IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 13, Issue 11 Ser. I (November 2020), PP 29-39
www.iosrjournals.org

Effects of basalt powder "Farina di Basalto®" on pepper crop growth parameters under greenhouse

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Abstract
Background:The present work aims to study the impact of a natural product derived from a volcanic rock, which is basalt on growth parameters of pepper crop under greenhouse. "Farina di Basalto®" is a natural mineral fertilizer produced by "Basalti Orvieto" in Italy. It is rich in nutrients (Si, Al, K, Fe, Ca, Mg), and is employed to improve crops growth parameters and production.During this study, three treatments were applied: T0: as control, T1 with 3% of "Farina di Basalto®" and T2 with 1.5%.Ontained results showed that basalt powder exerted an effect on pepper crop under greenhouse improving thus growth parameters such as plant height and leaf area, qualitative (leaves assimilating pigments rate and fruits sugar content) and quantitative parameters (fruits set rate, fruits number and total yiel). In fact, mostly treated plot units with basalt powder with both doses showed mean values higher than control. On the other hand, use of the fertilizer at a dose of 1.5% is as effective as at 3% and allowed to improve quantitative and qualitative parameters.

Keywords: *pepper crop, basalt, fertlizer, growth parameters, quatitative and qualitative paramiters.*

Date of Submission: 10-11-2020 Date of Acceptance: 25-11-2020

I. Introduction

In Tunisia, tomatoes (*Lycopercium esculentum*) and pepper (*Capsicum annuum*) are the most important crops cultivated under greenhouses that occupy an area surrounding 537.2 ha [2]. Regarding pepper crop, which is among the most important crops in Tunisia, it is cultivated almost in all regions and throughout the year which makes pepper a four season crop.In Africa, Tunisia is the third producer of pepper after Nigeria and Egypt, the third exporter after Morocco and South Africa [15]

To guaranteed a good pepper crop yield, certain characteristics are desired in order to facilitate fertilization operation. In contrast, most crops require well-structured and aerated soils so that the plant can establish easily [16].

Organic matter has an important role in soil condition due to its dynamic role in physical, chemical and biological properties.Organic amendments are incorporated products into the soil and which will bring carbon to it. They represent an energy source for soil microorganisms and promote biological activity [16, 17]. They intervene in the fertilization and restitution of poor soils and vary in their nature and forms. They mainly consist of compost, manure, crop residues and green manure [12].

Basalt is a tuff that comes from volcanic projections. These are small fragments, sometimes with blocks and ashes. Basalt tuffs are often found in active volcanic areas, or also on lands where eruptions have ended since years. Their color is generally black, red or even dark green [19]. Basalt is employed as a crushed rock in different areas such as in construction, in industrial and highway engineering, mineral fiber and cast stone material production, as well as in agronomy [4, 6, 18]. Basalt powder is intended for soil mineralization as a source of natural fertilizer due to its rich nutrient contents. This is explained by the fact that the composition of magmas and volcanic ashes from where it came, is rich in Silicon (Si) and other nutrients. These components are freshly ground and mixed into fine particles and they contain feldspar, micas and zeolites[1].

Basalt mass contents are; SIO_2 (37.76 to 59.64%), Al_2O_3 (11.77 to 14.32%), CaO (5.57 to 14.75%), MgO (5.37 to 9.15%), Fe_2O_3 (10.1 to 20.93%), K_2O (1.7 to 6.69%), Na_2O (1.4 to 3.34%) and TiO_2 (1.81 to 3.73%) [10].Basalt powder is used to restore fertility of poor soils and to restore the nutritional balance of crops. Natural mineral fertilization increases plant growth, total yield, fruits quality and certain chemical constituents and chlorophyll rate of pepper fruits and cucumber [7, 11]. Some other works on acacia in Panama showed that growth rate of trees has increased twice than in normal soils [9]. On the other hand, crushed basalt and tuff improved significantly iron nutrition of peanuts plants and their growth in very calcacerous soils and that chlorophyll content was doubled then that in plants grown in untreated soils[3].

Furthermore, indicated that Silicon, which is one of the most important components of basalt powder [1, 10], plays an active and important role in strengthening resistance to plants against diseases and pests by stimulating their natural defenses reactions. Treated crops with basalt are less attacked by pests and diseases that untreated ones[5, 7, 9].

The aim of this study is to evaluate the impact of a fertilizer from a volcanic rock on pepper crop growth parameters under greenhouse. The volcanic rock is basalt powder "Farina di Basalto®" produced by Basalti Orvieto in Italy, and which is rich in nutrients (Si, Al, K, Fe, Ca, Mg) and has an influence on the growth and production of the pepper.

II. Material and methods

Study location

The experiment took place in a greenhouse shelter at a High School Engineering, situated In Medjez El Beb ,wich belongs to the Beja governorate, Tunisia. The area belongs to the semi-arid bioclimatic floor with a mild winter variant. Its soil texture is a Clay loam, in which the clay content varies between 42 and 43%. It is also characterized by a low salinity level (1.09; 1.11) a basic pH (8.22, 8.58) and by an important organic matter content (2.90%). This soil is suitable for arboriculture, arable and vegetable crops.

