with a mater tape measure from the collar to the last apical bud. The number of leaves has been counted. Vegetative growth of eggplant was monitored at day 14, day 28, day 42 and day 56 from the third week after transplanting or two weeks after application of the different treatments. The average of vegetative growth speed (VGS in cm.day^{-1}) was calculated for collar, plant height and leaf emission according to the formula:

$$VGS = \frac{X_{tn+1} - X_{tn}}{t_{n+1} - t_n}$$

With $X_{tn+1} - X_{tn}$ discrepancy between the values observed at two consequential times t_{n+1} and t_n respectively for a given growth character. $t_{n+1} - t_n$ discrepancy between two consequential times that is to say 14 days.

The collected data were subjected to an analysis of variance (ANOVA) with SPSS software version 20.0.0 (IBM Corp., USA). The post-ANOVA test of Newman-Keuls at the 5% threshold was used for the comparison of averages.

3. RESULTS

3.1. EFFECTS OF MANURE TYPES AND IRRIGATION REGIMES ON EGGPLANT COLLAR CIRCUMFERENCE GROWTH

The collar growth dynamics of eggplant grown in a substrate supplemented with irrigated droppings with the drip system was highest. The collar circumference of eggplant seedlings increased from 1.21 cm to 2.79 cm after 52 days after application of organic manure from chicken dejection and the drip irrigation system (Figure 6). Regardless of the type of fertilizer applied (organic manure or urea), the lack of irrigation resulted in low collar circumference of eggplant (Figure 6). The application of both the droppings and the drip irrigation system favored a better growth rate (0.0035 cm.day^{-1}) of the collar of eggplant. The lowest collar growths were recorded with treatments without irrigation (0.0030 to 0.00045 cm.day^{-1}) (Figure 7).

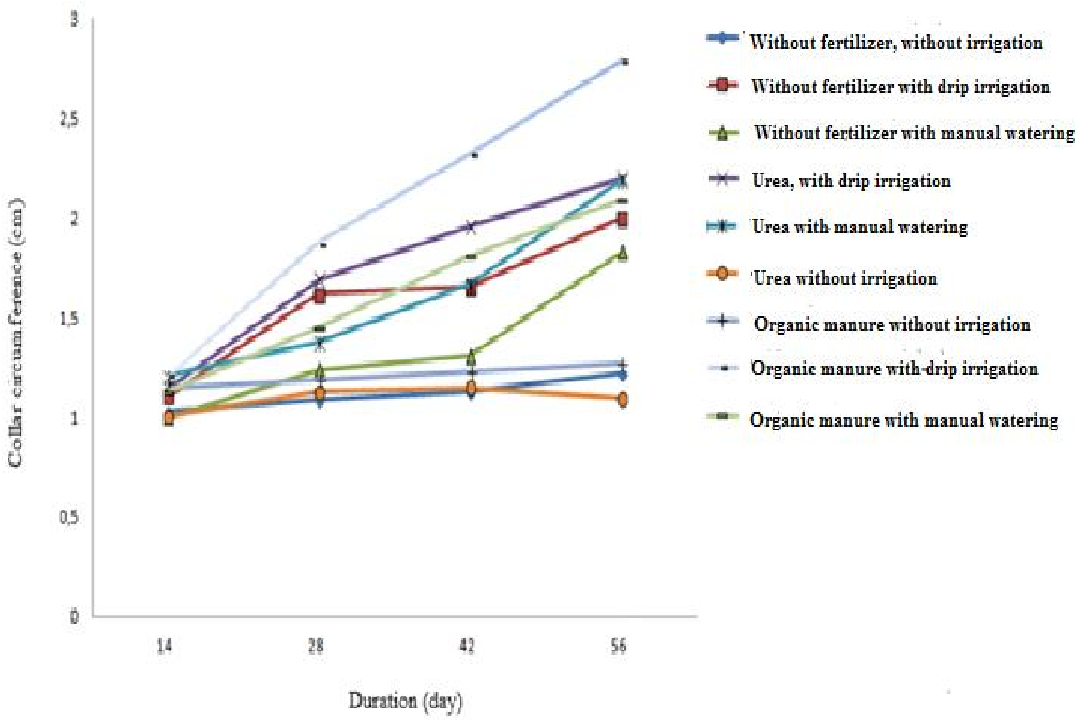

Figure 6: Effects of manure and irrigation type on eggplant collar circumference growth

