Original Research Article

Effect of charcoal and seedling depth on soil properties and melon yield components (*Cucumis melo***) in Poro, Côte d'Ivoire**

Abstract

The combined effect of charcoal amendment and seeding depth was tested on soil properties and yield components of melon (*Cucumis melo*) at the botanical garden of the Peleforo Gon Coulibaly University of Korhogo. W~~w~~ith the exception of the control plot, 6 kg of charcoal were applied by hand on ridges of 2.25 m2 in the first 10 cm of soil one month before sowing. The seeds were sown manually~~by hand~~ at 0.5 cm (control depth); 3 cm; 7 cm and 9 cm deep. The results showed that the application of charcoal significantly increased germination rate (($P< 0.002$), growth ($P < 0.0001$) and fruit yield ($p = 0.0001$). ~~t~~The combined effect of charcoal input and sowing depth was noticeable from the 47th day after sowing ($P = 0.0001$), the greatest values having been observed at a depth~~s~~ of 9 cm Correlated to the growth of the plants, the best fruit yields were obtained from the depths 9 cm with an average of 4 fruits per plant.

Key words

Charcoal, seedling depth, growth, yield, ***Cucumis melo***, Korhogo

INTRODUCTION

Pease note: Charcoal is not Biochar. Both are different in the preparation process. The Temperature plays a role here. TO under stand more on biochar pl read articles by Prof.LEHMANN, Dr.PANDIAN KANNAN

~~Biochar takes its name from the term "bio" in reference to organic residues and "char" for charcoal. In the context of uses in soils and porous media, they are called charcoal [1]. This c~~Charcoal is obtained from a thermal decomposition of carbon-rich materials such as grasses, wood, and various agricultural and forestry residues [2]. This material first appeared in South America as charcoal used for agricultural practices by the inhabitants of the amazon incorporated large amounts of charcoal into the soil to improve the yields of their crops [3]. Charcoal is of interest to agricultural and environmental authorities not only because it permits recycling~~to recycle~~ waste containing carbon, but also because of ~~also for~~ its physico-bio-chemical properties which influence those of the soil to which they are applied [1]. Its advantages in agronomy have been described by [4]. For these authors, an increase in soil organic matter, a greater cation exchange capacity (CEC) and an increase in yields of up to 200% are achieved compared to soils without amendment. In addition, it influences soil water dynamics [1].

In dry environments such as the transitional tropical climate prevailing in northern Côte d'Ivoire, the amount of water in the top soil layer is often limited at the optimum time for sowing. As a result, unless sowing is delayed until the next rains, crop stands may become poorly established, resulting in low yields. However, delaying sowing beyond the optimal time can also lead to yield reductions [5]. Increasing seedling depths can improve crop establishment due to higher soil water content in the seed zone, leading to better germination and seedling emergence [6]. At the same time, deep sowing can have adverse effects on seedling emergence [7 ; 8] and subsequently on the grain yields of cultivars not adapted to these conditions [9 ; 10].

Faced with the rainfall recession, the soils present constraints linked to acidity and~~,~~ to a strong desaturation in exchangeable cations (Ca, Mg, K, Na). This results in a drastic reduction in their productivity [11]. To improve production, farmers tend to use chemical fertilizers. Despite their applications, agricultural production drops considerably after one cropping season due to the leaching of minerals [12]. Moreover, the expensive cost of chemical fertilizers does not lighten the task of farmers who are generally on low and uncertain incomes.

The present study aims at evaluating ~~lightening~~ the combined effects of charcoal amendment of sandy-loamy soils and seeding depth on the components of melon yield under dry tropical conditions in the Poro region, Côte d'Ivoire.

MATERIALS AND METHODS

Plant material

The CAPORAL variety of Melon (*Cucumis melo*) constituted the plant material of the study. It is a variety that~~which~~ has ~~a~~ good vegetative growth and fruits of ~~a~~ good taste, fragrant, of good conservation and adapted to transport. This variety has a minimum germination rate of 85% ~~minimum~~ with a ~~and a degree of~~ purity of 99% ~~minimum~~ and ~~with~~ an earliness of 85 days between direct sowing and the first harvest.

Presentation of the study area

This study was carried out on the site of the botanical garden of the University of Péléforo Gon Coulibaly, Korhogo. This city is located in northern Côte d'Ivoire 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 (Figure 1).

