International Journal of Plant & Soil Science

34(5): 53-71, 2022; Article no.IJPSS.80872
ISSN: 2320-7035

Effectiveness of Aqueous, Alcoholic Extracts and Fertilizing of *Jatropha curcas* Leaves in the Control of Blossom end Rot of Fruit in Tomato

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Authors' contributions

This work was carried out in collaboration among all authors. Author KNP collected the data, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author BBBA and Author CM managed the analyses of the study. Author KNM managed the literature searche and data collected. Author KD designed the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2022/v34i530866

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/80872

Original Research Article

Received 08 December 2021
Accepted 17 February 2022
Published 24 February 2022

ABSTRACT

The blossom end rot of fruit caused by calcium deficiency causes extensive damage going up to more than 50% of yield loss in tomatoes (*Solanum lycopersicum L.*). The present study was carried out in a greenhouse in a semi-controlled environment to evaluate the effect of aqueous and alcoholic extracts and fertilizing with the powder of the leaves of *Jatropha curcas* on the growth parameters, the vigor of the plants, the size of the fruit, the rate of blossom end rot fruit, the yield and the accumulation of biomass Cobra 26 and Lindo varieties of tomato. The experimental system was a complete randomized block with 14 treatments repeated 3 times. Control plants were treated with tap water. Estimates of height, annulus diameter, fruit load, fruit size, blossom end rot fruit rate, yield as well as fresh and dry biomass were made. The aqueous extract at a concentration of 2 L/ha had the best vegetative development compared to all the treatments. As for the 3% alcoholic

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extract, it was the best in reducing the rate of blossom end rot fruits without any loss of yield and in accumulating fresh and dry aerial and root biomass. These results showed that the use of aqueous extracts, alcoholic extracts and the fertilizing with the powder of leaves of Jatropha curcas in the control of the blossom end rot of the tomato makes it possible to reduce efficiently the rate of blossom end rot fruits and the losses of yield.

Keywords: Calcium; Jatropha curcas; blossom end rot; tomato.

1. INTRODUCTION

Tomato (*Solanum lycopersicum L*.) is a herbaceous, perennial, annual, branching-stem plant cultivated worldwide for its fruits which are eaten fresh or processed. In the new climatic context with its corollary of reduced rainfall [1], abiotic diseases are becoming more and more restrictive. Among these diseases, the blossom end rot causes extensive damage, contributing to over 50 % of production loss [2]. This abiotic constraint in tomatoes and peppers is manifested by a physiological disorder linked to a local calcium deficit in the apical part of the fruit [3]. It is due to a poor supply or reduced transport of calcium to the apical part of the fruit, even when the content of this element in the plan is high [4,5]. The low calcium content in the plant can induce blossom end rot [6] such as light, temperature, air humidity [7], soil moisture [8], fruit size and growth rate [3]. All of these factors can favour the development of blossom end rot in several species, including peppers and tomatoes. Indeed, a negative correlation between fruit size and calcium concentration has been observed.

This negative correlation can be explained by an increase in the transport of assimilates by the phloemic route without an increase in the transport of Ca by the xylemic route during the phase of rapid fruit growth [3]. At this critical stage, there is a greater demand for calcium for the growth and rapid multiplication of cells exceeding the supply of Ca needed by fruit tissues [9]. Ho *et al*., [10] reported for a tomato that dry matter and water gains in the fruit are mainly provided by the phloem while Ca transport is limited to the xylem. Therefore, an imbalance between the assimilates of leaves and Ca supplied was the common cause of the induction of blossom end rot in bell pepper and tomato. The blossom end rot or black ass disease generally appears on the first two bunches of fruits [11]. At the beginning of this disease, pale brown patches appear at the stylar scar of the fruit (opposite the flower peduncle). The patches are getting darker. They harden and become an area of dark, depressing tissue that can affect the halt of the fruit. This zone of dead tissue is quickly invaded by opportunistic fungi which cause the decay of the fruit [11]. As a means of control, certain cultural and chemical techniques contribute to the reduction of blossom end rot [12]. The application of synthetic products whose recommended doses are still not respected is the most common practice used to reduce losses associated with this disease. Thus, it contributes to the pollution of the environment and the destruction of the consumer's health by the residues of these chemicals. To date, no consistent reduction in disease has been achieved thanks to chemical applications. Blossom end rot causes the abandonment of land by the farmer because of the lack of control of this abiotic constraint. However, the use of plant extracts and natural products is very encouraged, for these products are safe for the health of the producer himself, the consumer and more beneficial for the environment [13].

In fact, the crude extracts of Jatropha curcas oil stimulate the germination of wheat with a germination percentage between 90 and 100% [14]. According to these same authors, Jatropha extracts contain several phytohormones which are involved in photosynthesis and the stability of membrane cells. These extracts also contain phytosterols which have antioxidant properties. These biological materials or their extracts have beneficial effects on the properties of the soil, the growth and development of the plant, and resistance to biotic and abiotic stresses. They can be an alternative to chemical inputs. According to Aghofack *et al*., [15], the aqueous and alcoholic extracts of the leaves of *Jatropha curcas* improve several parameters of growth and development in tomatoes. It is believed that the aqueous and alcoholic extract and the fertilizing with the powder of the leaves of Jatropha curcas would reduce the blossom end rot by improving calcium absorption in tomato farming.

To evaluate the effect of aqueous and alcoholic extracts and fertilizing with the powder of the leaves of Jatropha curcas in the fight against the blossom end rot in tomatoes, a test was carried out in a greenhouse in a semi-controlled environment in the town of Songon-Té in southern Côte d'Ivoire.

2. MATERIALS AND METHODS

The experiment in a plastic greenhouse was carried out in Songon-Té to evaluate and select doses of aqueous and alcoholic extracts and fertilizing with powder from *Jatropha curcas* leaves in the control of blossom end rot in tomato.

2.1 Experimental System and Set-up of the Test

The nursery was carried out in August 2019 with potting soil in alveolate plates. After 24 days in the nursery, the plants were transplanted in September 2019 at the stage of three to four leaves. The experimental system was a randomized full block with 14 treatments and three repetitions. Two varieties of tomato were used including the Cobra 26 variety (V1) and the Lindo variety (V2). The plants were transplanted into plastic bags with dimensions of 40cm x 30cm. Each treatment consisted of 6 plants including 2 plants per bag, which makes a total of 504 plants. The land that served as the substrate was a humus peaty soil obtained at an average depth of 30cm. A composite soil sample was taken for routine physico-chemical analyzes. After extraction, drying and homogenization, the soil was distributed between the plastic bags at the rate of 5kg per bag. The soil field capacity (amount of water retained by the soil after 24 hours of soaking, expressed in %, was determined using a PVC tube 2cm in diameter and 18 cm high. One end of the tube was closed with a nylon mosquito net with a mesh of less than 2 mm. It was filled with soil to 2 cm from the edge. The weight X of the dry soil was determined by weighing. The soil was subsequently saturated with water before allowing it to drain for 24 hours to determine its wet weight Y ; the field capacity was determined by the following formula [16].

$$Field\ capacity\ (\%) = \frac{(Y - X)}{X} \times\ 100$$

X and Y are expressed in grams

2.2 Conduct of the Test

Watering was done once every other day in the morning. Two irrigation doses were used. The first dose was 0.5 L of water per sachet from transplanting to flowering and the second was 1 L of water per sachet from flowering to harvest. Samples of this water were taken and analyzes were carried out in the laboratory of the Pedagogical and Plant Physiology Research Unit of Félix Houphouët Boigny University. The pH, electrical conductivity (EC) and total dissolved solute (TDS) were evaluated. Total dissolved solute (TDS) is the number of dissolved ions, minerals, and other components dissolved in water. It is simultaneously used with EC as an indicator of the salt content of water in the absence of dissolved nonionic constituents [17].