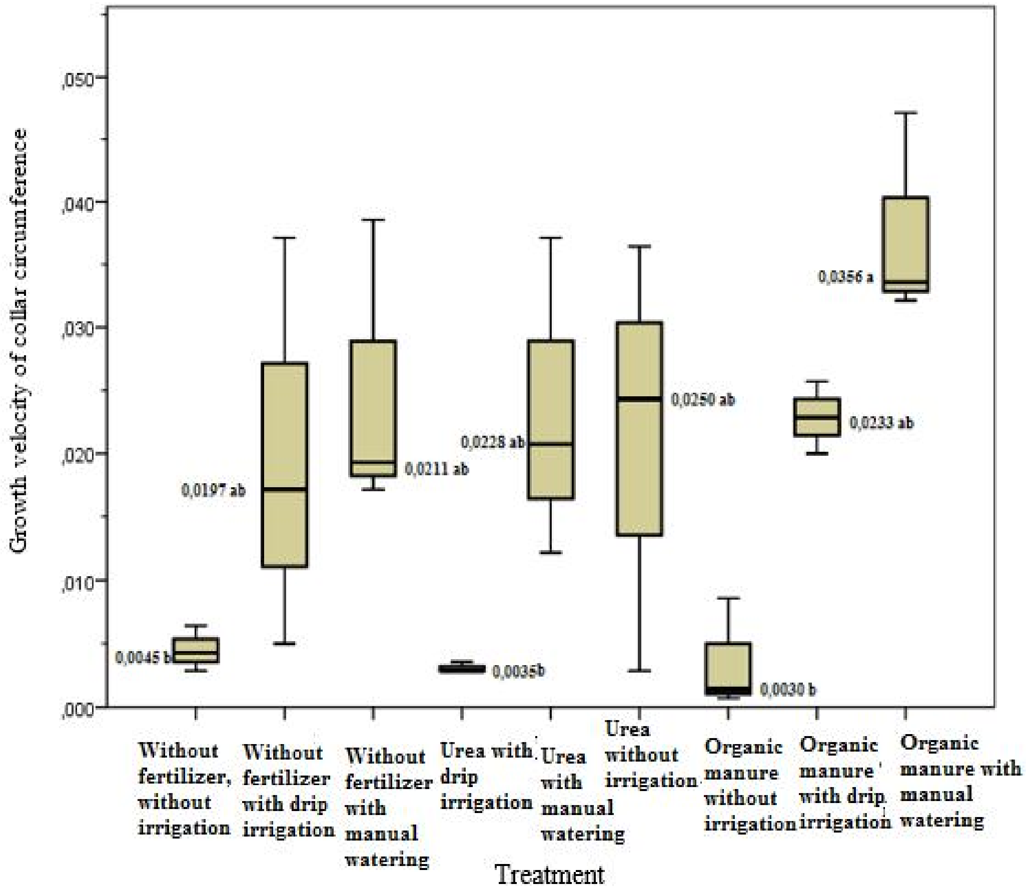

Figure 7. Boxplots that indicate the combined effect of manure and irrigation system on the average on eggplants collar growth.

3.2. EFFECTS OF MANURE TYPES AND IRRIGATION REGIMES ON EGGPLANT HEIGHT GROWTH

The combined effect of manure from chicken dejection and drip irrigation was significantly greater than other treatments on eggplant height growth. From the 14th to the 56th day, the height of the plants tripled from 11.27 cm to 35.08 cm. This treatment showed a significant growth rate in height (0.5669 cm.day^{-1}, ddl= 8, $F = 7.679$, $p <0.001$) of eggplant (Figure 8). Plants fertilized, either with urea or dung, without irrigation have got lowest heights of plants (Figure 9).

3.3. EFFECTS OF MANURE TYPES AND IRRIGATION REGIMES ON THE EMISSION OF EGGPLANT LEAVES

Increasing of leaf production of eggplant plants fertilized with organic manure from chicken dejection and drip irrigated was significantly higher than that of other treatments. Mean leaf production ranged from 19.53 to 150.70 from day 14 to day 56 after treatment (Figure 10). Plants from other treatments had the lowest numbers of leaves issued (18.93 to 43.30 leaves). Combination of application of organic manure from chicken dejection with the drip irrigation system (ddl= 8, F = 3.094, p = 0.022), significantly increased growth rate in height (3.12 cm day^{-1}) in eggplant (Figure 11).