The climate of the Poro region is of a 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~~centred on the months of August-September which accumulate almost half of the annual average height of precipitation equal to about 1200 mm [13]. The average temperature ranges between 24° and 33° C. The hottest months with 36°C are February, March, and April, and the coolest months with 16°C are December and January ~~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~~ [14]. The soils observed have a predominantly sandy-loamy clay texture with low humic impregnation [15].

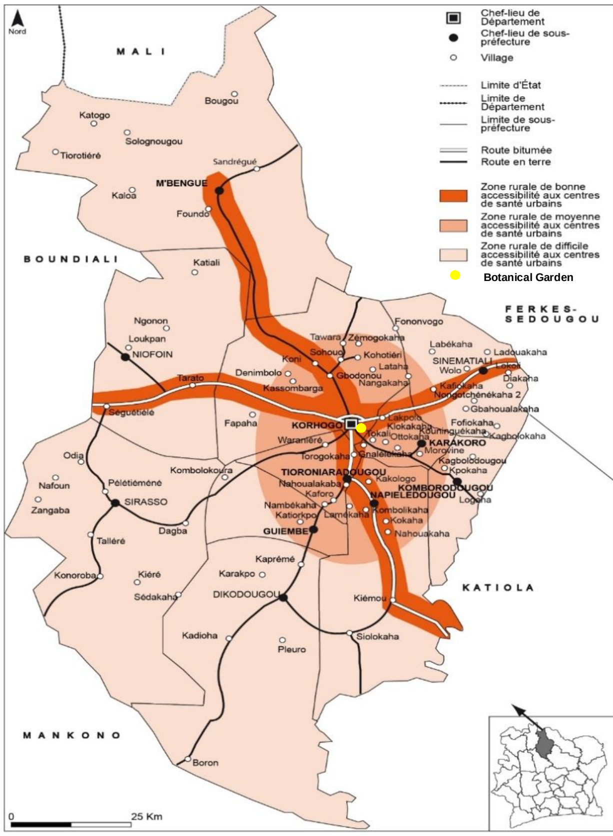

Figure 1 : Map of the Poro region

Experimenta plot preparations~~Experimental apparatus~~

The land was prepared in early September 2019 using a hoe. The experimental device was established on a rectangular plot 6.9 m wide and 10.5 m long, i.e., a total of 72.45 m^2 (Figure 2). The plot has been subdivided into three rows of 15.75 m^2 10.5 m long and 1.5 m wide. This configuration therefore consisted of a block of 15.75 m^2 with 3 repetitions. Each row was divided into 05 experimental units with a dimension of 1.5 m X~~×~~ 1.5 m or 2.25 m^2, each unit corresponding to an evaluated depth.

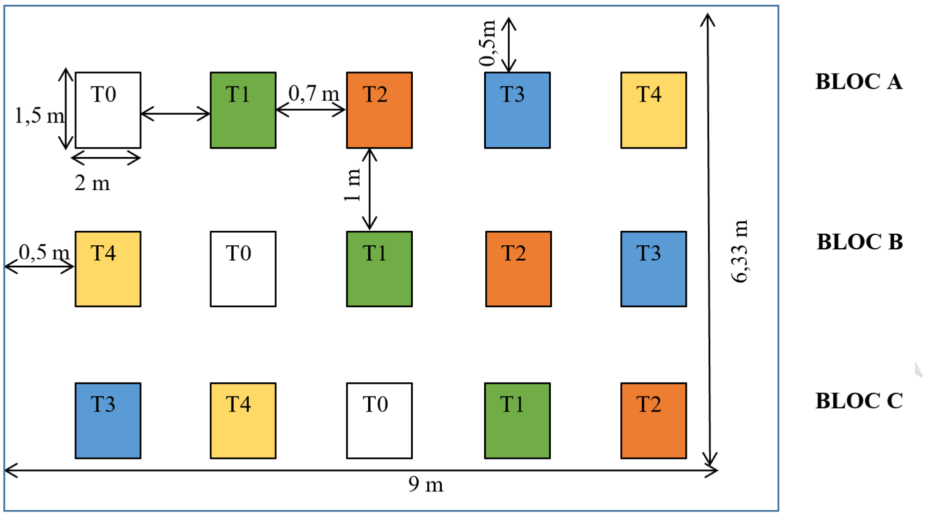

Figure 2 : Experimental apparatus

Sowing was carried out during early ~~at the beginning of~~ November, 2019. The method chosen was sowing in pockets. It consisted in making several holes with a dibber and 3 seeds were placed there at depths as follows:

