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Evaluation of the Effect of Charcoal and Seeding Depth on the Agronomic Performance of Zucchini (*Curcubita pepo*) in Korhogo

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Authors' contributions

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

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ABSTRACT

In order to improve zucchini production, the combined effect of charcoal amendment and seeding depth was tested at the botanical garden of the Peleforo Gon Coulibaly University in Korhogo. To this end, six (6 kg) of activated charcoal were buried in the elementary plots one month before

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sowing in order to assess its effect on soil fertility. The experimental design was that of completely randomized two-factor blocks which are charcoal amendment and depth. Sowing was carried out one month after the application of charcoal due to three seeds per hill at different depths. Namely 0 inch, 1.5 inch and 3 inch. These same depths were repeated on control plots in order to compare their effect on the agronomic performance of zucchini. The results obtained show that after a campaign of use of biochar, the chemical parameters of the soil (pH, CEC, K+, exchangeable Ca2+ and exchangeable Mg2+) experienced significant increases. The porosity has also been reduced. Zucchini fruit yields increased by 100-250% with charcoal compared to the control. Therefore, the use of charcoal can be popularized as a sustainable alternative to conventional fertilization to improve the yield of zucchini on sandy loam soils. Zucchini fruit yields increased by 100-250% with charcoal compared to the control. Therefore, the use of charcoal can be popularized as a sustainable alternative to conventional fertilization to improve the yield of zucchini on sandy loam soils. Zucchini fruit yields increased by 100-250% with charcoal compared to the control. Therefore, the use of charcoal can be popularized as a sustainable alternative to conventional fertilization to improve the yield of zucchini on sandy loam soils.

Keywords: Charcoal; zucchini (Curcubita pepo); sandy loam soil; seeding depth; Korhogo.

1. INTRODUCTION

Zucchini is a commodity very popular with the Ivorian population, especially that of the city of Korhogo. Due to the cost accessible on the market, its nutritional value and a favorable climate for its production, it contributes and participates in the development of the local economy. Zucchini production is strongly developed by women. This activity is an important source of income for them, enabling them to meet certain household expenses and participate in community social works.

In the aftermath of the 2012 post-electoral crisis, the redeployment of the public administration, the creation of the Peleforo Gon University and the implementation of several development projects that occurred after the post-electoral crisis caused the migration of several populations from other areas of the country to the town of Korhogo [1]. This displacement of populations favored the increase in the number of populations, which went from763 852inhabitantsin 2014 [1] at 1,040,461 in habitants in 2021 [2]. To this end, the consumption of this commodity is becoming increasingly important. The strong demand induced by the growing population, made the production of this commodity even more necessary.

To achieve these many demands, farmers resort to chemical fertilizers (NPK) to improve their yields. Despite their applications, production drops considerably after one cropping season due to leaching of minerals [3]. In order to contribute to the improvement of production and sustainable agriculture, it is therefore necessary to find an alternative to overcome this.

According to Yao et al. (2012), the use of biochar would therefore be conducive to an improvement in soil fertility and crop productivity via the reduction of nutrient leaching and via a better supply of the plant with nutrients. In addition, it would allow the soil to acquire a good cation exchange capacity (CEC) and better abilities to retain nutrients over long cultivation periods [4].

The use of biochar could be a means of combating deforestation and global warming through the sedentarization of farmers and the storage of carbon in the soil [5]. The water necessary for the development of plants is partly extracted from the soil. Thus, the rooting depth of the plant will determine the depth on which it will feed. Increasing seeding depths could be a way to improve crop yield due to higher soil water content in the seed zone, resulting in better germination and seedling emergence (Schillinger et al. [6]).

It is therefore an approach which should make it possible to improve the effectiveness of the amendment to biochar, in particular in a context of scarcity of the organic resource and climate change. It is within this framework that the present study took place, in order to evaluate the effectiveness of charcoal for the restoration of sandy-loamy soils and the added value of the depth of sowing on the production of zucchini in climate zone Sudanese.