NPK 12-22-22 fertilizer was applied when filling the bags at the rate of 300 kg/ha (19 g/bag) as a basic fertilizer. Urea was applied at the rate of 100kg/ ha (6 g/per bag) on the 30th day after transplanting the plants as maintenance manure. Phytosanitary treatment with Cypercal 50 EC (50 g/L of cypermethrin) were carried out at a rate of 0.8 L/ha to control insects. Thus two applications were carried out; the first during the vegetative phase and the last at the start of fruiting. To control fungal diseases, a binary fungicide; composed of 500 g/L of chlorothalonil and 100 g/L of carbendazim) was used. Two applications were made during the vegetative phase and one application during fruiting. These phytosanitary treatments were made based on a warning.

2.3 Preparation of Extracts and Fertilizing with Leaves Powder

Two types of extracts were prepared : the aqueous extract and the alcoholic extract. For the preparation of the aqueous extracts, 500g of fresh *Jatropha curcas* leaves were washed before being weighed and crushed with a grinder and then macerated in 2 liters of water for 3 days. Then, each macerated sample was filtered through percale. The resulting extract was stored in dark bottles in the refrigerator at 4°C [18].

The alcoholic extraction and the fertilizing with the powder of the leaves were done by full drying of leaves in a drier at 70°C. The dried samples were ground in a blender to obtain a powder. The powder was stored in plastic bags for use as a fertilizer. A 500g fraction of this powder was soaked in 2 L of ethyl alcohol and then stirred with a magnetic stirrer for one hour [15]. After

one hour of soaking in the solvent, the samples were filtered successively through percale, cotton and filter paper. The extracts thus obtained were dried using a rotary evaporator and stored in the refrigerator at 4° C.

2.4 Application of Treatments

Before each application, an analysis of the health status of the plants was carried out to determine the level of infestation of each elementary plot.

For the treatments, 15 ml of aqueous and alcoholic extract were added to 485 ml of water, corresponding to an extract concentration of 3% and three-half of 3%. These aqueous and alcoholic foliar treatments began at the 50% flowering stage (32 days after transplanting) and continued with a frequency of once every two weeks. In all, three extract sprays were performed [15]. However, the fertilizing with leaves powder was applied around the plants at three different rates (3%, three-quarters of 3% and three-half of 3%) as before. Two controls, one positive and one negative were added to the test. The positive control was Defender CA (T1) which is a deficiency corrector developed to prevent and correct calcium deficiencies. As for the negative control (T0), it consisted only of water. Folical (T2) and Codamin (T3) are physio-activators. They stimulate the physiological functions of flowering and fruit sets. Thus, the treatments below were applied (Table 1).

2.5 Data Collection

2.5.1 Agro-morphological data

The measurement of the growth and development parameters of the plants was carried out at the 50% flowering stage and the fruit maturity stage. The height of the plants and the circumference at the annulus of the stems were evaluated during the 2 phenological stages. As for the fruit load, the number of flowers, the number of bunches, the number of fruits per bunches and the number of aborted fruit per bunches and the number of aborted fruits were evaluated at the stage of fruit maturity. Three plants per treatment were chosen at random on which these above parameters were measured. Using a tape measure, the height was measured from the annulus to the apex of the stem. The diameter at the annulus of the stem was measured using a foot sliding according to the method of Lepengue *et al*., [19]. Thus, the vigor index (IV) of plants was calculated according to the formula of Berchoux and Lecoustre 1986 cited by Joachim *et al*., [20].

$$\text{Index (IV)} = \log ((C^2 \times H) / 4\pi)$$

C : the circumference in millimeters ; H : the height in meters

The other parameters were evaluated by counting and calculating.

Table 1. Concentration or active content and dose of the different treatments

Treatments	Name	Concentration or active content	Dose
T0	Untreated control	water	-
T1	Defender Ca	Free amino acids : 6% Calcium oxyde (CaO) : 14% Nitrogen: 1.1%	2.5 L/ha
T2	Folical	GA 14 Calcium oxyde (CaO) : 202.5 g / L Boron (B) 5 % p/p	5 L/ha
T3	Codamin	Molybdenum (Mo) 0.17 % p/p	0.25 L/ha
T4	Extracts aqueous	0.3 %	2 L/ha
T5	Extracts aqueous	3 %	23 L/ha
T6	Extracts aqueous	5 %	39 L/ha
T7	Extracts alcoholic	0.3 %	2 L/ ha
T8	Extracts alcoholic	3 %	23 L/ha
T9	Extracts alcoholic	5 %	39 L/ha
T10	Leaves powder	20 g / foot	1 t/ha
T11	Leaves powder	40 g / foot	1.5 t/ha
T12	Leaves powder	60 g / foot	2 t/ha

2.5.2 Agro-physiological data

For each variety of tomato, the duration of the cycle was noted by recording the date of 50% flowering and that of the first harvest.

2.5.2.1 Rate of blossom end rot fruits per treatment

Before the first harvest, blossom end rot fruits were counted by treatment. The number of blossom end rot fruits was also counted at each harvest and an accumulation was made. The rate of blossom end rot fruits was calculated according to the formula used by R'him and Jebari [21].

$$RCF\ (\%) = \frac{Nber\ CF}{Nber\ TF} \times 100$$

Nber CF: Number of blossom end rot fruits
Nber TF: Total number of fruits
RCF: Rate of blossom end rot fruits

2.5.2.2 *Yield evaluation*

Yield components were determined from the number and mass of healthy and damaged fruit. The number of fruits harvested was determined by counting. The spoiled fruits was separated from the healthy fruit. Their number and mass were also determined to estimate the potential yield and the net yield of each treatment :

- ***Average weight of a fruit***

At each harvest, all the fruits were weighed using a precision balance. The average weight of fruits was calculated per treatment according to the following formula :

$$Average\ weight\ of\ fruit\ (g) = \frac{\text{Total mass of fruits}}{\text{Number of fruits harvested}}$$

Accrued values were calculated at the end of harvests.

- ***Average yield***

The average yield of each elementary plot was calculated and related to one hectare using the expression bel:

$$Average\ yield = \frac{31250\ plants \times mass\ in\ tons\ of\ healthy\ per\ treatment}{Total\ number\ of\ plants\ of\ the\ treatment}$$

With 31250 plants as the density of plantation.

- Potential yield and net yield

It was calculated by taking the sum of the masses of healthy, blossom end rot fruits and other damaged fruits expressed in tons of each treatment and then extrapolating to the hectare. The net yield is the difference between the potential yield and the loss of yield.

2.5.2.3 Evaluation of fresh and dry plants biomass

At the end of the crop cycle, the accumulation of fresh and dry material was evaluated. This was done by sampling, at random, on 3 plants per treatment. Plants were carefully uprooted, rinsed in a bucket containing water. The root was separated from the stem and the stem from the leaves in order to determine the fresh biomass of the different organs (root, stem and leaf). The fresh mass (FM) of these organs was taken using a precision balance (0.001) from Sartorius. Samples were then dried at a temperature of 80° C in a Memmert brand drier until a constant mass was obtained. This mass constituted the dry material (DM). The water content (WC) of the samples was determined regarding the fresh mass and then expressed as a percentage according to the work of Virginie and Jules, [22] and M'Sadak and Saad, [23].

$$WC\ (\%) = \frac{FM - DM}{FM} \times 100$$

2.6 Statistical Analysis

The data obtained were analyzed for variance with the STATISTICA version 2006.7.1 software. In case of significant differences, the separation of averages was made at a 5% threshold according to Duncan's test.

3. RESULTS

3.1 Characterization of Soil and Irrigation Water

Soil analyses showed high organic matter contents (34%) and a good bulk density (0.57 g/cm³). The soil pH was moderately acidic (Table 2) with a variation of around 2 units (ΔpH= 1.84). The nitrogen (N) and phosphorus contents were much higher than the reference standards. The soil was almost saturated with a base saturation rate of 87.96% and a cationic exchange capacity

(CEC) of 35.06 meq/100g. The exchangeable levels of Calcium (Ca^{2+} /CEC x 100) and magnesium (Mg^{2+} /CEC x 100) were lower than the reference standards. As for the levels of exchangeable Potassium (K^+ /CEC x 100) and Sodium (Na^+ /CEC x 100), the values were much higher than the reference threshold values (Table 3). The irrigation water was moderately acidic (pH=5.94) non-saline with an electrical conductivity (EC) of 110.47 µs/cm and a dissolved solute content (TDS) of 55.37 mg/L (Table 4).