Study design

The pepper variety « *Chergui* » was planted on January 15th 2019 at the 5-leaf stage, on simple lines with a density of 6 plants / m².The greenhouse area is 239 m² which is established according to a complete random arrangement with 3 blocks.Each block has a dimension of 12 meters in length and 5 meters in width divided into 3 plot units, each of which represents a treatment.Each plot unit covers 14.4 m² and consists of 3 crop lines, each line contains 30 plants. The planting spacing are 0.6 m between the lines and 0.4m between the plants. This corresponds to a planting density of 6 plants / m². At each block, 6 lines are treated with basalt powder such as T0 corresponds to 0% of basalt powder (control), T1: 3% of the basalt powder, T2: 1.5% of the basalt powder (fig. 1).

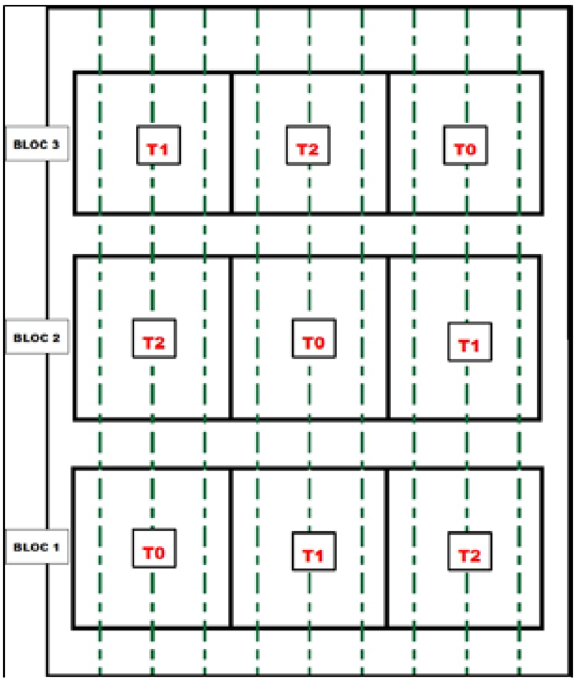

Figure 1. The study design (T0: control plot unit, T1: plot units that received 3% of basalt powder, T2: plot units that received 1.5% of basalt powder).

Measured parameters

Growth parameters

These parameters were measured on samples of three plants per treatment per plot unit. Plants were chosen randomly and marked in order to serve during all the study period. Measurements took place from February till the May.

Plant height

Plant height was measured from the crown to the highest point using a precision meter twice a month with an interval of time of about two weeks.

Leaf area

Leaf area was measured three times once a month during March, April and May using an Ushikataplanimeter. Leaves were sampled from different parts of the plant; apical part, median part and basal part. Three leaves were taken from each part making thus a total number of nine leaves per plant.

Production parameters

Fruits' set rate

Fruits' set rate was evaluated twice a month. This parameter is expressed as a percentage and calculated from the total flowers number and the tied flowers number according to the following formula:

Fruits' set rate = tied flowers number / tot l flowers number x 100

Fruits' number

It was evaluated on the same plants that were randomly chosen and marked for the other parameters.

Fruits' yield

Fruits' yield was evaluated at each harvest. It was determined according to the total yield of fruits by each experimental unit compared to the surface occupied by this plot unit.

$$\text{Yield (kg / m}^2\text{)} = \text{total yield / surface (m}^2\text{)}$$

Quality parameters

Dry matter content

This parameter was evaluated on leaves and fruits after drying in the oven at 70°C until constant weight were obtained. This parameter was measured twice (during March and April).

Pigments amount

This parameter was estimated according to the method mentioned by [14] that consists of extracting 0.1 g of fresh leaves and fruits. Then it must be mixed with 10 ml of acetone 80%. The obtained solution is then filtred through a filter paper and placer into Eppendorf tubes. These ones were placed in a centrifuge at 13 000 rounds per minute during twenty minutes in the reason to remove and eliminated all plant debris. Then the solution was placed in a quartz curve in the reason to measure its absorbance using a spectrophotometer (PG Instruments®). The wavelength used was between 430 and 710 nm.

Pigmentations amounts ($\mu g.ml^{-1}$) were determined according to formulae of [14].

Chlorophyll a (Ca) ($\mu g.ml^{-1}$) = $12.25\ A_{663.2} - 2.79\ A_{646.8}$

Chlorophyll b (Cb) ($\mu g.ml^{-1}$) = $21.5\ A_{646.8} - 5.1\ A_{663.2}$

Carotenoids and Xanthophylls $C_{(C+X)}$ ($\mu g.ml^{-1}$) = $1000\ A_{470} - (1.82\ Ca - 85.02\ Cb) / 198$

Knowing that Ca and Cb absorb light at wavelengths of 663.2 nm and 646.8 nm respectively and Carotenoïdes and Xanthophylls at 470 nm.

The Brix degree

The Brix degree or the total sugars of the fruit juice was determined twice (at each harvest) using a HI96801 refractometer by direct reading.

Treatment

Characteristics of the basalt powder

Basalt is a basic volcanic effusive rock containing natural mineral elements, such as Silicium, alumina, potassium and calcium. Micronized basalt powder was obtained by mechanical grinding of Basalt from Orvieto, using ceramic elements, without adding other minerals or chemical products. It does not contain any harmful substances that can damage the environment. The particle diameter is less than 30 mμ, its use therefore requires an application in aqueous dispersion, sprayed with a manual or mechanical nebulizer.

Chemical proprieties of basaltic mineral fines

Different components of basaltic powder are shown in table 1.

Table 1. Chemical proprieties of basaltic mineral fines [3].