2. MATERIALS AND METHODS

2.1 Presentation of the Study Area

This study was carried out on the site of the botanical garden of the University Péléforo Gon Coulibaly, Korhogo (Fig. 1). The texture of this soil is sandy loam type. This city is located in the North of the Ivory Coast between on the one hand, 8°30' and 10°25' of north latitude and, on the other hand, 5°15' and 6°20' of west longitude , with an average altitude of 325 m above sea level. The climate of the Poro region is of the dry tropical type with two seasons: one dry, from November to April and the other wet, from May to october. The rainfall regime is unimodal and centered on the months of August-September which accumulate almost half of the annual average height of precipitation equal to about 1200 mm [8]. Average temperatures vary between 24° and 33°C. The hottest months are February, March and April with 36°C and the coolest months are December and January with 16°C [9]. The soils observed have a predominantly sandy-loamy clay texture with low humic impregnation [10].

2.2 Plant Material

The plant material used is the AURORE F1 variety of zucchini. It is renowned for its good germination and purity. It is a variety that has a germination rate of 85% minimum and a degree of purity of 99% minimum. It is characterized by a crop cycle of 60 days with an average yield of 4 to 5 kg/m². However, it is heat demanding and grows well at temperatures between 16°C and 24°C. It also requires a pH close to neutral; between 5.5 and 7 [11]. Therefore, it prefers heavy soils to light ones because of its organic matter requirement.

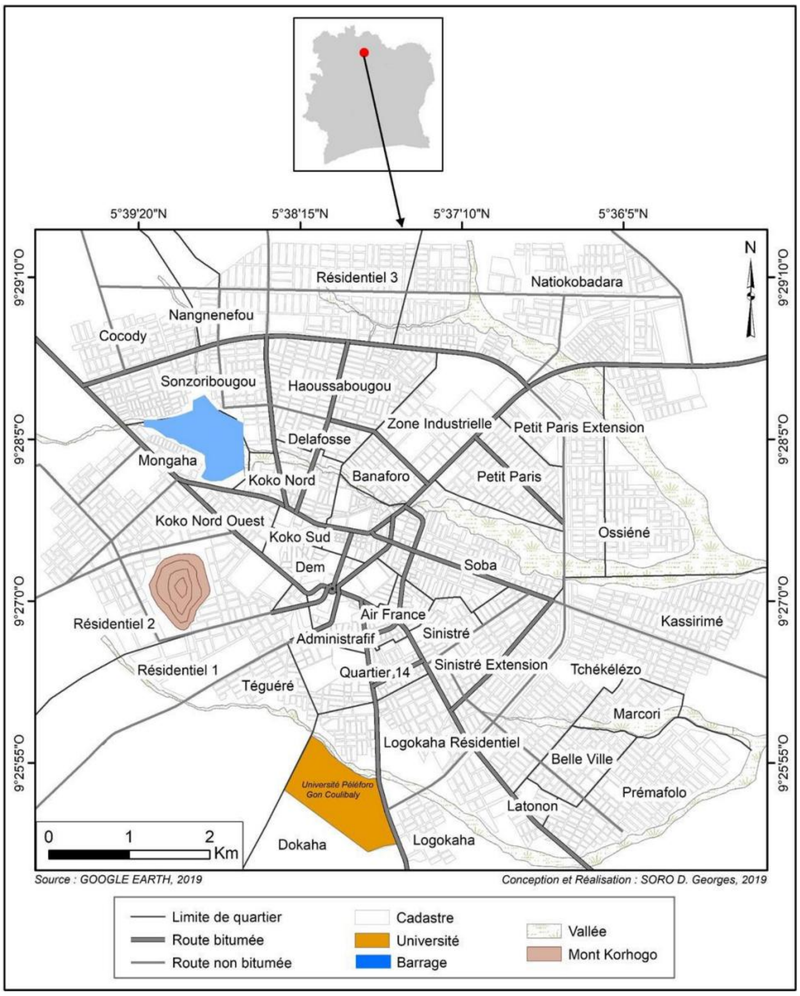

Fig. 1. Map of the city of Korhogo [7]

2.3 Fertilizing Material

The fertilizer used is charcoal. It is produced by the incomplete combustion of wood. In connection with its use in agriculture, it is called “biochar” [12]. This appellation takes its name from the term “bio” in reference to organic residues and “char” for coal. The small fragments of charcoal not marketed given their small dimensions, were obtained from merchants in the town of Korhogo.

2.4 Experimental Apparatus

The experimental device used is that of randomized complement blocks (BCR). It had four (4) rows of six (6) experimental units (Fig. 2). Within each block, six treatments were performed (Table 1).