Table 2. Soil physico-chimical parameters

Parameters	Values	Standards*
Clay (%)	0.08	-
Silt (%)	0.003	-
Sand (%)	40.68	-
Porosity (%)	7.82	-
Field capacity (%)	17.06	
Apparent density (g/cm^3)	0.57	-
Electric conductivity (µs/cm)	42.19	-
Water pH	6.05	5 – 6
pH KCl	4.21	4 – 5
Δ pH	1.84	-
OM (%)	58.4	3.6 – 6.5
OC (%)	33.87	1.26 – 2.5
N (%)	0.85	0.12 – 0.22
C/N	40.13	11 – 15
P (%)	0.27	0.02 – 0.023
K^+ (me/100g)	9.63	0.15 - 0.25
Na^+ (me/100g)	12.17	0.3 – 0.7
Ca^{2+} (me/100g)	8.83	5 – 8
Mg^{2+} (me/100g)	0.2	1.5 – 3.0
Fe (mg/kg)	1.83	-
SEB (me/100g)	30.85	7.5 – 15
CEC (me/100g)	35.06	10 ≤ CEC ≤ 20
V (%)	87.96	60 ≤ V ≤ 90

*ΔpH : pH Variation ; OM : Organic Matter ; CO : Organic Carbon ; SEB : Sum of exchangeable bases ; CEC : cations exchange capacity ; V : Saturation rate of the adsorbent complex. ;*Reference threshold values [24]*

Table 3. Cationic balances and saturation rate per exchangeable base on the adsorbent complex of the soil

Parameters	Values	Standards*
Ca^{2+}/K^+	0.91	
Ca^{2+}/Na^+	0.73	-
Ca^{2+}/Mg^{2+}	43.2	2 - 9
K^+/Mg^{2+}	47	0.05 – 0.1
$(Na^+ + Mg^{2+})/Ca^{2+}$	1.42	-
$(Ca^{2+} + Mg^{2+}) /K^+$	1.28	12 - 15
SAR	2.73	-
Ca^{2+}/CEC (%)	25.11	60 - 70
Mg^{2+}/CEC (%)	0.59	10 - 12
Na^+/CEC (%)	34.79	< 1
K^+/CEC (%)	27.46	2.5 – 3.5

SAR : Sodium adsorption report ; CEC : cations exchange capacity ; Reference threshold values [24]*

Table 4. Irrigation water characteristics

Components	EC in µs/cm	TDS in mg/l	pH
Values	110.47	55.37	5.94

CE : electronic conductivity, TDS : total dissolved solute

3.2 Effect of Treatments on the Height, Circumference, Plant Vigor Index and Fruit Load

A highly significant effect was observed between the different treatments for the 3 agro-morphological parameters measured (Fig. 1 and 2). The most vigorous tomato plants were recorded in the T4 treatment which contained 0.3% aqueous extract. Folical at 5 L/ha produced the least robust tomato plants (Fig. 3). Figure 4 shows the fruit load of tomato plants. The treatments were significantly different with a high number of fruits (7 fruits) in the treated plants with 0.3% aqueous extracts (T4). Reading the varietal effect, the 2 varieties (Cobra or V1 and Lindo or V2) were identical for the circumference parameters at the annulus (P = 0.089 < 0.05) and the vigor index where P = 0.435 but different for the height parameter with P = 0.049 < 0.05 (Table 5).

3.3 Effect of Treatment on the Rate of Blossom end rot Fruits at Harvest

The treatment very significantly reduced the rate of blossom end rot fruits (Fig. 5). Indeed, the T0, T3 and T5 had the highest levels of blossom end rot fruits unlike the T8, T7, T6 and T9 which permit obtaining the lowest levels of blossom end rot fruits. The two varieties of tomato had very different rates of blossom end rot fruits. It was more important on the Cobra 26 variety than on the Lindo F1 variety. The variety of Cobra 26 generated 17.52 % of blossom end rot fruits whereas the Lindo F1 variety was able to record 6.16 % of blossom end rot fruits (Fig. 6).

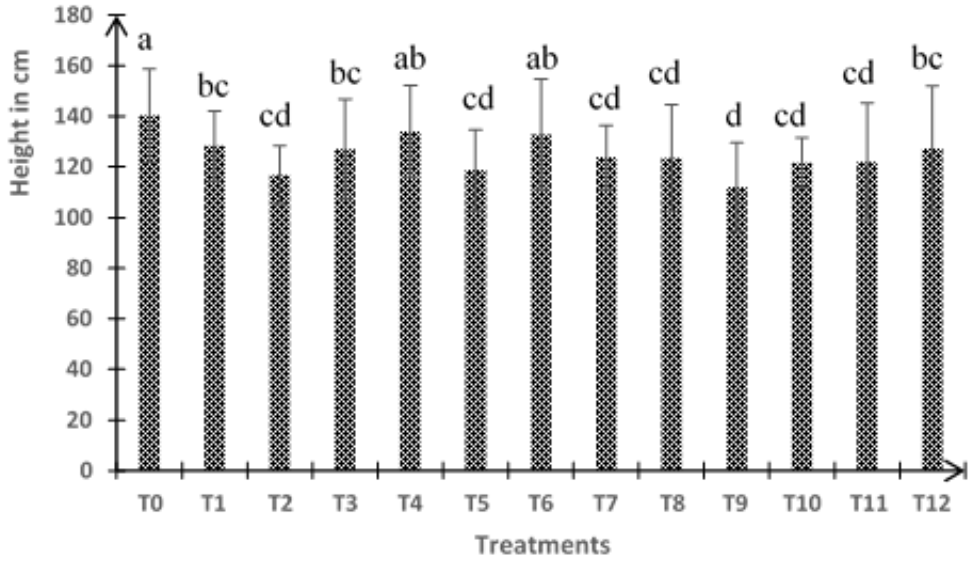

Fig.1. Effect of treatments on the height of plants at fruits maturity

T0= untreated control ; T1= defender Ca (2,5 L/ha) ; T2= folical (5 L/ha) ; T3= codamin (0,25 L/ha) ; T4= extracts aqueous (2 L/ha) ; T5= extracts aqueous (23 L/ha) ; T6= extracts aqueous (39 L/ha) ; T7= extracts alcoholic (2 L/ha) ; T8= extracts alcoholic (23 L/ha) ; T9= extracts alcoholic (39 L/ha) ; T10= leaves powder (1 t/ha) ; T11= leaves powder (1,5 t/ha) ; T12= leaves powder (2 t/ha)

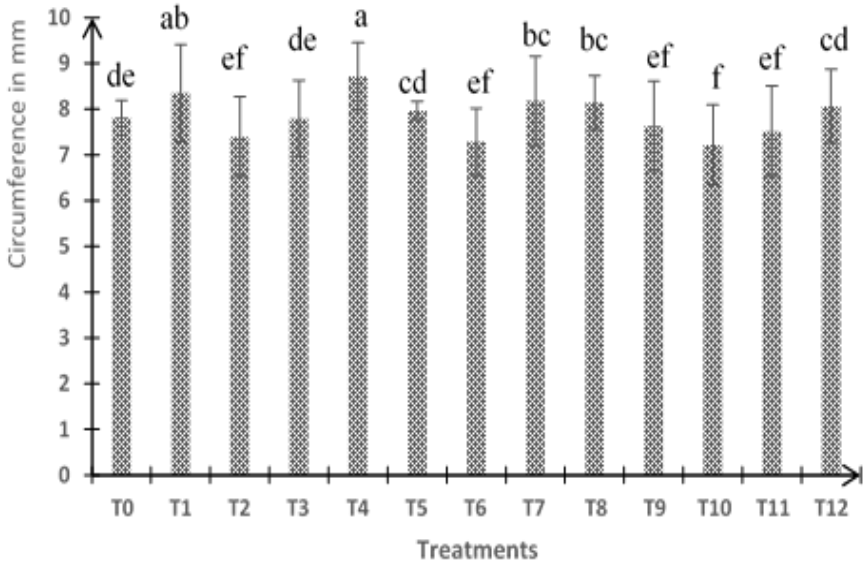

Fig. 2. Effect of treatments on the circumference at the annulus of plants at fruits maturity