Component	Pourcentage
(SiO_2)	49%
(Al_2O_3)	20,5%
(K_2O)	8%
(Fe_2O_3)	7,5%
(CaO)	7,2%
(MgO)	2,8%
(Na_2O)	2,5%

Basalt application

Basalt powder was mixed with water and then applied as a foliar spray using a backpack sprayer.The application was carried out every 20 days (three weeks). Three blocks received a dose of 3% of basalt (T2), and other three blocks received a dose of 1.5% (T3). T0 considered as control plots did not receive any treatment.

Statistical analysis

Statistical analysis was performed with the aid of statistical software SAS. This program was used for the analysis of variance (ANOVA) and the LSD test for the comparison of means with $p \leq 0.05$.

III. Results and Discussion

Measured parameters

Growth parameters

Plant height

Obtained results showed that height of pepper plants at unit plots treated with T1 and T2 were important than those recorded in control plots during the entire study period. In fact, maximum height registered was about 96.8 cm for T2 (1.5%) 16 weeks after planting (fig. 2).

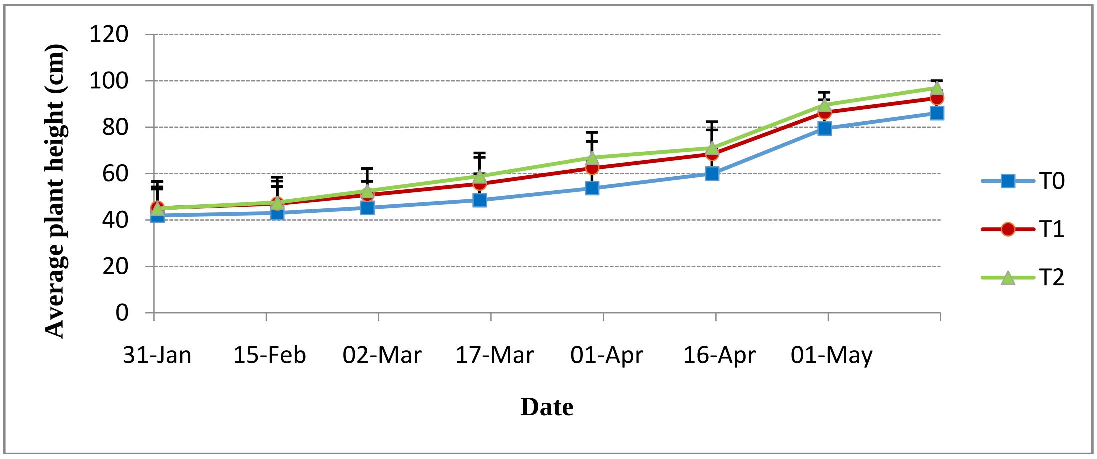

Figure 2. Average pepper plants heights in relation with different treatment (Legend: T0; Control, T1; 3% of Basalt, T2; 1.5% of Basalt).

Leaf area

Regarding this parameter, both basalt applications (T1 and T2) affected only leaves of the middle part. In fact, obtained results showed that significant differences were observed between both doses (T1 and T2) and control at $p \leq 0.05$ (fig. 3). Leaf area registered for T1 and T2 exceeded in all cases 60 cm^2, while in control it did not reached even 50 cm^2. These results demonstrated that basalt had an effect on leaf area of the middle part.

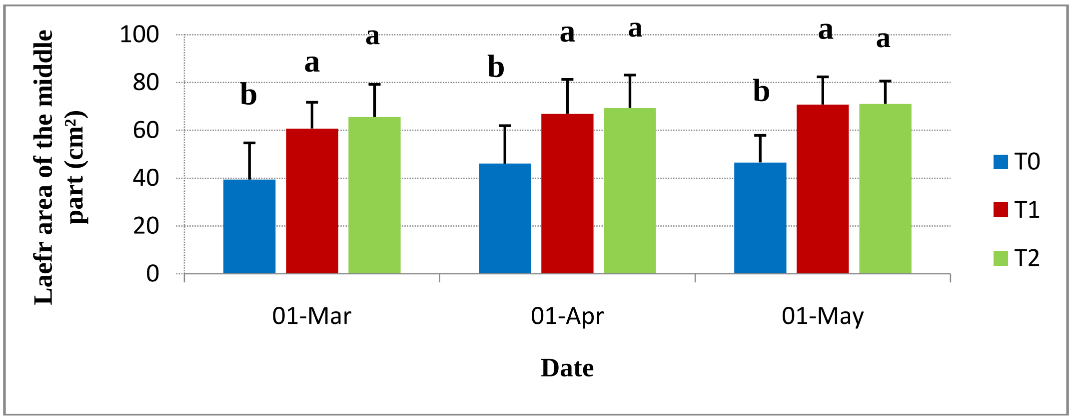

Figure 3. Average pepper plants leaf area of the middle part in relation with different treatment (Legend: T0; Control, T1; 3% of Basalt, T2; 1.5% of Basalt), (Values followed by the same letters are not significantly different at $p \leq 0.05$).

However, it must be noted that T1 and T2 did not affect leaf areas of the apical and basal part of pepper plants. In fact, for those both plant part no significant differences were observed between T1, T2 and control (figs. 4 and 5).