The plot has an average area of 45 m² and the experimental units had an average size of 1.80 mx 1.80 m or 3.24 m². The distances between the blocks were 0.8 m and 0.6 m between two experimental units. The experiment included two factors, Biochar and Seeding depth. Charcoal was introduced in the first 30 centimeters on each elementary bed at a rate of 6 kg per bed one month before sowing. In order to cause the activation of the charcoal, watering was done daily. The beds had five pockets containing three seeds per pocket. Two weeks after sowing, thinning was done to retain one plant per hill. This would reduce competition between plants.

2.5 Collection of Data

The diameter at the collar, the number of fruit, the number of leaves, and the yield per unit area are the data collected on 15 plants chosen at random according to the treatment carried out. The neck diameter was measured with a caliper; the number of leaves and that of the fruits was counted by hand. The fruits were harvested at maturity and grouped by associated treatment, then weighing on the scales was carried out.

Table 1. Characteristics of the treatments used in the experiment

Treatments	Features
T1	Soil not enriched with biochar and sowing carried out on the fly, i.e. at 0" (SBP0")
T2	Soil not enriched with biochar and seeding done at 1.5 inches deep (SBP1.5")
T3	Soil not enriched with biochar and sowing carried out at 3 inches deep (SBP3")
T4	Soil enriched with biochar and sowing carried out on the fly (0 inches) (ABP0")
T5	Soil enriched with biochar and sowing carried out at 1.5 inches deep (ABP1.5")
T6	Soil enriched with biochar and sowing carried out at 3 inches deep (ABP3")

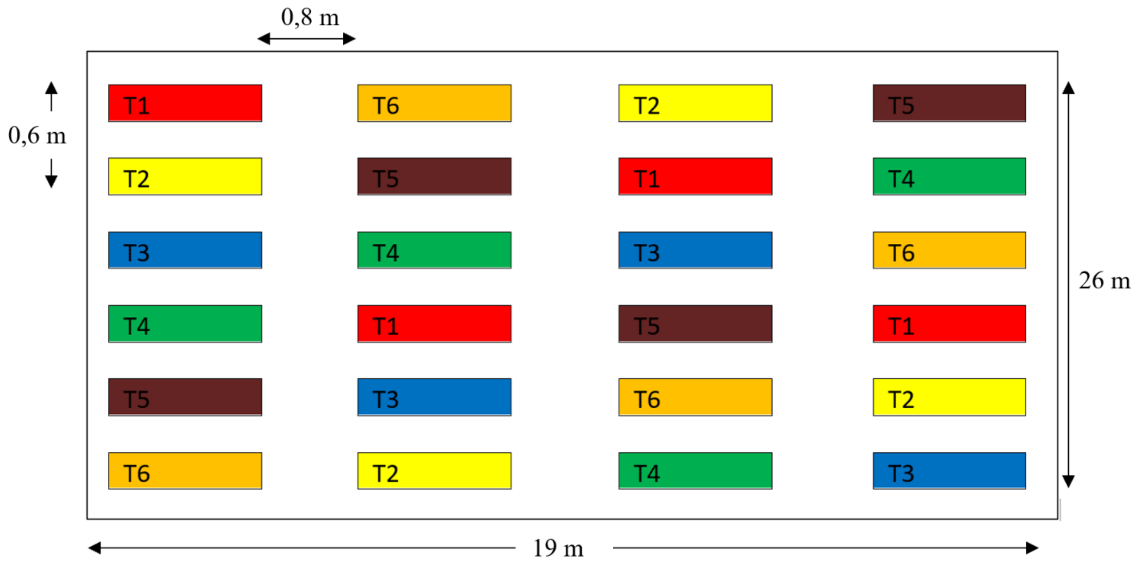

Fig. 2. Experimental apparatus

On each plot, soil samples were taken with a manual auger in the first thirty centimeters of soil corresponding to the zucchini rhizosphere zone [13]. A first sample was taken before cultivation and a second was taken after harvest. The soils were sampled according to a random device, at five different points of the plot to constitute a dry composite sample of 0.5 kg representative of the plot. These samples were then packaged in plastic bags and sent to the soil laboratory of the National Institute. Polytechnique Félix Houphouët-Boigny (INP-HB) in Yamoussoukro, for physico-chemical analyses. The soil analysis results were compared with threshold values, reference standards or results of previous work (example author of previous work with threshold values).