T0 – sowing at ~~corresponds to the depth of~~ 0.5 cm depth on ~~the~~ control soil;

T1 **– sowing** ~~corresponds to a depth of~~at 0.5 cm depth on soil enriched with charcoal;

T2 – sowing ~~corresponds to a depth of~~at 3.0 cm depth on soil enriched with charcoal;

T3 – sowing ~~corresponds to a depth of~~at 7.0 cm depth on soil enriched with charcoal;

T4 - sowing at ~~corresponds to a depth of~~ 9.0 cm depth on soil enriched with charcoal.

Sowing was~~is~~ carried out at a spacing of 1.0 X 0.5 m ~~on the line X 1 m between the lines~~. Earlier, ~~W~~with the exception of the control plot (T0), 6.0 kg of charcoal was applied manually~~by hand~~ to each elementary plot and mixed into the top 10 cm of soil during land preparation in September, 2019.

Fifteen days after germination, thinning was carried out to maintain ~~reduce the number of~~ 1 plant per pocket. The weeds were pulled out manually to avoid possible competition with the crop~~cultivated plant~~. Regular watering was~~is~~ done from sowing until the end of the study~~culture~~ according to the need~~s of the culture~~. The daily water needs have been estimated at 5 to 6 mm to ensure the growth and development of the plants [16]. No insect, pest or disease infestations was~~were~~ observed.

Plant sampling and soil analysis

The germination rate, ~~number of germinated grains, the~~ the stem height~~length~~ ~~of the stems~~ from the first to the fourth topping and the length of the branches from the second to the fourth topping were measured using a measuring tape ~~measure~~. The plants were harvested in January 2020. ~~The harvested fruits by each plant~~and were counted and reported as fruit number per plant.

Soil samples were collected, before seeding and at the time of harvest, at 20 cm soil depth and soil physicochemical properties were analyzed in the soil laboratory of Institut National polytechnique Houphouët Boigny (INP-HB) in Yamoussoukro. A random samping

~~Soil samples were taken with a hand auger from the top twenty centimeters of soil on each plot. A first sample was taken before cultivation and a second was taken during 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 was followed. ~~These samples were then packaged in plastic bags and sent to the soil laboratory of Institut National polytechnique Houphouët Boigny (INP-HB) in Yamoussoukro, for physico-chemical analyses.~~ The results of soil analyzes were compared with threshold values, reference standards or results of previous work.

The granulometry in five fractions was carried out by the Robinson pipette method, according to the AFNOR NF X31-107 standardized method [17]. Soil texture classification was made following the USDA Texture Triangle [17]. 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. The cation exchange capacity was measured by the Metson method of the AFNOR NF X31-130 standard [18]. Element content of Ca^{2+}, Mg^{2+}, K^{+} and Na^{2+}, wereas determined by the fluoro-nitro-perchloric method. Total phosphorus and assimilable phosphorus were measured according to international standard NF ISO 11263 [17].

Statistical analysis

The data collected ~~was~~ were processed using two software. The EXCEL version 2013 spreadsheet was used to enter the data, to draw up the tables and graphs. The XLSTAT 2014 software made it possible to perform analyzes of variance (ANOVA) at the 5% probability threshold. Therefore, each time a variable is significant, the ANOVA is supplemented with a TURKEY test which makes it possible to classify the means.

RESULTS

Effect of charcoal on the physical and chemical characteristics of the soil.

The ~~particle size analysis~~ results of the soil~~s~~ particle size studied are presented in Table 1. The particle size test show~~s~~ed that the soils enriched with charcoal ~~presented~~ had a loamy texture with 7.5% clay, 41.28% sand and 49.88% silt while, ~~. The~~ the control soils ha~~ve~~d a sandy loam texture with 4.2% clay, 65.59% sand and 30% silt.