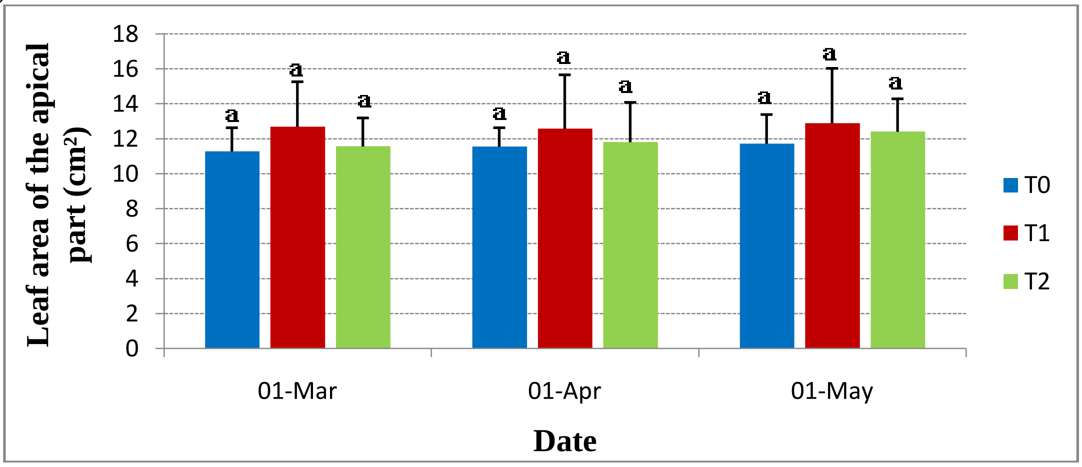

Figure 4. Average pepper plants leaf area of the apical part in relation with different treatment (Legend: T0; Control, T1; 3% of Basalt, T2; 1.5% of Basalt), (Values followed by the same letters are not significantly different at $p \leq 0.05$).

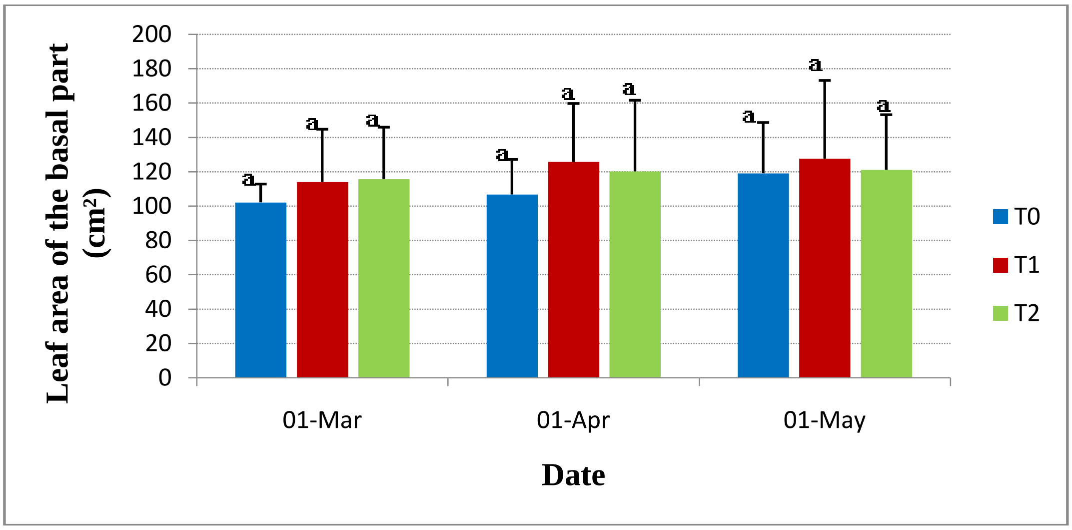

Figure 5. Average pepper plants leaf area of the basal part in relation with different treatment (Legend: T0; Control, T1; 3% of Basalt, T2; 1.5% of Basalt), (Values followed by the same letters are not significantly different at $p \leq 0.05$).

Production parameters
Fruits' set rate

Fruits' set rate monitoring during all the study period showed that in almost all observed cases, treated unit plots with both basalt doses T1 and T2 showed the most important percentages of fruits' set compared with control (fig. 6). In fact, maximum average values observed for T1 and T2 were comprised between 46 and 47%, while it was only about 38.28% for control unit plots.

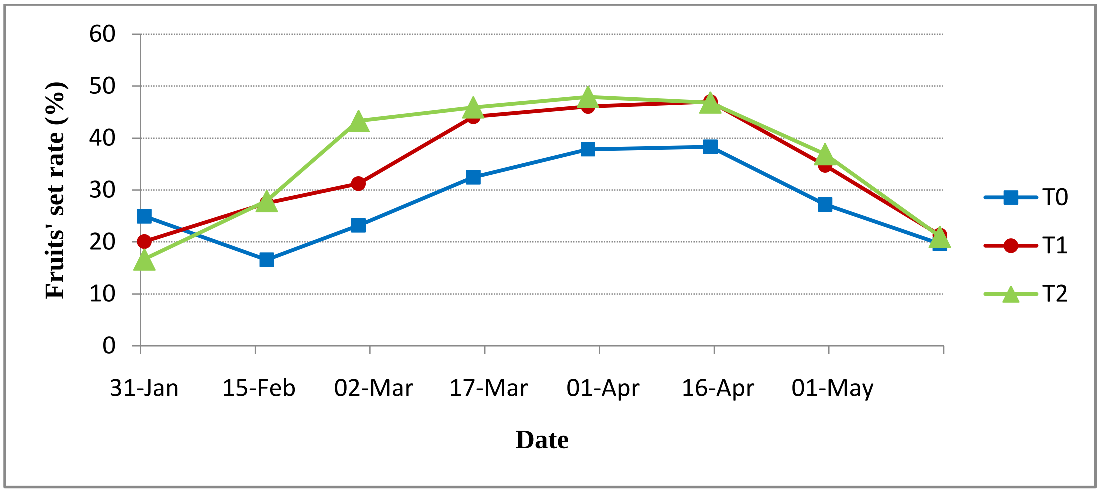

Figure 6. Average pepper plants leaf area of the apical part in relation with different treatment (Legend: T0; Control, T1; 3% of Basalt, T2; 1.5% of Basalt)