The granulometry in five fractions was carried out by the Robinson pipette method, according to the AFNOR NF X31-107 standardized method [14]. Soil texture classification was made following the USDA Texture Triangle [14,15]. The carbon and the total nitrogen were analyzed by the methods described in the international standard NF ISO 10694, for carbon, and NF ISO 13878, for nitrogen. The water and KCl pH were determined according to international standard NF ISO 10390 [16]. The cation exchange capacity was measured by the Mets on method of the AFNOR NF X31-130 standard [17]. Element contentCa^{2+}, Mg^{2+}, K^+ and Na^{+2}, was determined by the fluoro-nitro-perchloric method. Total phosphorus and assimilable phosphorus were measured according to international standard NF ISO 11263 [14].

2.6 Statistical Analysis

The software was used to determine the textural class of the soils of a. The EXCEL 2013 version spreadsheet was used to enter the data, to draw up the tables and graphs. One-way analysis of variance (ANOVA) was used to assess the effect of biochar and seeding depth on the agronomic parameters studied, with TUKEY's post hoc test (P=0.05) in case of differences between treatments. The XSLSTAT 2014 software was used for this purpose.

3. RESULTS

3.1 Effect of Charcoal on the Physical and Chemical Parameters of Soils

The results of the particle size analysis are recorded in Table 2. It appears that the texture of the soil enriched with charcoal is of the loamy type with a low clay content (7.5%), 49.88% of silt and 41.28% sand. On the other hand, that of the control soil is of the Limono-sandy type with 4.2% clay, 30% silt and 65.59% sand.

Table 3 indicates that at the CEC level, the values show a large difference between the two soils. Charcoal-enriched soil shows a good CEC of around 13.6cmol.kg-1, 6.8 times higher than that of the control, which has a CEC of 2 cmol.kg-1. The results also reveal a calcium ion (Ca^{2+}) content higher on the soil enriched with charcoal (8.61 cmol.kg-1) than on the control soil 0.56 cmol.kg-1. The control soil obtained a much higher porosity (90.50%) compared to the soil enriched with charcoal (30.50%). In addition, the rate of organic matter is slightly higher on the soil enriched with charcoal 1.34 against 0.21 on the control soil. As for the C/N ratio, the values are between 4 and 6. This indicates rapid mineralization of organic matter on both soils. The phosphate content is around 83 ppm on the soils enriched with charcoal and 45 ppm for the control soil.

Table 2. Results of the particle size analysis

	Granulometry (%)					
Types of plots	**Clay (%)**	**Fine silt (%)**	**Coarse silt (%)**	**Fine sand (%)**	**Coarse sand (%)**	**Texture**
Charcoal Enriched Soil	8.01	22.03	28.68	29.56	11.72	Loam
Control soil	4.2	17.52	12.51	31.29	34.48	Sandy Loam
Coefficient of variation	0.4	0.2	0.5	0	0.7	

Table 3. Cation exchange capacity, pH and exchangeable bases

	Absorbent complex (cmol.kg-1)						
Types of plots	CEC	Ca2+	Mg2+	K+	Na+	pH	Porosity (%)
Soil enriched with biochar	13.6	8.61	1.41	0.56	0.2	7.2	30.4
Control soil	2	0.56	0.51	0.06	0.16	6.8	90.5