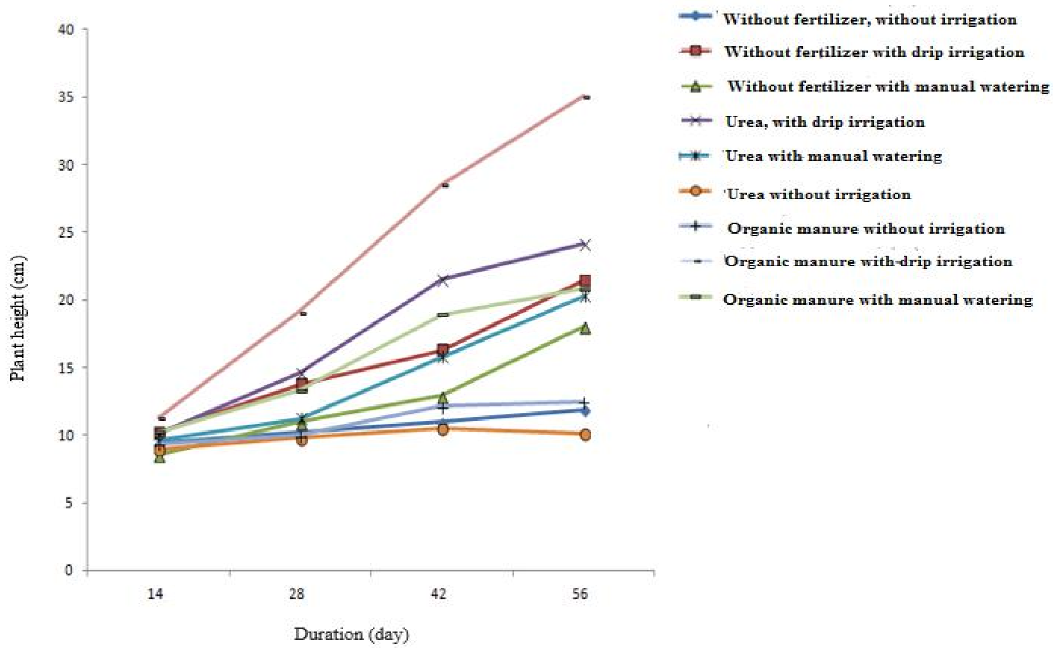

Figure 8. Effects of manure and irrigation type on eggplant height growth

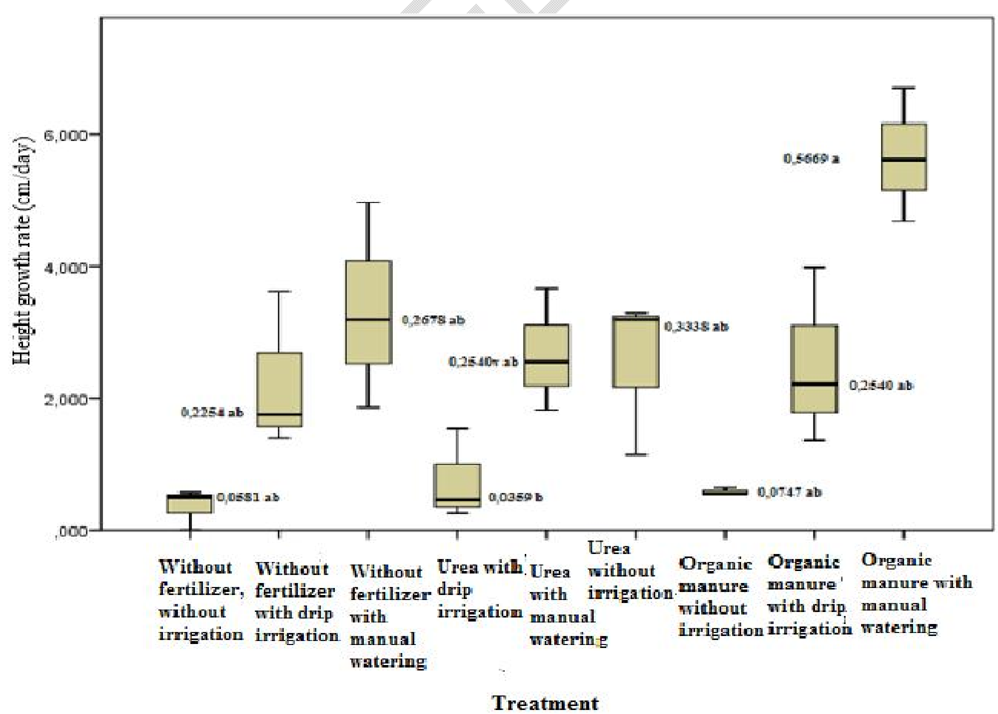

Figure 9: Boxplots that indicate the combined effects of manure and irrigation type on the average of eggplant height growth

