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Full Length Article

Effects of *Azolla caroliniana* Based Biofertilizers Filtrate and Compost on Tomato (*Solanum lycopersicum*) Growth and Production in Côte d'Ivoire

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Abstract

Arable land becomes depleted of nutrients over the years it is farmed. Farmers use chemical inputs to maintain or increase production. The abusive use of these chemical fertilizers has a negative impact on the environment and on consumers health. It is therefore timely to look for alternatives with biofertilizers. The aim of this study was to evaluate the effects of *Azolla caroliniana* Willd fern filtrate and compost on tomato (*Solanum Lycopersicum* L., variété Boomerang F1) growth and production, in comparison with NPK. To achieve this objective, the experiments were conducted in a Fisher block design with three replications. Several parameters identified as being essential in assessing the effect of fertilizers were regularly monitored in the plantation during the vegetative and reproductive phases. These were plant height, leaf length, collar diameter, number of branches, number of flower clusters, number of fruits produced and yield. At the end of the study, it was found that *A. caroliniana* filtrate significantly increased the height of the plants (145.72 cm) and enabled them to produce more fruit (51.33 per plant), which in turn increased yield (44.23 t/ha). *A. caroliniana* filtrate is a biofertilizer that may therefore be an effective alternative for improving agricultural production of tomato.

Keywords: Biofertiliser; *Azolla caroliniana*; Compost; Growth; Production; Tomato

Introduction

The tomato (*Solanum lycopersicum* L.) is a plant native to the Andes region of South America. It then spread to South and East Asia, Africa and the Middle East. Its cultivation began in Côte d'Ivoire in the 1970s with intensive cropping systems on irrigated perimeters (CNRA 2016). The rush towards this crop is due to its high protein, vitamin A and C content (Hanson *et al.* 2001) and its use in a number of food menus.

In Côte d'Ivoire, the average tomato yield is 10 t/ha (CNRA 2016). Annual production is between 22,000 and 35,000 tonnes (Yeo *et al.* 2021), which is insufficient to fulfill the needs of the population, currently estimated at over 100,000 tonnes per year (Soro *et al.* 2007). This low tomato production in Côte d'Ivoire could be explained by several factors. There is the lack of control over technical itineraries, and attacks by numerous pests and diseases (Bado 2002; Samba *et al.* 2013). There is also the impoverishment of arable land due to over-exploitation and poor management of cultivated land. One of the direct consequences of this is the depletion of the mineral elements needed to fertilize the soil and enable crops to flourish (Mario 2016). Another factor linked to low tomato production is the poor use of agricultural inputs. Excessive use of these inputs in agricultural plots certainly improves crop yields (N'dah 2012), but results in poor quality harvests. In addition, the effects of overuse of inputs, once neglected, have become a major source of pollution. The long-term use of chemical fertilizers has harmful effects on the environment (Pierre 1996; Groga *et al.* 2018a). As a result, farmers are increasingly turning to the use of biofertilisers as a way of farming that minimizes the risk of polluting the environment while producing high quality, high quantity crops.

Several studies have shown that the use of organic fertilisers by farmers is an alternative crop management method aimed at reducing or eliminating synthetic inputs (Abawi and Widmer 2000). In this context, organic farming offers new prospects with the use of manure, poultry manure-based composts, sheep dung and guano (Tchabi *et al.* 2012). These less expensive biofertilizers improve soil

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fertility and structure and enable good plant development (Douglas *et al.* 2006). They also increase yields and improve fruit quality (Oka 2010; Zodape *et al.* 2011). The aim of this study was to evaluate the effects of biofertilizers and compost prepared from *Azolla caroliniana* on the tomato growth and production.