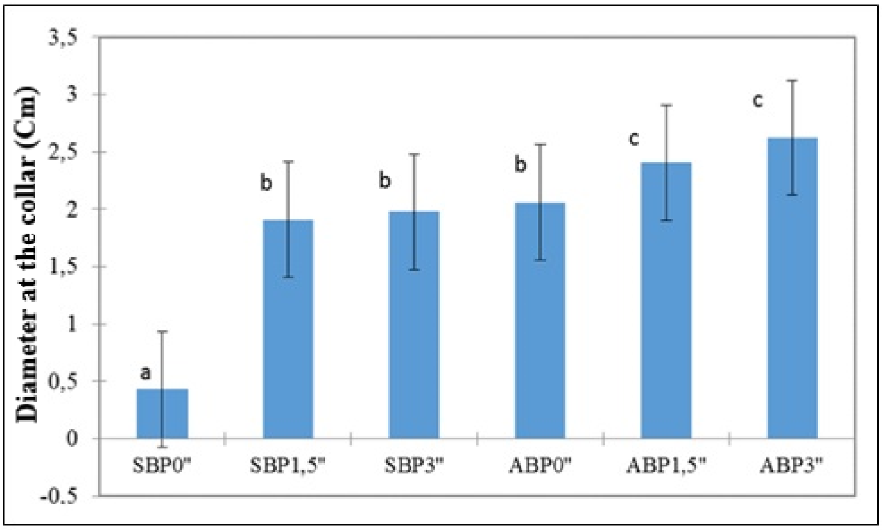

Fig. 3. Variation of collar diameter depending on substrate and seeding depth

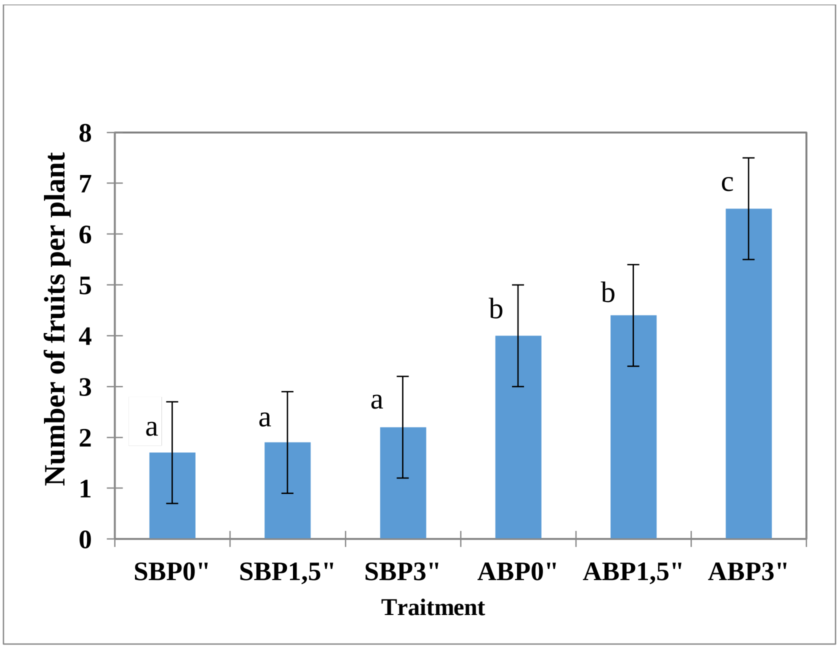

Fig. 4. Number of fruits according to substrate and sowing depth

3.2 Effect of Charcoal and Seeding Depths on Collar Diameter

Statistical analysis showed that seeding depth had a significant effect ($p < 0.05$) on plant collar diameter (Fig. 3). On the control soil, the values are respectively 0.43 cm for the depth 0 inch; 1.91 cm for 1.5 inch depth and 1.98 cm for 3 inch depth. On soil enriched with charcoal, the largest diameters are obtained with the 3 inch depth with 2.62 cm in diameter and 2.41 cm for the 1.5 inch depth.

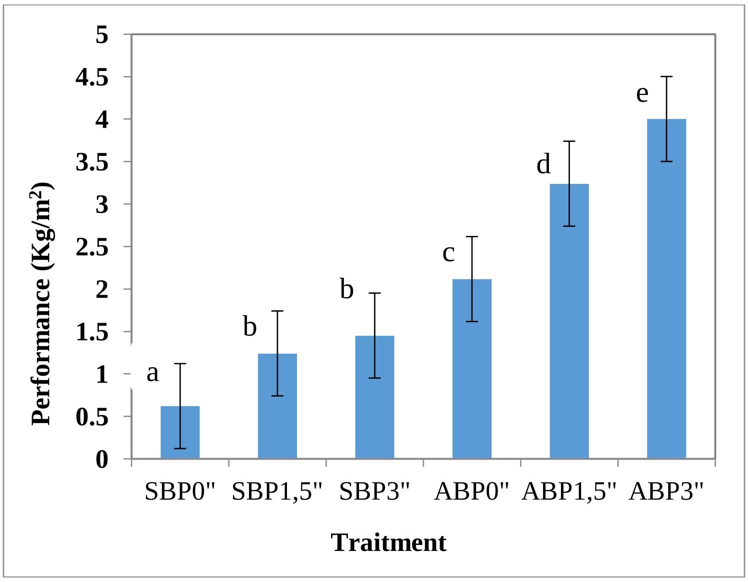

Fig. 5. Yield per unit area as a function of substrate and seeding depth

3.3 Effect of Charcoal and Depths on the Number of Fruit

The variation of the sowing depth did not have a significant difference (p-value > 0.05) on the number of fruit on the control soil. The number of fruits is two per plant depending on the associated depth. However, on soil enriched with charcoal, there is a significant difference (p-value < 0.05). The number of fruits is four (4) for the 0 and 1.5 inch depth and seven (7) for the 3 inch depth (Fig. 4).