T0= untreated control ; T1= defender Ca (2,5 L/ha) ; T2= folical (5 L/ha) ; T3= codamin (0,25 L/ha) ; T4= extracts aqueous (2 L/ha) ; T5= extracts aqueous (23 L/ha) ; T6= extracts aqueous (39 L/ha) ; T7= extracts alcoholic (2 L/ha) ; T8= extracts alcoholic (23 L/ha) ; T9= extracts alcoholic (39 L/ha) ; T10= leaves powder (1 t/ha) ; T11= leaves powder (1,5 t/ha) ; T12= leaves powder (2 t/ha)

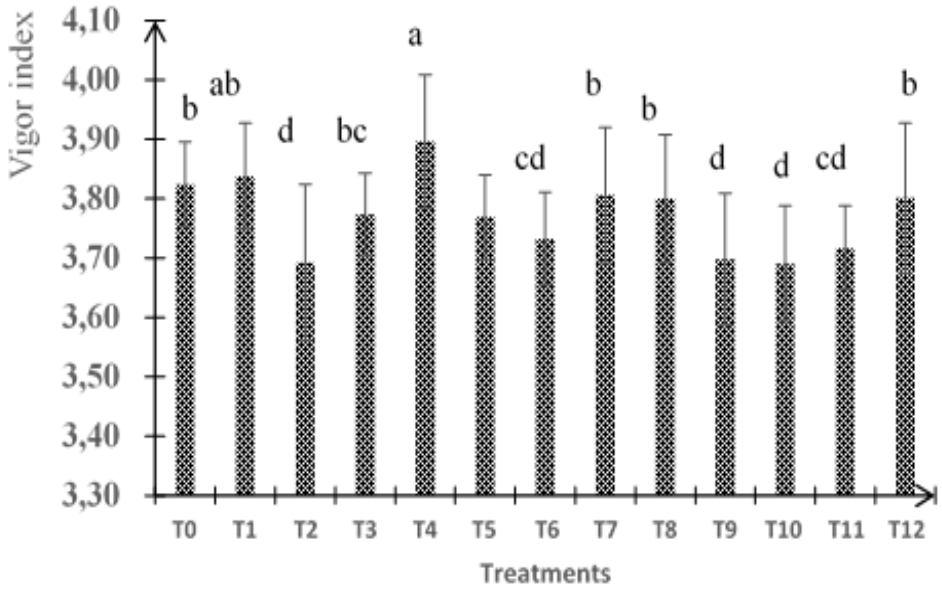

Fig.3. Effect of treatments of the vigor of plants at fruits maturity

T0= untreated control ; T1= defender Ca (2,5 L/ha) ; T2= folical (5 L/ha) ; T3= codamin (0,25 L/ha) ; T4= extracts aqueous (2 L/ha) ; T5= extracts aqueous (23 L/ha) ; T6= extracts aqueous (39 L/ha) ; T7= extracts alcoholic (2 L/ha) ; T8= extracts alcoholic (23 L/ha) ; T9= extracts alcoholic (39 L/ha) ; T10= leaves powder (1 t/ha) ; T11= leaves powder (1,5 t/ha) ; T12= leaves powder (2 t/ha)

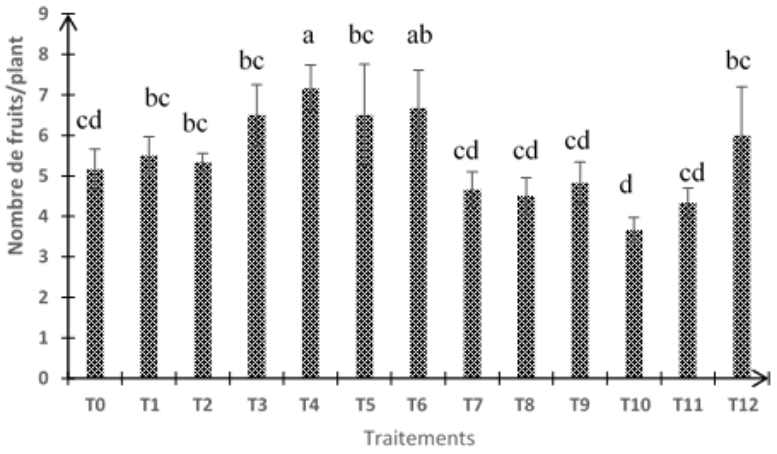

Fig.4. Effect of treatments on fruits load

T0= untreated control ; T1= defender Ca (2,5 L/ha) ; T2= folical (5 L/ha) ; T3= codamin (0,25 L/ha) ; T4= extracts aqueous (2 L/ha) ; T5= extracts aqueous (23 L/ha) ; T6= extracts aqueous (39 L/ha) ; T7= extracts alcoholic (2 L/ha) ; T8= extracts alcoholic (23 L/ha) ; T9= extracts alcoholic (39 L/ha) ; T10= leaves powder (1 t/ha) ; T11= leaves powder (1,5 t/ha) ; T12= leaves powder (2 t/ha)

Table 5. Height, circumference and vigor indix of tomatoes variety

Varieties	Height (cm)	Circumference(mm)	Vigor Index	Fruit load
Cobra	123.154 ± 17.37 b	7.933 ± 0.73 a	3.777 ± 0.097 a	5.538 ± 3.831 a
Lindo	127.359 ± 20.52 a	7.767 ± 1.03 a	3.767 ± 0.129 a	5.359 ± 1.90 a
CV (%)	15.24	11.41	3.02	55.46
P	0.049	0.089	0.435	0.633

In a column, the values followed by the same letters are not significantly different (Duncan's test at 5% level).

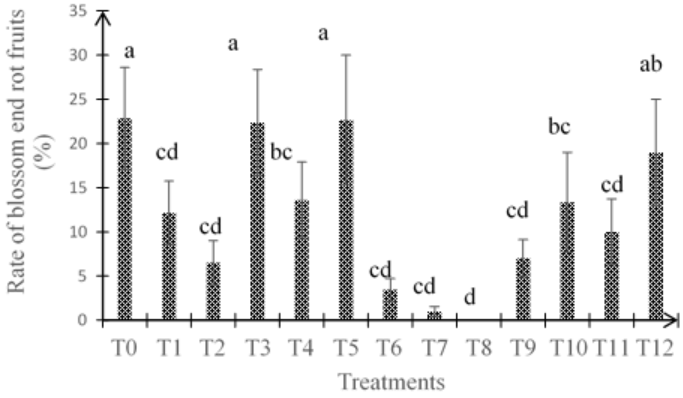

Fig.5. Effect of treatments on the rate of blossom end rot fruits at harvest

T0= untreated control ; T1= defender Ca (2,5 L/ha) ; T2= folical (5 L/ha) ; T3= codamin (0,25 L/ha) ; T4= extracts aqueous (2 L/ha) ; T5= extracts aqueous (23 L/ha) ; T6= extracts aqueous (39 L/ha) ; T7= extracts alcoholic (2 L/ha) ; T8= extracts alcoholic (23 L/ha) ; T9= extracts alcoholic (39 L/ha) ; T10= leaves powder (1 t/ha) ; T11= leaves powder (1,5 t/ha) ; T12= leaves powder (2 t/ha)