Materials and Methods

Description of the study area

The study was conducted at the experimental site of the Université Jean Lorougnon Guédé in Daloa, Côte d'Ivoire. It lies between 6°54' longitude North and 6°26' longitude West. The area enjoys a humid tropical climate with four distinct seasons. A long rainy season from April to mid-July, a short dry season from mid-July to mid-September, a short rainy season from mid- September to November and a long dry season from December to March (N'Guessan *et al.* 2014). Average annual temperatures range from 24.65 to 27.75°C. Annual rainfall, which was 1,868.5 mm in 1968, fell to 1,200 mm in 2008, a drop of 40% (Ligban *et al.* 2009). The soil is highly or moderately altered ferralitic (Die 2006). The vegetation belongs to the ombrophilous sector of the Guinean domain, characterized by dense humid forest with regressive evolution. Climate data of the study area during the trials are presented in Table 1.

Tomato material

The vegetable material used consisted of tomato plants of the Boomerang F1 variety. This is an improved tomato variety whose seeds come from the French seed center TECHNISEM, distributed in Côte d'Ivoire by SEMIVOIRE. This variety was chosen for its high yield of around 24 t/ha, its taste quality and the ease with which seeds can be obtained.

Biofertilizers preparation

The fertilisers (organic and chemical) used during the experiment consisted of filtrate from the *A. caroliniana* fern (Fig. 1), compost made from white sawdust, chicken droppings, and charcoal, and NKP (10-18-18) for comparison.

Preparation of *Azolla* filtrate: A 75 g of *A. caroliniana* was mixed with 25 g of chicken manure (in 3: 1 ratio). The mixture was then groung, with the addition of water. The crushed maetriel was filtered to get the filtrate. The filtrate thus obtained was diluted with water in 2:1 ratio (filtrate/water) before use.

Compost preparation: The compost used in this study was made from chicken manure, *Triplochiton scleroxylon* (Samba) sawdust, coffee parchment and charcoal. Composting required 120 kg of chicken droppings, white sawdust and charcoal each, as well as 60 kg of coffee parchment and 200 L of water. All the products were mixed to obtain a homogeneous mixture. The resulting mixture was then stored on a tarpaulin and covered for two months.

Experimental design

The trial was conducted in a Fisher block design with three replicates. Each replicate consisted of four treatments, including *A. caroliniana* filtrate, compost, NPK (10-18-18) and the no-fertilizer control. Each block consisted of four 12 m² plots. The distance between two blocks and between elementary plots within the same block was 2 m. The tomato plants were transplanted in three rows with 0.6 m between rows and 0.4 m on the row. The planting density was 37500 plants/ha, either 45 tomato plants per elementary plot.

Fertilization of plants

Application of NPK (10-18-18): The amount of NPK applied per bed throughout the tomato cycle was 240 g. This amount was divided into two applications. The 1st application was made two days before transplanting at a rate of 105 g per individual plot. The 2nd application was made two weeks after transplanting, at a rate of 3 g per plant, either 135 g per elementary plot.

Application of *Azolla* filtrate: The *A. caroliniana* filtrate was diluted by half and then applied to the tomato plants in two doses. Each plant received 0.40 L of liquid *A. caroliniana* filtrate diluted during its development at a rate of 0.2 L per addition. The first application was made 3 days after transplanting and the second application was made 21 days after transplanting.

Application of compost: Compost was incorporated at a rate of 36 kg per bed in two applications according to Inckel *et al.* (2005). The first application was made two weeks before transplanting, at a rate of 30 kg per bed. The second application was made at transplanting time, at a rate of 6 kg of compost per bed.

Parameters assessed

Twelve tomato plants were selected at random from each elementary plot. Observations and measurements were taken every week from the 35th day of the tomato's vegetative cycle. The parameters assessed were: stem height, leaf length, crown diameter, number of branches, number of flower clusters, number of fruits produced and yield.

Statistical analysis of the data

The data collected were subjected to an analysis of variance (ANOVA) with a classification criterion (mean) using "Statistica v.7.1" software. In the event of a significant difference, the means were separated using the Newman-Keuls test with a threshold of 5%.