Table 1 : Results of soil particle size analysis studied

	GRANULOMETRY				
	Clay (%)	Fine silt (%)	Coarse silt (%)	Fine sand (%)	Coarse sand (%)
Charcoal Enriched Soil	7.5	22.08	27.8	29.56	11.72
Control soil	4.20	17.5	12.5	31.22	34.37
resume	0.4	0.2	0.5	0.0	0.7

The pH of the both control soil and ~~that of the soil treated with~~ charcoal treated soil did not show any significant difference. However, there was a numerical ~~is a slight~~ difference ~~between these values.~~ with ~~It is~~ 6.8 for the control soil and 7.2 for the treated soil. ~~treated with charcoal.~~ It, therefore, appears that these two types of soil have a relatively neutral pH, as the values are close to 7 (6.6 ‹ pH › 7.4). ~~The pH of soil enriched with charcoal is 6.8.~~

The contents of soil exchangeable bases were~~are~~ higher in the charcoal ~~plot~~ treated plots ~~with charcoal~~ compared to the control ~~soil~~ (Table 2). The addition of charcoal increased the rate of these bases except that of Na+ (0.2 cmol/kg). The content of exchangeable bases in the treated soil is of the order of 8.60 cmol/kg for (Ca^{2}+), 1.41 cmol/kg for (Mg^{2}+) and 0.56 cmol/kg for (K^{2}+) against 0.56 cmol/kg for (Ca^{2}+), 0.51 cmol/kg for (Mg^{2}+) and 0.16cmol/kg for (K+) on the control plot. As regards the cation exchange capacity (CEC), it wasis average in the order of 13.6 cmol/kg in the soil amended with charcoal and very low at 2 cmol/kg in the control soil.

Table 2 : Exchangeable cations and cation exchange capacity of the studied soils

	Absorbent complex (cmol.kg-1)				
	CEC	**Ca2+**	**Mg2+**	**K+**	**Na+**
Charcoal enriched soil	13.6	8.61	1.41	0.56	0.20
Control soil	2	0.56	0.51	0.06	0.16
resume	1.1	1.2	0.7	1.1	0.2

The analysis results showed a highlyvery significant difference in the assimilable phosphate content of the soil. It wasis good at 83 ppm for the charcoal-treated soil and 45 ppm for on the control soil.

The organic matter content in the control soil wasis very low but, it was and more or less high in the soil amended with charcoal. The addition of charcoal varied the organic matter content of the soil, which remained low, increasing going from 0.21% (on the control soil) to 1.34% (on the charcoal-treated soil).

The sodium content (Na+) was reduced from 0.2 to 0.16 on the treated soil. However, the charcoal improved the soil nitrogen rate to (0.13%) against 0.03% on the control soil (0.03%).

The results of the soil analysis revealed a highly significant difference (P=0.001) on the porosity of the soil. The porosity of the soil increased from 90.50% on the control soil to 30.40% on the charcoal amended soils.

The low available carbon level in the control and biochar-amended soils increased from 0.12% on the control to 0.78% after biocharcharcoal incubation.

The C/Nt ratio wasis low on both soils despite a significant difference (P=0.001). This ratio increased from 4 on the control soil to 6 after application of charcoalbiochar.

Effect of Ccharcoal and Ddepth on Germination Kinetics

The germination rate was significantly influenced by the contribution addition of charcoal (p = 0.002). It was is more important at the level of 75±8% for soils enriched with charcoal while it was only for an average of 75±8% against 58.6±3.2%) for on the control plot.

Figure 3 shows the evolution of the germination rate as a function of time for each seeding depth. ~~The germination curves have an evolution in three phases:~~

The germination started in 5th day in all the treatments and continued for next couple of days.

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~~The first phase, germination, marked by the appearance of the first leaves, lasts 4 to 5 days and corresponds to the emergence of the first seeds. The greatest number of germinated seeds for this period is obtained with the 0.5 (T1) inch depth (68%), followed by the 3 cm depth (50%) then the 7 cm depth (40%), of the control (34%) and finally the depths 9 cm (20%).~~

~~The second phase which lasts 2 – 3 days is accumulative. The 3 cm depth had the highest cumulative germination rate (87%), followed by the 0.5 cm depth (T1) with 77%, then the 7 cm depth (70%) and the 9 inch depth. (46%). The controls recorded the lowest germination rate with 40%.~~

~~The third phase corresponds to the end of germination with the maximum rates of germination~~. The highest germination rate is observed on 6th day ~~over the 6-day time interval for sowing carried out~~ at depths of 0.5 cm, 3 cm and 7 cm and ~~over 7 days for control plots and sowing carried out at 9 cm. depth.~~