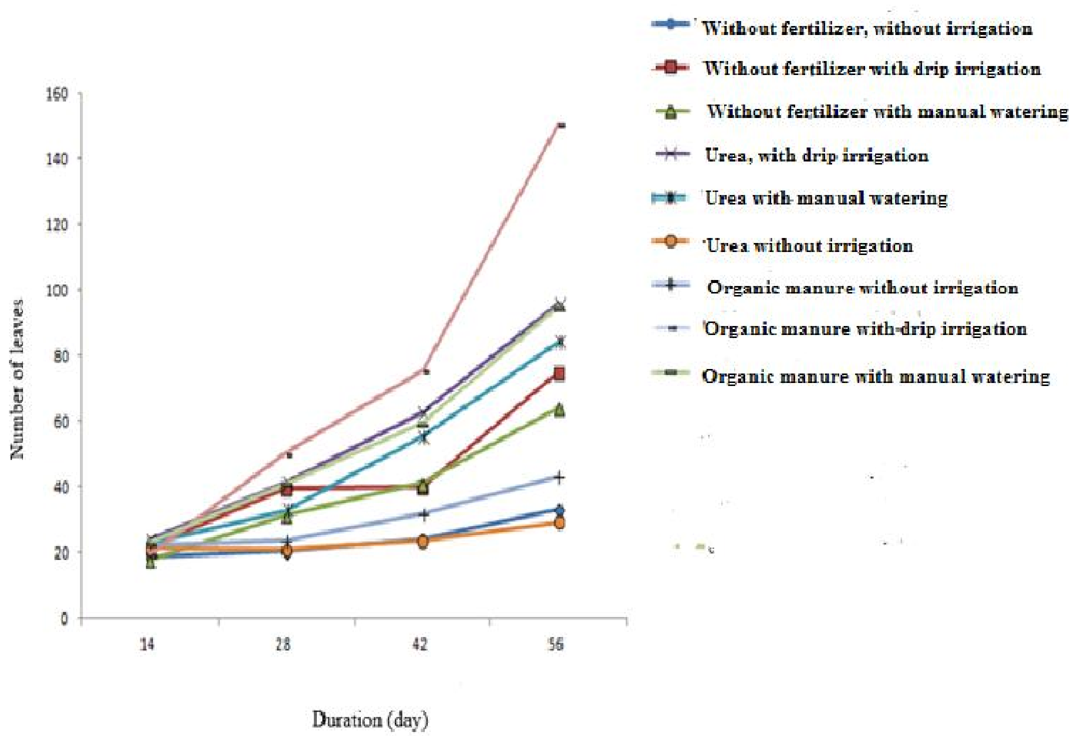

Figure 10. Effect of manure and irrigation type on eggplant leaf production

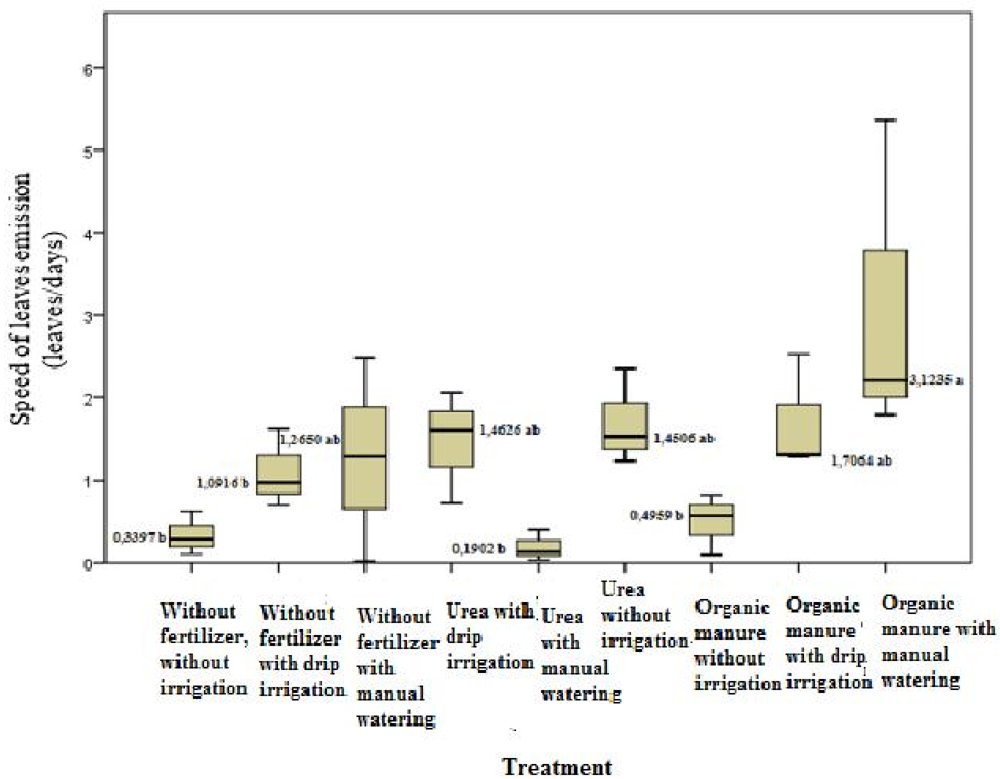

Figure 11. Boxplots that indicate the combined effect of manure and irrigation type on eggplants leaf velocity

4. DISCUSSION

Vegetative growth of eggplant grown on littoral tertiary soil of Côte d'Ivoire was improved from treatments combining drip irrigation and organic manure proceeds from chicken dejections. This result could be explained by the fact that organic fertilizers on sandy soils have a beneficial effect on crops unlike chemical fertilizers which are subjected, in addition to being very volatile, to percolation (seepage into the soil) after irrigation or rain [7].
In addition to the nitrogen supplied, organic manure from chicken dejections provides other mineral elements (potassium, phosphorus and trace elements). It improved soil structure by increasing its water and nutrient retention capacity and stimulate microbial activities [13]. Also, organic manure from chicken dejections, which constitutes an organic fertilizer, generally influence the chemical properties of the soil and especially the pH (H_2O) of the soil, making it slightly neutral. A pH close to neutrality is an asset for better root absorption of nutrients [13, 14].
The application of organic manure from chicken dejections would bring additional quantities of nutrients to the soil to increase its fertility. In addition to its high nitrogen content, the other mineral elements contained in organic manure from chicken dejections would be sufficient to stimulate the growth and development of all living tissues of eggplant seedlings as mentioned in corn [15]. These major or secondary mineral elements enter into the synthesis and consolidation of plant tissues. These results confirm those reported about the good growth of cassava plants treated with organic manure from chicken dejections [16]. Similarly, these results corroborate those mentioned the importance of organic manure on the harmonious development of young coconut trees [8]. The beneficial effects of organic manure on the vegetative growth were reported in *Zea mais* L. and *Moringa oleifera* L. [15]. Since nitrogen is a constituent element of chlorophyll, it is a determining factor