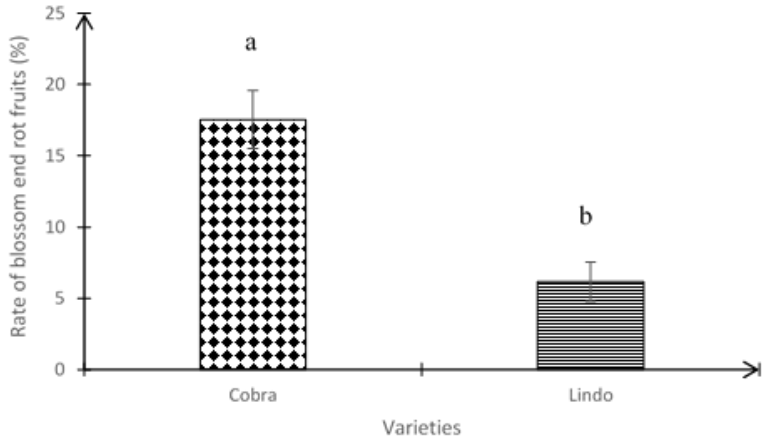

Fig.6. Behavior of varieties according to the rate of blossom end rot fruits at harvest

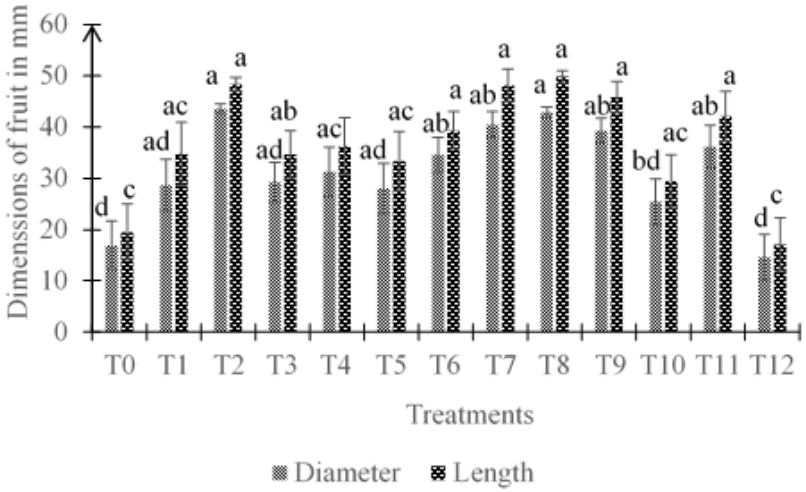

Fig.7. Diameter and fruit length according to treatments

T0= untreated control ; T1= defender Ca (2,5 L/ha) ; T2= folical (5 L/ha) ; T3= codamin (0,25 L/ha) ; T4= extracts aqueous (2 L/ha) ; T5= extracts aqueous (23 L/ha) ; T6= extracts aqueous (39 L/ha) ; T7= extracts alcoholic (2 L/ha) ; T8= extracts alcoholic (23 L/ha) ; T9= extracts alcoholic (39 L/ha) ; T10= leaves powder (1 t/ha) ; T11= leaves powder (1,5 t/ha) ; T12= leaves powder (2 t/ha)

Table 6. Effect of treatments on yield parameters

Treatments	Middle weight of a fruit (g)	Middle Yield (t/ha)	Potential yield (t/ha)	Loss of yield (t/ha)	Net yield (t/ha)
T0	29.35 ± 4.32 cd	0.42 ± 0.09 d	0.57 ± 0.11 d	0.15 ± 0.03 b	0.42 ± 0.09 d
T1	38.59 ± 3.91 ab	1.28 ± 0.21 a	1.53 ± 0.23 a	0.25 ± 0.07 a	1.28 ± 0.21 a
T2	40.75 ± 3.53 ab	1.08 ± 0.19 bc	1.12 ± 0.19 cd	0.04 ± 0.02 d	1.08 ± 0.19 bc
T3	35.42 ± 2.87 ab	0.91 ± 0.15 bc	1.06 ± 0.14 de	0.15 ± 0.04 b	0.91 ± 0.15 bc
T4	42.96 ± 2.13 a	1.17 ± 0.14 ab	1.25 ± 0.14 bc	0 .09 ± 0.02 bc	1.17 ± 0.14 ab
T5	31.78 ± 2.90 bc	1.25 ± 0.23 ab	1.38 ± 0.22 ab	0.13 ± 0.04 bc	1.25 ± 0.23 ab
T6	34.78 ± 3.32 bc	1.02 ± 0.16 bc	1.05 ± 0.16 de	0.03 ± 0.01 d	1.02 ± 0.16 bc
T7	40.41 ± 3.14 ab	1.13 ± 0.14 bc	1.15 ± 0.14 cd	0.02 ± 0.01 d	1.13 ± 0.14 bc
T8	36.72 ± 3.67 ab	0.93 ± 0.09 bc	0.93 ± 0.09 de	0.00 ± 0.00 d	0.93 ± 0.09 bc
T9	33.10 ± 3.94 bc	0.92 ± 0.10 bc	0.98 ± 0.10 de	0.06 ± 0.02 cd	0.92 ± 0.10 bc

Treatments	Middle weight of a fruit (g)	Middle Yield (t/ha)	Potential yield (t/ha)	Loss of yield (t/ha)	Net yield (t/ha)
T10	24.14 ± 4.25 cd	0.66 ± 0.16 cd	0.68 ± 0.16 de	0.02 ± 0.01 d	0.66 ± 0.16 cd
T11	41.98 ± 5.60 a	0.77 ± 0.09 cd	0.82 ± 0.09 de	0.06 ± 0.02 cd	0.77 ± 0.09 cd
T12	20.87 ± 3.67 d	0.77 ± 0.23 cd	0.85 ± 0.23 de	0.09 ± 0.04 cd	0.77 ± 0.23 cd
CV (%)	60.91	94.06	88.32	216.16	95.05
p	0.000020	0.00241	0.00058	0.00000	0.002405

In a column, the values followed by the same letters are not significantly different (Duncan's test at 5% level). T0= untreated control ; T1= defender Ca (2,5 L/ha) ; T2= folical (5 L/ha) ; T3= codamin (0,25 L/ha) ; T4= extracts aqueous (2 L/ha) ; T5= extracts aqueous (23 L/ha) ; T6= extracts aqueous (39 L/ha) ; T7= extracts alcoholic (2 L/ha) ; T8= extracts alcoholic (23 L/ha) ; T9= extracts alcoholic (39 L/ha) ; T10= leaves powder (1 t/ha) ; T11= leaves powder (1,5 t/ha) ; T12= leaves powder (2 t/ha)

Table 7. Evaluation of the yield of tomato varieties

Varieties	Middle weight of a fruit (g)	Middle yield (t/ha)	Potential yield (t/ha)	Loss of yield (t/ha)	Net yield (t/ha)
Cobra	29.65 ± 17.52 b	0.72 ± 0.62 b	0.85 ± 0.67 b	0.22 ± 0.02 a	0.72 ± 0.62 b
Lindo	39.72 ± 23.17 a	1.17 ± 1.07 a	1.21 ± 1.07 a	0.11 ± 0.01 b	1.17 ± 1.07 a
CV(%)	60.91	94.06	88.32	216.16	95.05
p	0.0000	0.0000	0.000028	0.00000	0.00000

In a column, the values followed by the same letters are not significantly different (Duncan's test at 5% level).

3.4 Evaluation of the Effect of Treatments on the Size of the Fruit and on the Yield

The treatments were very significantly different for the median diameter and the length of the fruits at harvest. Apart from the T12, all the other treatments were more effective than the negative control (T0) for these 2 parameters. Also, treatments based on alcoholic extract (T7 and T8) as well as T2 based on seaweed extract were the best in terms of diametrical and longitudinal growth of the fruit (Fig. 7). The treatments were significantly different for all the parameters evaluated. The treatment based on aqueous extract at a dose of 2 L/ha (T4) and that based on leaf powder at a dose of 1.25 t/ha (T11) had the highest average weight with respective values of 42.96 g and 41.98 g (Table 6). The highest values of average yield were obtained with the T1 (Defender Ca 2.5 L/ha) followed by the T5 (aqueous extract 23 L/ha) with 1.25 t/ha and T4 (aqueous extract 23 L/ha). The lowest average yield (0.42t/ha) was obtained with the untreated control (T0). Treatment T1 also achieved the highest potential yield (1.53 t / ha) and the greatest yield lost (0.25 t / ha). However, the T8 treatment (alcoholic extract 23 L / ha) did not record any loss in yield.