Table 1: Meteorological data of the study area during trials

Month	Rainfall (mm)	Relative humidity (%)	Average air temperature (°C)
January	5.40	58.15	28.25
February	18.03	67.55	28.55
March	151.65	77.90	27.60
April	81.53	79.09	27.40
May	120.66	81.50	26.80
June	189.11	84.20	26.20
July	121.16	87.55	25.15
August	175.62	88.40	24.85
September	143.32	88.70	25.25
October	141.97	83.80	26.30
November	50.53	79.35	26.95
December	42.54	73.15	26.90

Table 2: Influence of fertilizers on the growth parameters of the tomato variety Boomerang F1

Fertilizer	Plant height (cm)	Leaf length (cm)	Number of branches per plant	Collar diameter (cm)
Compost	128.55b	27.33a	12.50a	1.39 a
Azolla	145.72a	26.73a	12.10a	1.50 a
NPK	130.30b	28.15a	15.50a	1.37 a
Control	111.15c	24.95a	10.60a	1.22 a
CV	5.83	1.24	1.14	1.02
P	0.0002	0.71	0.25	0.2

In a column, means followed by the same letter are statistically identical at the 5% threshold (Newman-Keuls test). CV: Coefficient of variation; P: Probability

Fig. 1: Growth of *Azolla caroliniana*

Results

Effects of fertilizers on growth parameters

The results relating to the effects of fertilizers on growth parameters are given in Table 2. The effect of fertilizers was significant ($P<0.05$) on plant height, which ranged from 111.15 to 145.72 cm. The plants fertilized with *A. caroliniana* filtrate were the tallest (145.72 cm) and the lowest heights were recorded in the control plants without fertilizer (111.15 cm). For the other parameters, the effect of fertilizer was not significant ($P>0.05$).

Effects of fertilizers on production parameters

Number of flower clusters per plant: The average number of flower clusters per plant fluctuated between 3.80 and 8.20 (Table 3). The differences observed were significant ($P<0.05$). The number of flower buds per plant was highest in NPK-fertilised plants (8.20) and lowest in untreated control plants (3.80). The numbers of flower buds observed in plants fertilized with 336 *A. caroliniana* filtrate (6.93) and compost (7.07) were statistically identical ($P>0.05$).

Number of fruits produced per plant: The effect of fertilizers was significant ($P<0.05$) on the number of fruits

Table 3: Influence of fertilizers on tomato production parameters for the Boomerang F1 variety

Fertilisers	Production parameters	
	Number of floral per plant	Number of fruits per plant
Compost	7.07ab	36.47b
Azolla	6.93ab	51.33a
NPK	8.20a	41.73b
Control	3.80c	14.93c
CV	3.46	9.71
P	0.0001	0.00001

Means in the same column followed by the same letter are statistically identical at the 5% threshold (p <0,05). CV: Coefficient of variation; P: Probability

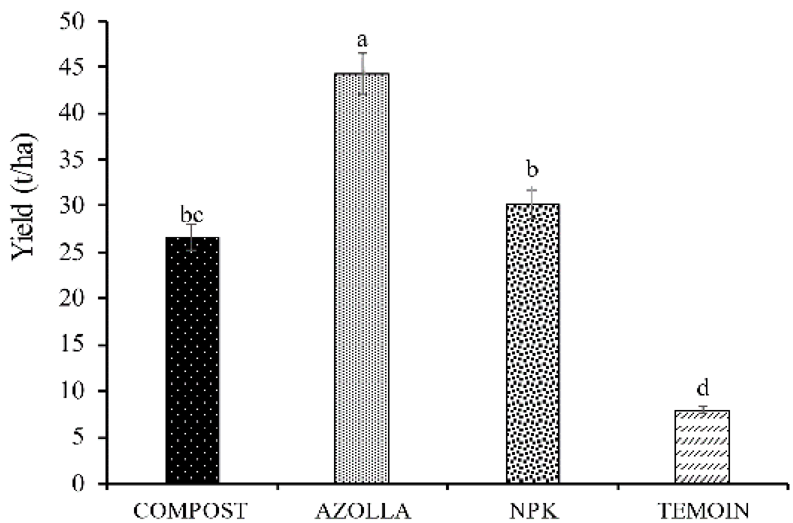

Fig. 2: Yield of the tomato variety Boomerang F1 as a function of fertilizer treatments