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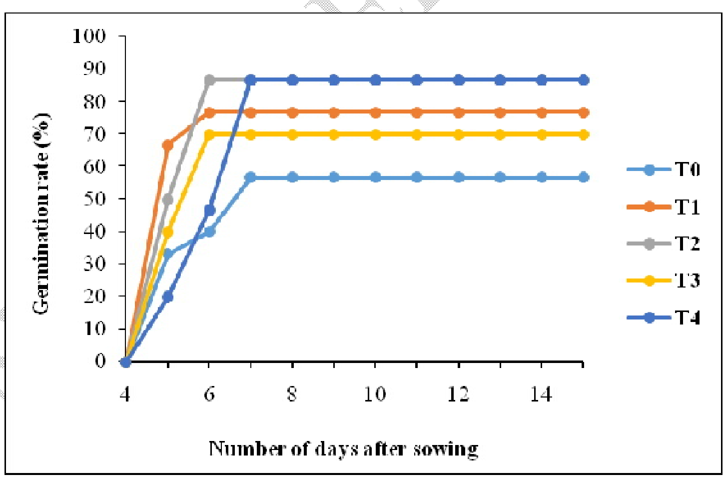

Figure 3 : Germination rate as a function of time

Effect of charcoal and seedling depth on seedling growth

Figure 4 indicates that the sowing depth had a significant effect (P<0.0001) on the heights of the plants at the first topping (~~, that is to say~~ 19 DAS) ~~days after sowing~~. At this date, the heights varied between 5.5cm and 7.5cm. The highest values ~~are~~ were recorded at depths of 0.5 cm for soils enriched with charcoal and control soils with plant heights ~~equal to~~of 7.5 cm. ower~~The low~~ values (5.8 cm, 5.5 cm and 5.7 cm) were observed on soils enriched with charcoal at depths of 3 cm, 7 cm and 9 cm respectively.

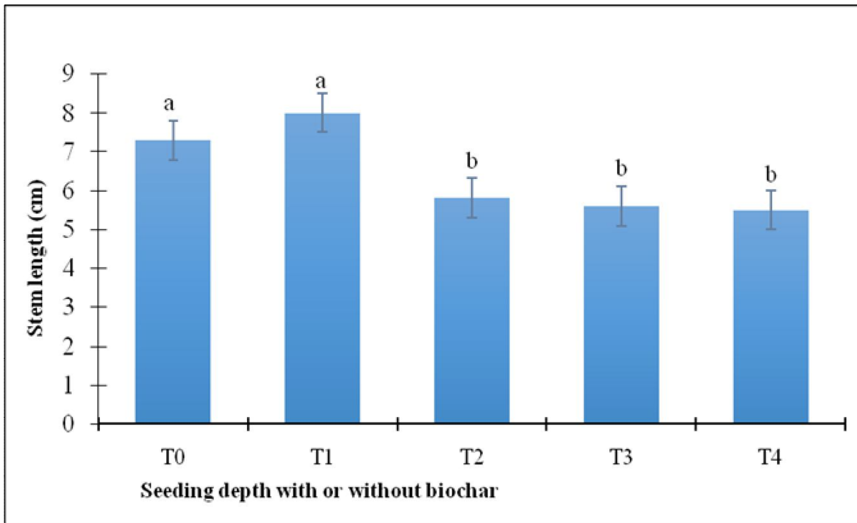

Figure 4: Height of plants at first topping

Significant differences (P = 0.004) were observed for stem lengths on the 34th day after sowing, before the second pruning. The height of the plants varies from 13 cm to 16.5 cm. The highest values were observed for plants of depths of 0.5 cm and 9 cm, with an average length of 16.5 cm, followed by plants of depths of 7 cm and 15 cm, and plants of depths of 3 cm (14 cm). The controls obtained the smallest lengths (13cm) ~~Significant differences (P = 0.004) were observed for stem lengths on the 34th day after sowing, before the second pruning. The height of the plants varies between 13 cm to 16.5 cm. The highest values were observed for plants of depths 0.5 cm and 9 cm with almost lengths of 16.5 cm, followed by plants of depths 7 cm 15 cm high and plants of depths 3 cm (14 cm). The controls obtained the smallest lengths (13cm)~~ (figure 5).