Beyond the lower yield loss (0.11 t/ha), the tomato cultivar Lindo F1 had the highest values for the average weight of fruit, the average yield, the potential yield. And the net return. This cultivar was more productive than the Cobra 26 cultivar (Table 7).

3.5 Effectiveness of Treatment on Fresh and Dry Biomass and on the Water Content of the Leaves, Stems and Roots of Plants

A highly significant difference was observed between the different treatments in terms of the fresh, dry mass and the water content of the different organs of the tomato plants. At the leaves level, the highest fresh masses were obtained with the T4, T12 and T0 with the respective values of 120.59, 114.98 and 106.89 g. T2, T7 and T1 permitted to obtain respectively 35.56; 52.54 and 60.52 g as the lowest values for the fresh mass of the leaves. For the fresh biomass of the stem, the T0, T8 and T4 treatments were imposed with the respective values of 97.51; 95.70 and 94.89 g. For the lowest fresh mass values, the T11, T2, and T5 were ranked in ascending order with values of 51.47; 52.82 and 62.93 g. The results relating to the root biomass revealed a highly significant difference between the treatments at 5% levels. The Duncan means separation test at the 5% threshold showed a highly significant difference between treatments in fresh root biomass. The T6, T4 and T8 for the production of fresh root biomass more than the other treatments (Fig. 8).

For the leaves dry mass, T0, T4, and T12 treatments were more effective in accumulating dry matter with values of 23.56, 23.11, and 22.72 g respectively. As for the T2, T7 and T1 treatments, they were the least effective in the accumulation of dry matter in the leaves at 10.29; 13.74 and 14.53 g of dry matter. The dominant values for dry masses at the stem were 18.02 ; 16.99 and 16.91 g with the respective T4, T8 and T0 treatments. The T11, T5 and T6 treatments were less dominant in dry matter accumulation with values of 7.79; 8.77 and 10.39 g respectively. In addition, T10, T8 and T4 treatments were more productive in producing dry root biomass compared to other applications that were the least productive in the accumulation of dry root biomass (Fig. 9).

The influence of the treatments on the water content in the leaves, stems and roots of tomato plants showed that the T4, T12 and T8 treatments had the highest water contents respectively 81. 22; 80.51 and 79.04 unlike the T1, T2 and T7 treatments with respective values of 68.34; 69.52 and 73.31 %. Regarding the second component, the T6, T12 and T5 applications were the most impressive with 88.30 ; 86.87 and 86.01% as the respective values of the water content. The least impressive were the T2, T3 and T9 applications with respectively 70.58; 80.42 and 80.60% water content. Finally, the results for the root water content showed a significant difference between the treatments after Duncan's test at the threshold of 5%. Thus, the T6, T0 and T11 treatments generated respective water contents of 83.20 ; 82.15 and 80.77 % which were the largest values. As for the smallest values of water content, they were obtained with the T2, T10 and T3 treatments with the following respective values 45.20, 71.62 and 74.60% (Fig.10). In sum, the treatments, T4 and T8 were the most effective in accumulating fresh and dry biomass in the leaves, stem, and roots. The T2 treatment, for its part, permitted the recording of the fresh and dry biomass as well as the lowest water content in the different organs (stem, leaves and root) of the plant. At the root level, the T6 treatment was the best in accumulating fresh biomass and water content. This treatment was also excellent in the accumulation of water in the stems.

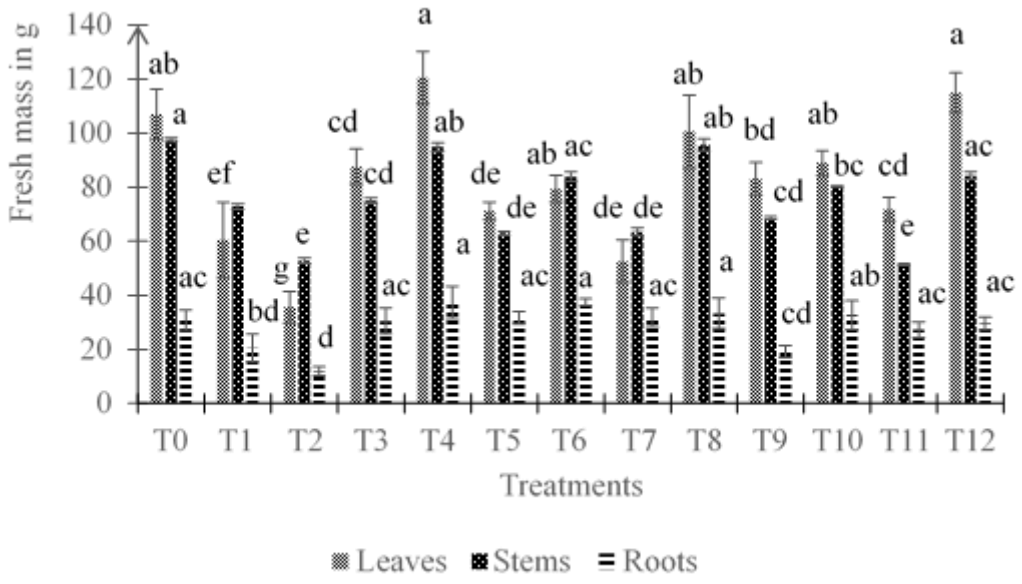

Fig.8. Effect of treatments on the fresh mass, leaves of stem and the root of tomato

T0= untreated control ; T1= defender Ca (2,5 L/ha) ; T2= folical (5 L/ha) ; T3= codamin (0,25 L/ha) ; T4= extracts aqueous (2 L/ha) ; T5= extracts aqueous (23 L/ha) ; T6= extracts aqueous (39 L/ha) ; T7= extracts alcoholic (2 L/ha) ; T8= extracts alcoholic (23 L/ha) ; T9= extracts alcoholic (39 L/ha) ; T10= leaves powder (1 t/ha) ; T11= leaves powder (1,5 t/ha) ; T12= leaves powder (2 t/ha)

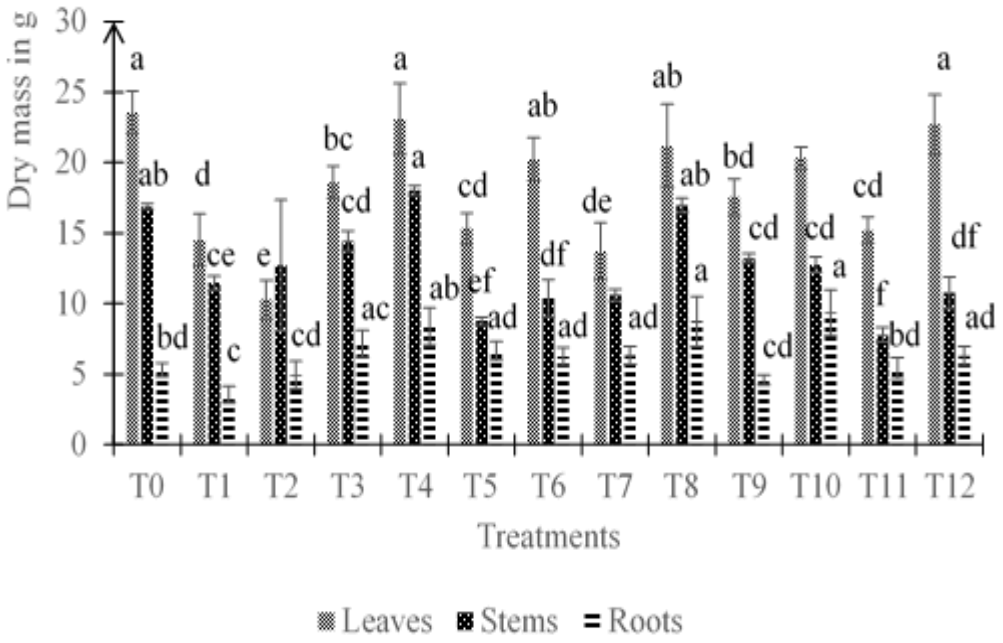

Fig.9. Effect of treatments on the dry mass, leaves of stem and the root of tomato