produced per plant. Plants fertilized with *A. caroliniana* filtrate produced more fruit (51.33/plant) than plants fertilized with other fertilizers (Table 3). The average number of fruits produced by plants fertilized with compost (36.47) and NPK (41.73) was statistically identical (P>0.05) to and higher than those of unfertilized control plants (14.93).

Tomato yield: Fig. 2 shows the yields according to the fertilizers tested. The highest yield was obtained from plants fertilised with *A. caroliniana* filtrate (44.23 t/ha), followed by those fertilized with NPK (30.20 t/ha) and compost (26.56 t/ha). The lowest yield was recorded in the unfertilized control plants (7.95 t/ha).

Discussion

The effects of biofertilizers (*A. caroliniana* filtrate and compost) were evaluated on a number of tomato growth and production parameters in comparison with a positive control (NPK) and a negative control (no fertilizer). Plants fertilized with *A. caroliniana* filtrate were taller than those treated with compost, NPK and soil control (Table 1). In this regard, Groga *et al.* (2018b) showed that the average height of tomato plants treated with *A. caroliniana* was higher than those of plants in the other formulations tested (NPK, compost and the control without fertilizer). This may be due to the fact that the Azolla-based filtrate was better absorbed by the plants, which enhanced the effectiveness of the minerals in the soil. Nitrogen is the main nutrient responsible for quantitative plant growth (Kotaix *et al.* 2013). *A. caroliniana* can gradually release minerals, which may ensure the availability of nitrogen to the plant at the time of its nutritional needs (William 2003; Ojetayo *et al.* 2011). With regard to leaf length, collar diameter and the average number of branches on tomato plants (Boomerang F1), the effect of the treatments was not significant (Table 1).

In terms of production parameters, the average number of fruits of tomato plants treated with *A. caroliniana* was higher than those treated with compost and those of the two controls (Table 2). The *A. caroliniana* filtrate also gave the tomato plants the highest yields. In their study, Fondio *et al.* (2013) showed that biofertilizer application to tomato and chilli resulted in higher fruit numbers. This high yield obtained in this study could be justified, firstly, by the supply of nitrogen in organic form to the growing medium. This led Thomas *et al*. (2004) and 368 Kitabala *et al.* (2016) to conclude that nitrogen fertilization affects all the parameters contributing to good yields. Secondly, *Azolla sp* and compost provide primary and secondary nutrients and trace elements to plants. NPK fertiliser contains only the 3 primary elements of fertilizers. According to Giller *et al.* (2002) and Alvarez (2005), mineral fertilizers alone cannot maintain soil productivity over the long term because of leaching and degradation of soil properties. According to these authors, organic fertilizer is the best basic fertilizer.

Conclusion

Biofertilizers used significantly increased stem height, collar diameter and number of fruits compared with the controls (NPK and unamended control) in tomato. Among them, the filtrate biofertilizers of *A. caroliniana* proved to be significantly more effective for both vegetative organ growth and tomato plant productivity than the compost used. These biological fertilisers could be an alternative for crop improvement.

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Author Contributions

Kouamé Kouassi Thiègba planned the experiments and collected the data. GROGA Noël carried out statistical analyses of the data and produced illustrations. ESSIS Brice Sidoine, HALA Kinampinan Adelphe and EHOUNOU Adou Emmanuel interpreted the results. The report was written by Kouamé Kouassi Thiègba, Dibi Konan Evrard Brice and KONAN Kouakou Séraphin

Conflicts of Interest

All authors declare no conflict of interest

Data Availability

Data presented in this study will be available on a fair request to the corresponding author

Ethics Approval

Not applicable to this paper

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