3.4 Effect of Charcoal and Seeding Depth on Yield per Unit Area

The yield per unit area did not show any significant difference on the control soil.

Indeed, the yield is less than 1 kg / m2 with depth 0 inches (0.62 kg / m2) and less than 2 kg / m2 for depths 1.5 (1.24 kg / m2 of (1.45 kg/m2) for the 3" depth. Whereas on the charcoal-enriched soil, it is 4kg/m2 for the 3" depth, 3kg/m2 for the 1.5" depth and 2 kg/m2 for depth 0 in. Its yields are clearly significant compared to those of the control soil (Fig. 5).

4. DISCUSSION

4.1 Effect of Charcoal on the Physical and Chemical Characteristics of the Soil

Physico-chemical analyzes were carried out to evaluate the effect of biochar-based amendments on the characteristics of the soil, at the end of the zucchini production cycle. The results of the granulometric study show that the contribution of charcoal modified the texture and the porosity of the soils treated. The addition of biochar made it possible to change from a sandy-loamy texture on the control soil to a sandy-loamy texture for the biochar-enriched ones. These results agree with most of the results obtained by other authors [18-20] which show that the physical properties on which the biochar acts are the porosity, therefore the particle size. The present study showed that this modification resulted in the reinforcement of the content of agile, of silt and the reduction of the content of sand. Compared to the control, the biochar-based treatments had effects on the chemical properties of the soil. This corroborates most of the results obtained by other authors [21,22]. This work has shown that the addition of biochar as an amendment allows a significant improvement in the chemical properties of the soil. One of the salient results of our study is the increase in pH and Ca2+ content, while there was no lime amendment. The alkalinity observed in the treated soils is explained by the presence of ashes as well as carboxylic groups in each type of biochar. These ashes rich in carbonates or organic anions contribute after their hydrolysis to the neutralization of the acidity of the soil and to the raising of the pH. Biochar by increasing the pH of the soil not only solves the acidity problem but also allows the soil to have a net negative charge and retain more nutrients. Therefore, tropical soils being acidic [23], the biochar amendment could be recommended in tropical agriculture as an alternative to the use of heat, which is a costly operation and not economically justified for the small farmer.

4.2 Effect of Charcoal and Seeding Depth on Collar Diameter

According to the results, the largest collar diameter was obtained with the 3-inch depth on the control soil as well as on the soil enriched with charcoal. Deep sowing would therefore be a considerable factor in the growth of plant diameter. Indeed, deep sowing promotes deep rooting allowing the plant to establish good contact with the soil, to ensure good water and mineral nutrition, and to resist water deficit. On charcoal-enriched soil, the increase in diameter could be related to good mineral nutrition, as demonstrated by the work of [24]. These authors explain that plants grown in biochar soil had a larger rhizospheric zone contributing to better uptake of nutrients by the roots.

4.3 Effect of Charcoal and Seeding Depth on Fruit Number

The best fruit yield was observed on soil amended with charcoal. It went from two fruits per plant on the control soil regardless of seeding depth to seven on the charcoal-amended soil with the 3 inch depth. This could be explained by the combined effect of charcoal and seeding depth. Indeed, the charcoal creates a favorable environment for the development of the plant. As indicated by our results, the presence of wood charcoal improves the texture of the soil, raises its content of exchangeable bases, as well as its cation exchange capacity. L' The use of biochar is conducive to an increase in soil fertility and crop productivity via reduced nutrient leaching and via better plant nutrient supply (Yao et al. 2012). Both disk deep sowing provides the plant with good water and mineral nutrition, as well as resistance to water stress. These allowed the plants grown on the substrate to have a better availability and use of nutrients promoting good fruit yield. Alongside the yield per unit area or yields were even better these soils. These allowed the plants grown on the substrate to have a better availability and use of nutrients promoting good fruit yield. Alongside the yield per unit area or yields were even better these soils. These allowed the plants grown on the substrate to have a better availability and use of nutrients promoting good fruit yield. Alongside the yield per unit area or yields were even better these soils.

5. CONCLUSION

At the end of our work, it appears that the charcoal and the depth of sowing had a significant effect on the physical, chemical parameters and on the agronomic parameters evaluated during this study. The combined effect of these two factors appears to be an adequate solution to improve production and replace chemical inputs.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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