Fruits' number

Concerning this parameter, it did not show important differences between different treatments (fig. 7). However, it should be noted that in the majority of cases, the number of fruits was higher in treated plants especially for the T2 dose than in control. This demonstrate that basalt improves fruits' number per plant.

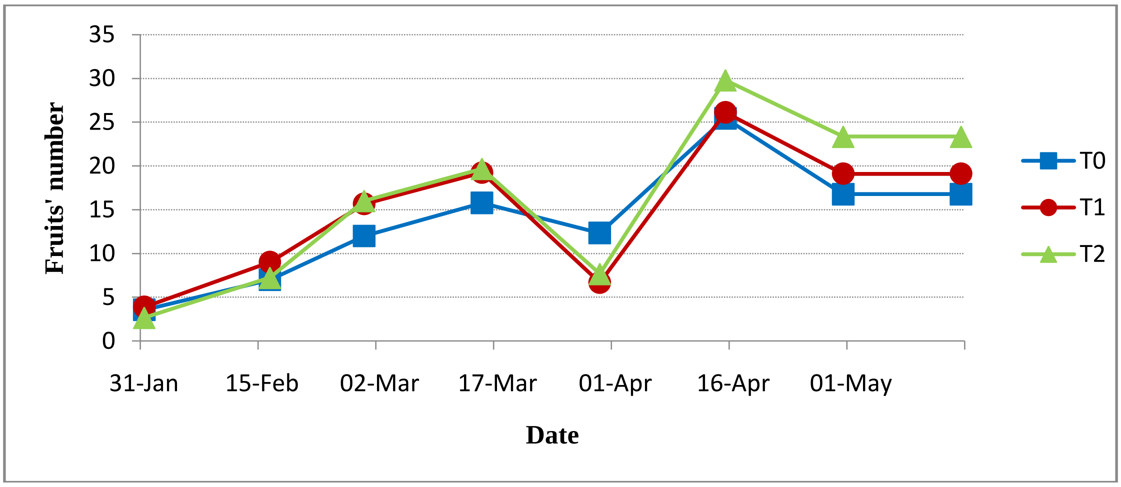

Figure 7. Average pepper plants leaf area of the apical part in relation with different treatment (Legend: T0; Control, T1; 3% of Basalt, T2; 1.5% of Basalt)

Fruits' yield

Average fruits' yield during March and April showed significant differences between both basalt doses and control (fig. 8). In fact, plants treated with T1 showed the highest total yield about 2.94 kg/m², followed by T2 with an average value of about 2.77 kg/m² while control did not exceed 2 kg/m² during March. In April, almost same results were obtained where fruits' yields in T1 and T2 were about 4.39 and 3.69 kg/m² respectively and only 2.59kg/m² for control. These results demonstrated also the impact of basalt application in improving pepper plants production.

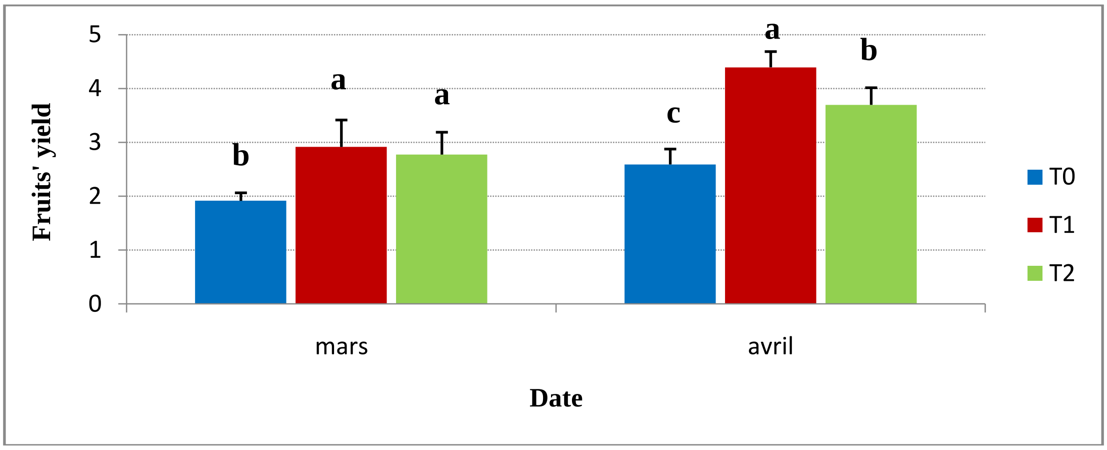

Figure 8. Average fruits' yield in relation with different treatment (Legend: T0; Control, T1; 3% of Basalt, T2; 1.5% of Basalt), (Values followed by the same letters are not significantly different at $p \leq 0.05$).