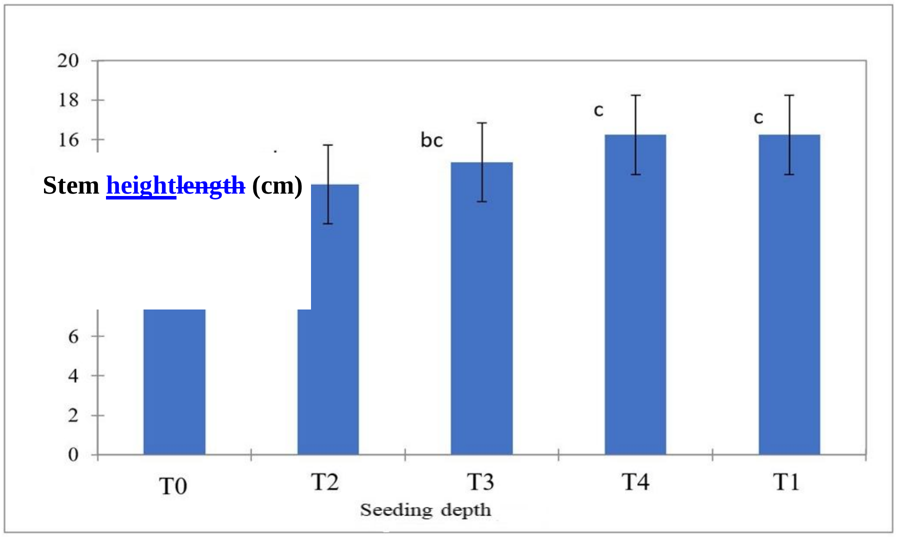

Figure 5 : Height of plants at second topping

The combined effect of the supply of charcoal and the seedling depth was particularly noticeable at the third and fourth pruning (figures 6 and 7). The analysis of variance showed significant differences for these two periods (P = 0.0001).

On the third topping (47th day after sowing), the stem heights ~~of the stems~~were ~~are~~ between 20 cm (T0) and 28 cm (T3 and T4). The sowing depths of 3 cm and 0.5 cm ~~which~~ obtained ~~respectively~~ the stem heights of lengths 25 cm and 24cm, respectively.

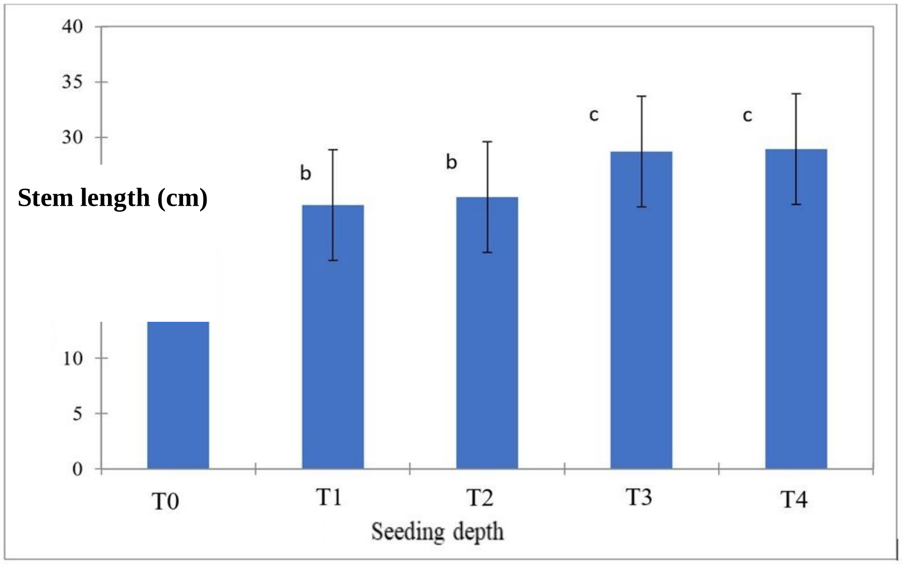

Figure 6: Height of plants at third topping

On the fourth topping, i.e. 61 DAS~~on the 61st day after sowing~~, the heights of the stems reached between 25 cm (T0) and 37.5 cm (T4). These results showed that the ~~lengths of the~~ stem heights ~~s~~ are greater on the plots treated with charcoal compared to the control~~s~~. The sowing depth of 7 cm made it possible to obtain 33.5 cm height while ~~and~~ the depths of 3 cm and 0.5 cm gave ~~plants of~~ only 29 and 28.5 cm tall plants, respectively. Control soils recorded ~~stems~~ 25 cm tall~~.~~ Stems.