T0= untreated control ; T1= defender Ca (2,5 L/ha) ; T2= folical (5 L/ha) ; T3= codamin (0,25 L/ha) ; T4= extracts aqueous (2 L/ha) ; T5= extracts aqueous (23 L/ha) ; T6= extracts aqueous (39 L/ha) ; T7= extracts alcoholic (2 L/ha) ; T8= extracts alcoholic (23 L/ha) ; T9= extracts alcoholic (39 L/ha) ; T10= leaves powder (1 t/ha) ; T11= leaves powder (1,5 t/ha) ; T12= leaves powder (2 t/ha)

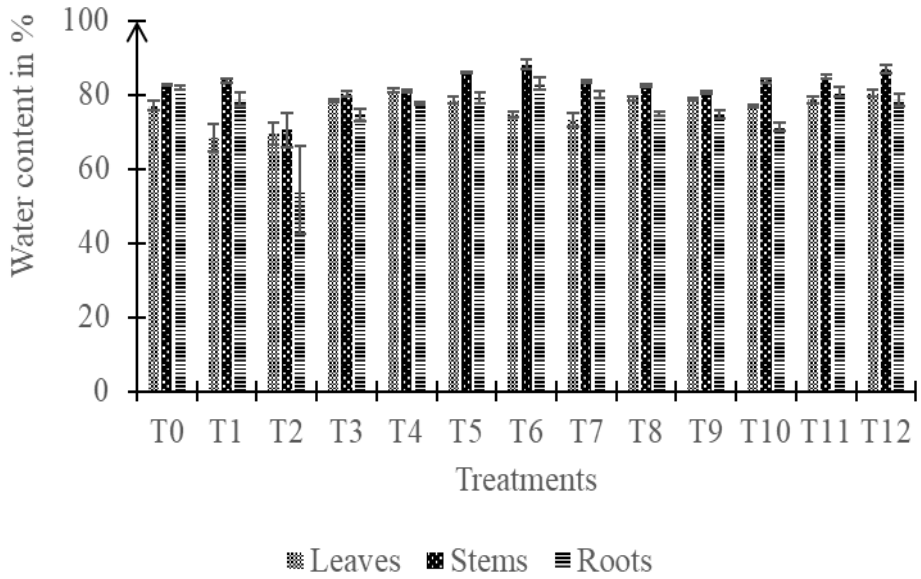

Fig.10. Effect of treatments on the water content, leaves of stem and the root of tomato

T0= untreated control ; T1= defender Ca (2,5 L/ha) ; T2= folical (5 L/ha) ; T3= codamin (0,25 L/ha) ; T4= extracts aqueous (2 L/ha) ; T5= extracts aqueous (23 L/ha) ; T6= extracts aqueous (39 L/ha) ; T7= extracts alcoholic (2 L/ha) ; T8= extracts alcoholic (23 L/ha) ; T9= extracts alcoholic (39 L/ha) ; T10= leaves powder (1 t/ha) ; T11= leaves powder (1,5 t/ha) ; T12= leaves powder (2 t/ha)

4. DISCUSSION

Soil analyses showed high organic matter contents (34%) and a good apparent density (0.57 g / cm^3). The soil pH was moderately acidic with a variation of around two units (ΔpH : 1.84). The nitrogen (N) and phosphorus (P) contents were much higher than the reference standards. The soil was almost saturated with a base saturation rate of 87.96% and a cation exchange capacity (CEC) of 35.06 meq / 100g. The exchangeable levels of Calcium ($Ca2^+$ / CEC × 100) and Magnesium ($Mg2^+$ / CEC × 100) were lower than the reference standards. As for the levels of exchangeable Potassium (K^+ / CEC × 100) and Sodium (Na^+ / CEC × 100), the values were much higher than the reference threshold values. The irrigation water was moderately acidic (pH= 5.94) non-saline with an electrical conductivity (EC) of 110.47 μs/cm and a dissolved solute content (TDS) of 55.37 mg/L.

The results of the particle size analysis of the soil at the experimental site revealed a sandy loam texture which is most often favorable for growing tomatoes. These results show that the soil of this site is suitable for tomato farming. We could therefore not have blossom end rot if the mineral elements provided are insufficient quantities. The pH of the moderately acidic soil is also favorable for tomato farming, but with variations that could induce mineral deficiencies, in particular in Calcium (Ca^{2+}) and Magnesium (Mg^{2+}). The soil pH would also justify the high nitrogen (N) and phosphorus (P) contents observed in the soil. Indeed, according to Rawat, [2] nitrogen and phosphorus are available in the soil when the pH of the latter is between 5.5 and 8.5 in the case of nitrogen and between 6 and 8.5 for phosphorus.

The high organic matter content of the soil gives this soil its peaty appearance. Indeed, high organic matter contents are generally found in peaty soils. The ratio of carbon to nitrogen (C/N = 40.13) far above the reference standard reflects poor mineralization of organic matter. The calcium contents (8.83 me / 100g) in the soil are slightly higher than the normative values (5-8 me / 100g). However, the percentage of exchangeable calcium (25.11%) is much lower than the reference standard. This result demonstrates the lower availability of calcium in the soil solution. Therefore, it is very little available to plants, unlike sodium and potassium. This unavailability of calcium could be explained on the one hand by the pH value of the soil and its variation because the pH of the soil is moderately acidic, a variation of two units can give a very acidic pH which would limit the availability of the calcium element in the soil solution to plants. On the other hand, by the massive presence of sodium and potassium ions on the adsorbent complex to the detriment of calcium ions. These results showed that there is a marked deficiency in calcium and magnesium. Our results coincide with those of [24] who showed that the increase of potassium concentration in a nutrient solution decreases the absorption of calcium and magnesium.

Irrigation aims to create, for the plant, an environment adapted to its ecology by adding water at the times it needs it. These massive inputs, intended to increase the production capacity of the soil, will profoundly modify the environment and the evolution of the soil by increasing humidity and salt inputs. This irrigation water was moderately acidic (pH=5.94) non-saline with an electrical conductivity (EC) of 110.47 μs / cm and a dissolved solute content (TDS) of 55.37 mg / l. This water would be usable for the irrigation of most crops on most soils, with little chance of the appearance of salinity in the soil according to the work of [25,26,17]. According to these authors, good irrigation water should have its pH in the range 6.5 – 8.4, EC less than 250 μs / cm and TDS less than 450 mg/L. However, a slight leaching could occur in irrigation with this water because of its pH and the very low permeability of the soil.

The results indicated that plants treated with the T4 had very good vegetative development compared to controls and all other treatments. On the other hand, the plants which received the T2, T9 and T10 treatments exhibited poor vegetative development. This could be explained by the fact that the treatment containing 0.3 % aqueous extract of *Jatropha curcas* improved the diameter at the annulus and the biomass of tomato plants, evidenced by the greater circumference (8.72 mm) obtained with this treatment. This result corroborates with those of [15] who tested the effects of extracts or powder of *Spirulina platensis* and *Jatropha curcas* on the growth and development of the tomato. According to these authors, the aqueous extracts of *Jatropha curcas* improve the diameter and the root biomass of tomato plants.

Regarding the height of the plants, the results showed that the height of the plants varied between 112 and 140. 33 cm. The T9 treatment (5% of alcoholic extract) gave the smallest size,

while the negative control T0, where the plants are treated with water, had the largest size. These results indicate that the height growth of tomato plants appears to be influenced by the water supply as a foliar sprayer. The foliar applications of water increase the flow of water in the plant which is at the origin of the height growth of the plant.