Quality parameters

Leaves' dry matter content

Figure 9 illustrated the cumulative average values obtained for leaves' dry matter content. The maximum average value was observed for T2 with 32.42% followed by control unit plots with 22.32%. However, lowest dry matter value was recorded for T1 with 22.09%. It should be noted that this difference between treatments is statically insignificant at $p \leq 0.05$.

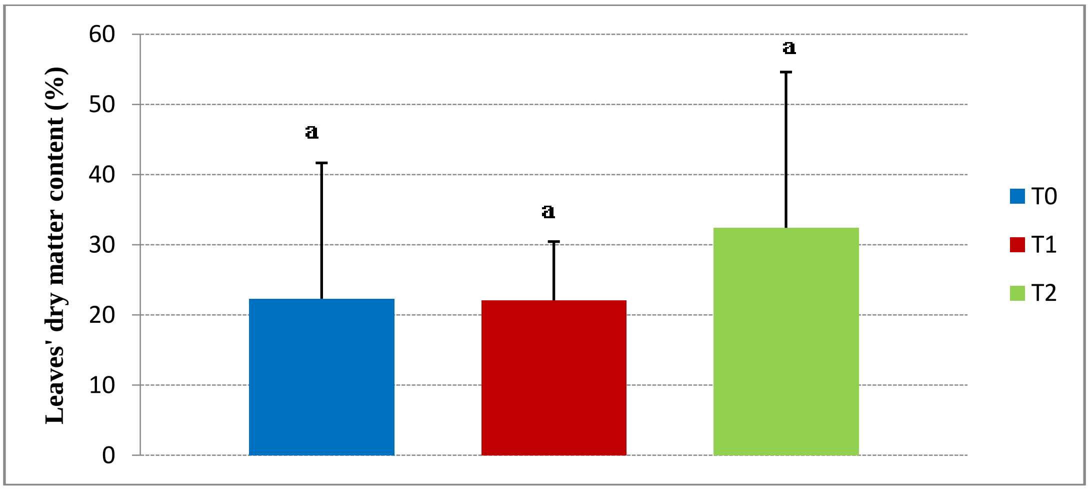

Figure 9. Cumulative averageleaves' dry matter content in relation with different treatment (Legend: T0; Control, T1; 3% of Basalt, T2; 1.5% of Basalt), (Values followed by the same letters are not significantly different at $p \leq 0.05$).

Fruits' dry matter content

Maximum cumulative average values for this parameter were recorded during March with 8.52% in control unit plots, and 8.52% for T2 during April (fig. 10). It must be noted that during both months of measurements, no significant differences were recorded between different treatments. This demonstrated that basalt had no effect on dry matter contents neither on leaves nor on fruits.

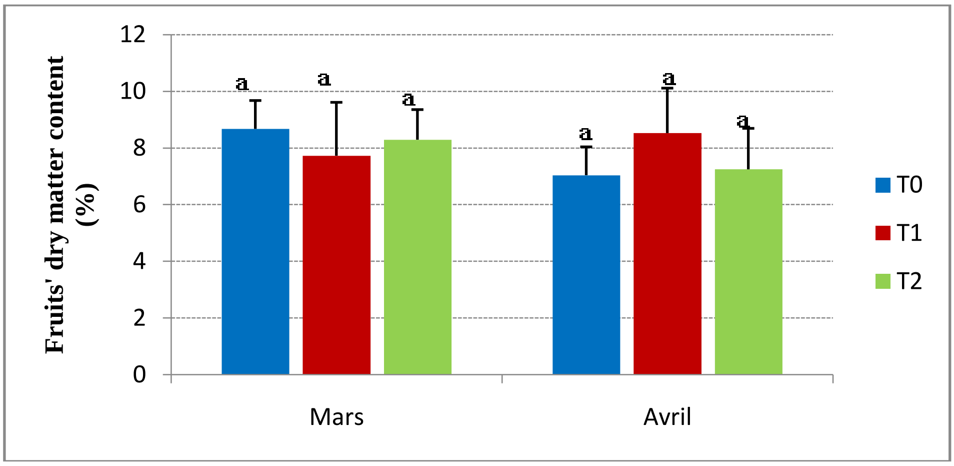

Figure 10. Cumulative average leaves' dry matter content in relation with different treatment (Legend: T0; Control, T1; 3% of Basalt, T2; 1.5% of Basalt), (Values followed by the same letters are not significantly different at $p \leq 0.05$).

Pigments amount

Results regarding the effect of basalt on different photosynthetic pigments amounts such as Chlorophyll a (Ca), Chlorophyll b (Cb) and Xanthophyll and Carotenoids, showed that this mineral improved these pigments amounts. In fact, basalt caused the increase of Ca content in leaves. The highest levels of Ca were recorded in treated leaves with T& and T2 doses with respectively 7.66 µg / ml and 7.80 µg / ml with no significant differences between both doses. While in control, it was only about 4.41 µg / ml with significant difference compared with T1 and T2 at $p \leq 0.05$ (fig. 11).