in the vegetative growth of plants [13]. Several bioclimatic factors being at the origin of the process of decomposition of organic residues, those conditioning the dynamics of mineralization of organic manure from chicken dejections would be favored by irrigation especially the drip system [17, 18]. Indeed, drip irrigation confers permanent moisture to the soil, allowing telluric microorganisms, fundamental players in the degradation of organic matters to have an efficient activity. Water is brought near the root zone of the plants thanks to the drippers which would thus optimize the water nutrition and the assimilation of solubilized nutrients. Drip irrigation combined with organic manure would correct the chemical and physical properties of the littoral tertiary soil with a positive effect on the rooting and diffusion of water and fertilizers.
Urea combined with drip irrigation also favored, to a lesser degree compared to organic fertilizer, the vegetative growth of eggplant. The immediate availability of nitrogen from urea would have contributed to these results. That shows the importance of applying urea during the vegetative phase and for leaf formation [19]. Also, the nitrogen supply provided by organic manure from chicken dejections would be more durable than that induced by urea, under drip irrigation conditions. Indeed, urea is very often subject to losses due to leaching after irrigation [19]. The nitrogen from the droppings would therefore be progressively available for the eggplant and reasonably distributed within the cells of the latter for its metabolism.

5. CONCLUSION

This study was carried out with the aim of finding a better method of combining fertilization and irrigation on the sandy soils of the littoral, within the reach of market gardeners for the cultivation of eggplant. It focused specifically on assessing the effect of organic and inorganic fertilizers on eggplant growth. It appears that the supply of organic manure from chicken dejections associated with drip irrigation therefore seems to be a good practice for producers to ensure optimal vegetative growth that would guarantee high yields in eggplant.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO, Culture. FAOSTAT data. Available at http://www.fao.org/faostat/en/#data/QC. 2017.