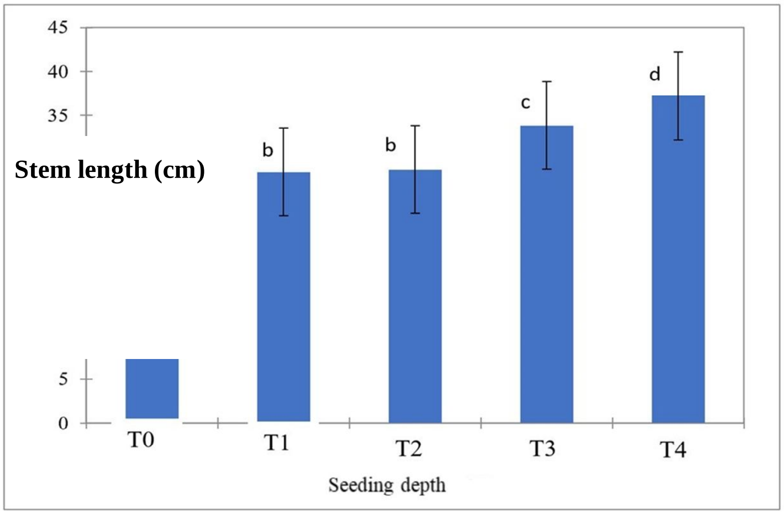

Figure 7: Height of plants at third topping

Effect of Charcoal and Seedling Depth on Yield

It appears from the analysis of variance that charcoal and seed~~l~~ling depth have a highly significant effect (p = 0.001) on melon yield.

The yield of the plots varied between 1 fruit/plant and 4 fruits/plant (figure 8). Thus, plots treated with ~~biochar~~ charcoal and sown at 9 cm deep were the best with 4 fruits/plants, followed by plots amended with ~~biochar~~charcoal and sown 3 cm deep. Finally, among the plots sown at 0.5 cm depth, the ~~biochar~~charcoal amendment made the difference allowing a yield of 2 fruits/plant against 1 fruit/plant.

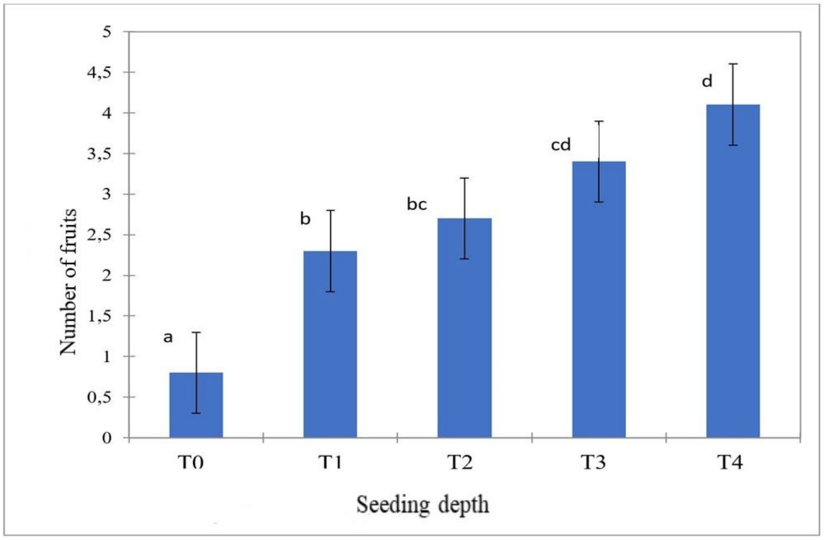

Figure 8: Average number of fruits borne by the plants according to the substrate and the depths of sowing

DISCUSSION

Effect of charcoal on the physico-chemical characteristics of the soil

The results of the granulometric study show that the contribution of charcoal modified the texture and the porosity of the soils treated. The contribution of charcoal made it possible to raise a little more the content of clay and silt in the treated soil. This increase in clay and silt was accompanied by a decrease in the sand content. In addition, the pH was slightly increased to be in the neutral to slightly basic soil class. These results are similar to those [19 ; 20] who consider that the particular physical properties of ~~biochar~~charcoal influence the texture, structure, porosity, pore size and distribution as well as the density of the soil in which it is incorporated. According to a study conducted on the effect of different rates of ~~biochar~~charcoal amendment (0%, 25%, 50%, 75% and 100% v/v) in sandy loam, the results showed an improvement in physical properties and soil hydraulics by adding ~~biochar~~charcoal [21]. Furthermore, [22-23] demonstrated that generally, the ~~biochar~~charcoal has a pH higher than neutrality, an excellent porosity as much at the level of the macropores as of the micropores and a low bulk density.