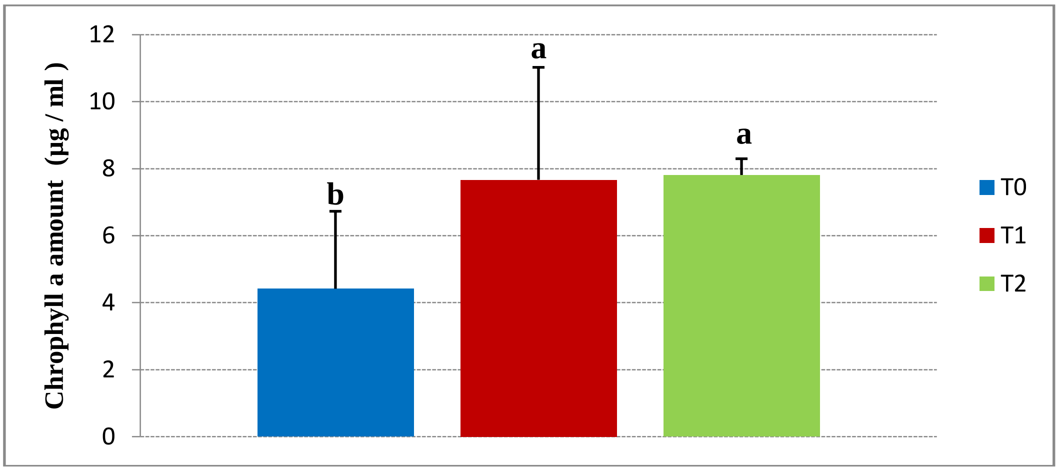

Figure 11. Leaves' chlorophyll a (Ca) amount in in relation with different treatment (Legend: T0; Control, T1; 3% of Basalt, T2; 1.5% of Basalt), (Values followed by the same letters are not significantly different at $p \leq 0.05$).

Same results were registered for Chlorophyll b (Cb) (fig. 12). This pigment amount in leaves increased with basalt application. The highest recorded values were about 7.80 µg / ml and 7.66 µg / ml respectively for T2 and T1 treatments and with no significant difference. The lowest value was obtained in the control with 4.41 µg / ml and which is significantly different according to the analysis of variance ($p < 0.05$) compared to T1 and T2.

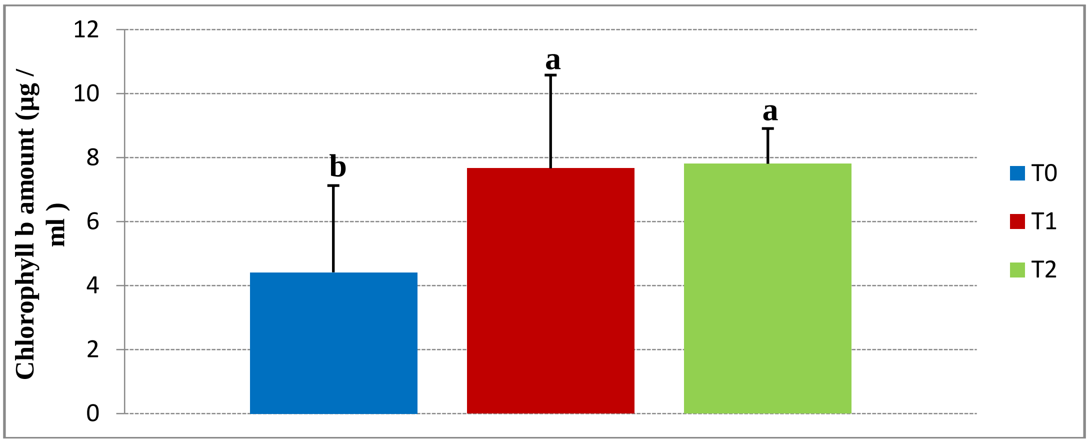

Figure 12. Leaves' Chlorophyll b (Cb) amount in in relation with different treatment (Legend: T0; Control, T1; 3% of Basalt, T2; 1.5% of Basalt), (Values followed by the same letters are not significantly different at $p \leq 0.05$).

Concerning Xanthophyll and Carotenoids, an increase in their content in analyzed leaves treated with basalt was observed compared to control (fig. 13). Basalt application at T1 gave the highest level with 1249 µg / ml followed by T2, which was around 1151 µg / ml. However, the lowest value was noted for the control with only 734 µg / ml and which is significantly different compared to T1 and T2.

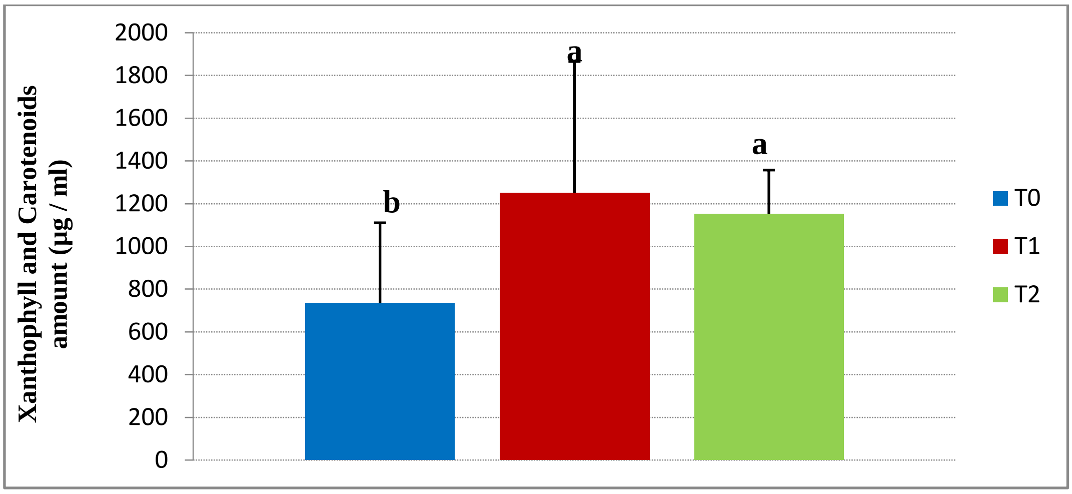

Figure 13. Leaves' Xanthophyll and Carotenoids amount in in relation with different treatment (Legend: T0; Control, T1; 3% of Basalt, T2; 1.5% of Basalt), (Values followed by the same letters are not significantly different at $p \leq 0.05$).