Concerning the fruit load, it varied from 4 to 7 fruits per plant. The leaves powder fertilizing with dose 1 t / ha and 1, 5 t / ha had the lowest number of fruits per plant. The treatment with aqueous extract at a dose of 2 L / ha and the Codamin positive control (0.25 L / ha) resulted in a high number of fruits per plant. The explanation for these results lies in the chemical composition of the different treatments. Indeed, the leaves of *Jatropha curcas* flavonoids (vitexin, isovitexin), saponosides, polyphenols, tannins, steroidal saponosides, cyanogenic heterosides, alpha-amyrin, alkaloid (0.026 %) sterols (stigmasterol, campesterolcas), terpenine (toxalbumin) according to the work of Gallé *et al*., [27] and those of Jide-Ojo [28]. As a result, the aqueous and alcoholic extracts and the fertilizing to the powder of the leaves of this plant used in this study would also be rich in these organic molecules. Indeed, these biochemicals, are also known under the name of allelochemicals. They influence the germination, growth and reproduction of other organisms. These allelochemicals can have beneficial (positive allelopathy) or harmful (negative allelopathy) effects. In this study, positive and negative allelopathic effects were observed. Positive allelopathy of the aqueous extract (T4) was observed in the height growth of the plants, the circumference at the annulus and the number of fruits per plant. Negative allelopathy was noted with alcoholic extract (T9) on the height growth of the plants. Similar results were obtained by [28] on wheat.

Concerning the varietal effect, the two varieties (Cobra or V1 and Lindo or V2) were identical for the annulus circumference and vigor index parameters but different for the height parameter. Variety V1 gave the smallest height (123.15 cm) while variety V2 had the largest height of the plants would depend on the intrinsic characters of each variety and above all on the particular pedoclimatic conditions permitting them to develop their growth potential to the maximum. The variability observed concerning the height of the plants would also result from the difference in their capacity to adapt to the environment. The work of [29] on the evaluation of the agronomic performances of nine varieties of tomato showed that the difference observed in the growth of various varieties of tomato would be related to their genotype and to the environment in which they have been tested.

The effect of aqueous (T4) and alcoholic (T6, T7, T8) treatments on reducing the rate of blossom end rot fruits could be explained by the presence of the phenolic compounds contained in the leaves of *Jatropha curcas*. In addition, polyphenols are known for their antioxidant activities. In fact, under physiological conditions, the dioxygen produced in the mitochondria of reactive oxygen species (ROS) is toxic to the entire cell. This cellular toxicity can cause the blossom end rot of epidermal tissues in fruits. In tomatoes, stressful conditions lead to the production of free radicals in young growing fruits and could lead to tissue oxidation and develop symptoms of the blossom end rot [30]. In this case, the antioxidant activity of the polyphenols can be achieved by direct trapping of the ROS, both in the aqueous phase and in the organic phase. These polyphenols also act through 2 other mechanisms of action one consists of the inhibition of pro-oxidant enzymes and the chelation of metal ions and the second consists of the protection of biological systems from anti-oxidant defences. The tannins existing in the leaves of the Jatropha curcas would also elucidate these results because the molecules exhibit antioxidant properties. These compounds have a great capacity for trapping free radicals and also in the inactivation of pro-oxidant ions [31]. These organic molecules would reduce the presence of free radicals in the tissues of growing tomato fruits and therefore limit the sensitivity of the fruits to the occurrence of the blossom end rot. The best extract that induces a reduction in the rate of blossom end rot fruits has been the alcoholic extract.

The extraction solvents (water and ethyl alcohol) were in the order of decreasing polarity. Alcohol, which is less polar than water, has made it possible to extract certain organic compounds that are less or not soluble in water. These organic compounds which would be polyphenols, sterols and alkaloids would seem to have beneficial effects on the calcium nutrition of tomato plants. Variability in the reduction in the rate of blossom end rot fruits was observed at the level of alcoholic and aqueous treatments. This variability would be attributed to the presence of phytohormones in aqueous and

alcoholic extracts. Regarding the aqueous extracts, the T4 (2 L/ha) made it possible to have the highest vigor index (3.90), the highest fruit load (7 fruits/plants) and which had reduced the rate of blossom end rot fruits compared to the untreated control (T0) and the T6 (39 L/ha) which had a rate of blossom end rot fruits lower than those of the controls (T0, T1 and T3) can be used in the control against blossom end rot. As for alcoholic treatments, the three doses tested were better compared to the various controls in reducing the rate of blossom end rot fruits. However, the two low concentrations (T7 and T8) can be used in the treatment of the blossom end rot of the tomato.

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The two tomato varieties had very different rates of blossom end rot fruits. It was more important on the Cobra 26 variety than on the Lindo F1 variety. The Cobra variety was more susceptible to the blossom end rot than the Lindo variety in this test. However, the Cobra variety had a small size of fruits with an average weight of 29.65 g compared to 39.72 g for the Lindo variety. It would therefore be less sensitive to the blossom end rot than the Lindo variety which had the largest fruits according to Ho *et al*., [6] and Saure, [32]. According to these authors, large-sized fruits are more susceptible to blossom end rot than small fruits. Such a tendency may be due to varietal sensitivity which is a genetic trait that would be influenced by the pedoclimatic conditions of the culture medium [21].

The treatments were very significantly different for the medium diameter and the length of the fruits at harvest. Apart from the T12, all the other treatments were more effective than the negative control (T0) for these two parameters. Also, the treatments based on alcoholic extract were the best in terms of the diametral and longitudinal growth of the fruits. These results highlight the probable positive action of the various plant extracts tested on the growth and /or filling of fruits. Regarding the yield parameters, the treatment based on aqueous extract at the dose of 2 L/ha (T4) and the fertilizing of leaves powder at the dose of 1.25 t/ha (T11) had the highest average fruit weight with respective values of 42.96 g and 41.98g. This result is believed to be due to the polysaccharides, phytohormones and minerals contained in the leaves of *Jatropha curcas* which are said to be the cause of good fruit growth and good yield. Our results are comparable to those obtained by Aghofack *et al*., [15]. According to these authors, the leaves of *Jatropha curcas*_contain nitrogen and minerals which have improved the growth and yield of sorghum and beans. The highest average and potential yields (1.5 t/ha and 1.53 t /ha) obtained by the T1 treatment (positive control) could be explained by the composition of this deficiency corrector. Indeed, the ‘‘Defender Ca’’ deficiency corrector contains 6% of the free amino acids which would be the source of a quality yield. The low productivity of the negative control plots (T0) can be attributed to characteristic factors of the soil such as variation in the pH (ΔpH = 1.2) which could induce deficiencies in nutrients, in particular magnesium and calcium. The very high rate of the percentage exchange of sodium ($Na^+/CEC \times 100 = 34.79 > 1$) observed on the adsorbent complex would be the basis of the symptoms of toxicity (burns) observed on the plants which would reduce their development. This strong presence of sodium would also limit the absorption of other minerals resulting in reduced yield. The very low porosity of the soil (7.82 %) would also justify the low production of the plots of the T0 treatment. In addition, a low porosity of the soil (7.82% <30%) would cause root asphyxiation at the level of the plants which would reduce the contact surface of the roots

with the nutriments of the soil thus resulting in a low yield.

The Lindo F1 tomato cultivar had the highest values for the other yield parameters namely average fruit weight, average yield, potential yield and net yield. This cultivar was more productive than the Cobra 26 cultivar. The large size of the plants of this variety would firstly justify such a result. Indeed, a larger size of the plants would favor the appearance of several bunches of fruits and consequently, the obtaining of a high yield. Secondly, the low rate of blossom end rot fruits generated by variety V2 would be the cause of this observation.

5. CONCLUSION

This study allowed us to test the effectiveness of the aqueous and alcoholic extracts and the fertilizing with the powder of the leaves of *Jatropha curcas* and Folical (seaweed extract) on the vigor of the plants, the rate of blossom end rot fruits, the production and the accumulation of fresh and dry biomass in tomato. Given the results of this study, the aqueous extracts (2 L/ha and 39 L/ha), the alcoholic extracts and the fertilizing with the powder of the leaves at the dose of 1 t/ha and 1.5 t/ha seem to constitute alternatives to optimal production in areas where the blossom end rot rife. It appears that they greatly reduce the rate of blossom end rot fruits compared to the negative control and identical to the positive control. These applications promote the calcic nutrition of tomato plants. The aqueous extracts which are 100% biodegradable with negligible impact on human health and the environment, the production cost of which is very low, appear as innovative ecological inputs for sustainable agriculture.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
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