Effect of charcoal and seedling depth on melon germination

Adding charcoal to the soil increased the germination rate. Sowing at 3 cm recorded high germination rates of 87%. The results also showed that melon seeds germinate better in a medium enriched with charcoal in Korhogo. These results are in contradiction with the work of Rogovska et al., [24] who showed that the contribution of ~~biochar~~charcoal to the soil has no effect on the germination rate of maize seeds in Nevada in the USA. Soil moisture and temperature must have been different due to seeding depth on sandy loam. This effect could suggest that the ideal seeding depth in the presence of ~~biochar~~charcoal would be 3 cm to obtain good seedling emergence. Indeed, water and temperature are determining factors for the germination of seeds. Both factors can, separately or together, affect the germination percentage and germination rate [25]. Guibert and Le Pichon, [26] reported that the temperature range of 13°C to 20°C is favorable for germination and emergence. This temperature optimum was observed for English oak by Suska et al., [27].

Effect of charcoal and seedling depth on seedling growth

The results showed that the length of stems and branches was greater on the soils amended with charcoal compared to the control soil throughout this study. The increase in the size of the plants can be explained by the content of exchangeable bases raised at the level of the soils enriched with charcoal. Indeed, the study showed that the enrichment with charcoal made it possible to bring the contents of exchangeable bases closer to the intervals of the reference values for melon which are 10-20 $cmol.kg^{-1}$ for the CEC, 5-8$cmol.kg^{-1}$ for Ca^{2+}, 1.5-3.0 $cmol.kg^{-1}$ for Mg^{2+}, and 0.3-0.7 $cmol.kg^{-1}$ for Na^{2+}. In addition, the charcoal amendment resulted in an increase in K^{+}. This increase in cation concentrations favoured plant growth through better availability, as certain studies have shown [28-30]. Indeed, ~~biochar~~charcoal can have direct and indirect physical effects on plant growth by contributing to deeper root penetration and improved water and air availability in the root zone [31].

Concerning the effect of depth on the agronomic parameters, the results showed that on the 19th day, the sowing carried out at 0.5 cm obtained the longest plants. On the 47th and 61st day, the plants of the seedlings made at 7 cm and 9 cm had the longest stems. For the branches, the sowings carried out at 9 cm obtained the longest branches on the 47th day and on the 61st day. The beneficial effect of seeding depth on seedling growth can be attributed to good root development, as Duparque et al. [32] demonstrated. These authors believe that planting at a depth of 6 cm to 9 cm helps ensure adequate absorption, provides good moisture and good contact between roots and soil, promoting good growth. The weak growth of the plants observed at the level of the seedlings carried out between 0.5 cm and 3 cm could be due to a poverty of the soil in mineral elements linked to a low content of organic matter. This is in line with the work of Mandoli and Briggs [33] who showed that shallow sowing increased stress, which slowed root development, reduced stem diameter and length.

Effect of Charcoal and Seedling Depth on Yield

Fruit yields showed a significant difference between sowing depths on the one hand and an effect of ~~biochar~~charcoal on the other hand. Treatments that contain charcoal as a soil amendment gave the best yields. Charcoal-enriched soils were richer in P, K, Mg. The study showed that soils enriched with charcoal had a pH of 6.8. This value is included in the favourable pH zone for melon cultivation, varying between 6.5 and 7.5; acid soils below 5.6 should be avoided. This explains better plant growth on soils enriched with charcoal. Similar results have been obtained by several studies [34].

Conclusion

The use of charcoal in agriculture allows for better productivity and sustainability of production by improving the physico-chemical quality of the soil leading to the development of microbial flora and a reduction in the leaching of nutrients. The results under our experimental conditions show that the germination of seeds and the agronomic parameters of melon are influenced by the charcoal and the depth of sowing. The addition of charcoal to the soil in Korhogo promoted better mineral nutrition for the plants. The 3 cm seedling plants obtained a better germination rate. However, the plants of the 7 cm and 9 cm seedlings recorded the most important agronomic parameters.

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