The Brix degree

During first Brix degree analysis in March, T1 and T2 treatments showed an important amount around 2.91 and 3.12 respectively compared with control that registered only 2.08 with significant differences. However, the sugar content at the second harvest during April increased for all treatments with average values of about 3.75, 3.54 and 3.43 respectively for T1, T2 and control with no significant differences (fig. 14).

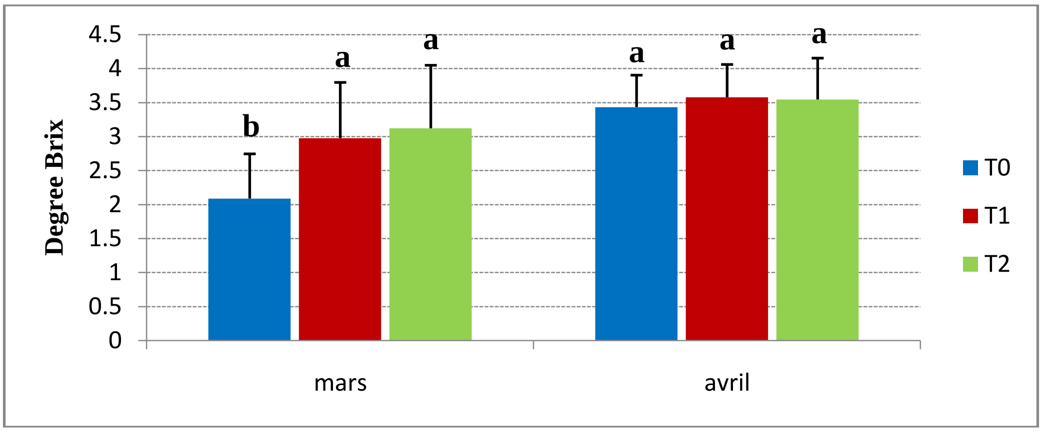

Figure 14. Average degree Brix in in relation with different treatment (Legend: T0; Control, T1; 3% of Basalt, T2; 1.5% of Basalt), (Values followed by the same letters are not significantly different at $p \leq 0.05$).

Obtained results showed that basalt application had an impact on plants heights and especially on leaf area of the middle part of the sampled plants. In fact, natural mineral fertilization increases the height growth of plants [12]. On the other hand, basalt powder improves growth and development of trees such as Acacia treated with basalt powder [9].

Fruits' set estimation throughout the trial period detected significant differences. The highest value of the fruit set was obtained by the T2 dose.This seems to have a rapid and positive influence on the yield in the same treated plants with a maximum value obtained in T1 treatment followed by T2. In fact, fertilization by crushed rocks such as (basalt, shale, gabbro) mixed with nitrogen and phosphorus has a positive effect on productionand total fruits' yield during harvest [3, 20].

Dry matter evaluation in leaves and fruits at each harvest did not show any significant differences between the treatments. This allowed us to say that basalt has no effect on the dry matter contents of different parts of the plant.

Regarding assimilating pigments, an improvement in the levels of (Ca), (Cb) and of Xanthophylls and Carotenoids was observed when plants are treated by basalt.In fact, 1 to 2% of basalt powder doubles the chlorophyll content [3].

The treatments also have an influence on the sugar content (the Brix degree) which only increased during the first harvest.The increase in sugar content and the increase in yield are strongly linked to significant photosynthetic activity. In the same context, fertilizers based on (Si) allow to obtain a better quality of fruits [15].

The results allow to demonstrate that basalt powder sparing on pepper crop under greenhousehad an impact on some growth and quality parameters and that the two doses 3% and 1.5% act in the same way.

IV. CONCLUSION

Basalt powder (Farina di Basalto) spraying on pepper crop under greenhouses with two different doses (1.5 % and 3%)had a significant influence on phenological parameters of pepper crop such as growth, quality and production parameters. Fertilization allowed the plants to benefit from a very high fruit-setting rate. This improvement was reflected in the importance of the cumulative total yield, which was most interesting for the treatment with the 3% dose. In fact, this mineral fertilizer increased the yield to 38%. Quality parameters were also affected by basalt application, such as the content of assimilating pigments and the sugar content of the fruits under the effect of the treatments (T1) and (T2). In general, we have shown that the 3% dose of basalt powder allowed us to reach an optimal yield, however the half-dose had the same effect as the 3% dose.

ACKNOWLEDGEMENTS

Authors would like to express their profound appreciation to the Higher School of Engineer of Medjez El Beb, MedjezElBeb, for providing all the necessary materials and the greenhouse.

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Mohamed Elimem, et. al. "Effects of basalt powder "Farina di Basalto®" on pepper crop growth parameters under greenhouse." *IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)*, 13(11), 2020, pp. 29-39.