2. Keffing D. Analysis of the causes of malnutrition in 3 Sahelian countries: Burkina Faso, Mali and Chad. Report. 2008, 74 p.

3. Kagambega L., Konkobo M. and Thiamobiga D. Socio-economic impact of the producer organization on market gardening production in Burkina Faso: case of Bobo-Dioulasso, Ouagadougou and Ouahigouya. Master's thesis, Polytechnic University of Bobo-Dioulasso (UPB), Bobo-Dioulasso, Burkina Faso. 84 p. 2016.

4. Fondio L., Kouame C., Nzi J.C., Mahyao A., Agbo E. and Djidji H. Survey of Indigenous Leafy Vegetables in the Urban and Peri-Urban Areas of Côte d'Ivoire. *Acta Hortic*. 2007; 752, 287-289

5. Sangaré A., Koffi E., Akamou F. and Fall C. State of Plant Genetic Resources for Food and Agriculture. Ministry of Agriculture Côte d'Ivoire, National Report. 2009; 65 p.

6. Ministry of Agriculture. National Agricultural Investment Program. http://www.sara.ci/wp-content/uploads/2014/10/PNIA_fiches-filières.pdf. 2010.

7. Yèhouénou E., Pazou A., Toko A. and Houndantodé J. Variability of chemical elements of the sandy soil of the coastline amended with by-products of sewage treatment in Sèmè-Podji in South Benin. Agricultural Research Bulletin of Benin, 2009; 64, pp. 27-33.

8. Lékadou T., N'guessan A., Konan L., Zakra N., Kouame A. and Allou K. Effect of density on the dendrometric parameters of Acacia auriculaeformis in association with Coconut (Cocos Nucifera) On Sands quaternaries in Ivory Coast. *African Agronomy*. 2008; 21 (1), pp 71-82.

9. Brou Y., Akindes F., Bigot S. Climate variability in Côte d'Ivoire: between social perceptions and agricultural responses. *Cahiers Agricultures*. 2005; 14 (6). 533-540.

10. FAO. Fertilizers and their applications: Precise for use by agricultural extension agents. Fourth edition, revised version, published by FAO, IFA and IMPHOS. 2003.

11. Liang Z. Investment needs in irrigation in sub-Saharan Africa. Diagnostics of national infrastructures in Africa. 2008; 12 p.

12. Weil A. and Duval J. Green Fertilizer. Manuscript of the global management guide of organic and diversified vegetable farm. Module 5, Rotation and green manure, Chapter 9. 2009. 18 p.

13. Biaou O.D.B., Saidou A., Bachabi F.-X., Padonou G.E. and Balogoun I. Effect of adding different types of organic fertilizer on soil fertility and carrot production (*Daucus carota* L.) on ferralitic soil in southern Benin. *Int. J. Biol. Chem. Sci*. 2017; 11 (5): 2315-2326.

14. Saïdou A., Bachabi S., Padonou G., Biaou O., Balogoun I. and Kossou D. Effect of the contribution of organic fertilizers on the chemical properties of a ferralitic soil and the production of lettuce in the South Benign. Rev. *CAMES-Series A.* 2012. 13 (2): 281-285.

15. Ogbonna D., Isirimah N. and Princewill E. Effect of organic waste compost and microbial activity on the growth of maize in the utisoils in Port Harcourt, Nigeria. *African Journal of Biotechnlogy*. 2012; 11 (62): 12546-12554.

16. Akanza P.K., N'Zue B. and Anguete K. Influence of mineral manure and poultry litter on cassava production (*Manihot esculenta* CRANTZ) in Côte d'Ivoire. *African Agronomy*. 2002; 14 (2): 79-89.

17. Recus S., Machet J.M. and Mary B. Partioning of fertilizer -N between soil microflora and crop: Comparison of ammonium and nitrate applications. *Palart and soil.* 1992; 101-111.

18. Recus S., Darwis D., Robin D. and Machet J.M. Decomposition of crop residues: interaction with nitrogen dynamics. In: Decroux J., Ignazi J.C. (eds) *Organic matter and agriculture.* 1993.13p.

19. N'goran A. Improvement of the chemical fertility of Quaternary sand in Côte d'Ivoire in the coconut / *Acacia sp.* association. University of Gent Belgium, Thesis, 193 p. 2005.