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THE EFFECTS OF BIOCHAR ON THE GROWTH AND YIELD OF ZUCCHINI (*CUCURBITA PEPO* VAR. *GIRAUMONTIA* FILOV)

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Abstract

The aim of the study was to determine the influence of biochar, incorporated as a soil meliorant on the growth and yield of zucchini. The experiment was carried out in the experimental field on University of Forestry - Sofia (42° 7' N, 23° 43' E). The soil type on the experimental field is fluvisols. Six variants have been developed: 1) V1 - pure soil; 2) V2 - with manure (4 t/ha^{-1}); 3) V3 - with biochar (500 kg/ha^{-1}); 4) V4 - manure (4 t/ha^{-1}) + biochar (250 kg/ha^{-1}); 5) V5 - manure (4 t/ha^{-1}) + biochar (500 kg/ha^{-1}); 6) V6 - manure (4 t/ha^{-1}) + biochar (750 kg/ha^{-1}). Within the experiment, the average weight of one fruit, dry matter content, water content, was determined. The dynamics of yield between different harvests were monitored. Nine harvests were implemented, with the highest yield of all variants reported at the fourth harvest. The highest yield was reported for variant 6 - 3219 kg/ha^{-1}, followed by variant 2 - 3168 kg/ha^{-1}.

Key words:*:biochar, manure, yield, zucchini.*

INTRODUCTION

Biochar is rich in C product, which is produced by pyrolysis of various organic materials.

Depending on the type of material used and the conditions of pyrolysis, biochar shows various physical and chemical characteristics. This makes it suitable for various uses: for remediation of contaminated soils, for reducing greenhouse gas emissions, for controlling soil erosion, etc. (Ippolito et al., 2012; Oldfield et al., 2018; El-Naggar et al., 2019; Oni et al., 2019).

Biochar shows good results in improving soil properties and plant growth, alleviating stress from drought and salinity, interacting with heavy metals and organic pollutants, and more. (Nigussie et al., 2012; Kavitha et al., 2018; El-Naggar et al., 2019; Eissa, 2019; Guo et al., 2020).

As regards the physical properties of the soil, the application of biochar increases the stability of the soil aggregates and the water retention capacity, by improving the characteristics of the soil pores and water retention. (Kavitha et al., 2018).

There are a number of studies worldwide focused on the effect of biochar and its influence on the yields of different crops grown on different soil types, under different climatic conditions. (Zhang et al., 2010; Sovu et al., 2012).

Studies on the beneficial effects of biochar have been conducted with a number of vegetable crops (Blackwell et al., 2010; Zhang et al., 2011; Nigussie et al., 2012; Ty et al., 2013; William and Qureshi, 2015; Ni et al., 2017), arable crops (Kimetu et al., 2008; Husk and Major, 2011) and vineyards (Sovu et al., 2012).

Experimental application of biochar for crops of Cucurbitaceae family, in different soil types, in most cases shows an increase in yields.

In some studies, researchers have found that the application of biochar increases the yield of zucchini compared to the control variant (Van Zwieten et al., 2009).

Amin и Eissa (2017) find that application of biochar changes the pH of calcareous sandy soil from 7.9 to 6.65, increases soil organic matter and N utilization efficiency which increases the yield of zucchini (Yu et al., 2019).

Although the majority of experiments and analyzes show the positive aspects of the application of bio-carbon in agriculture, there are also data showing various problems and negative results in its application. (Kavitha et al., 2018; El-Naggar et al., 2019)

Such data were obtained in eksterimenst with zucchini. For example Gartler et al. (2013) have found that treatment with biochar (alone or in combination with biosolids) does not lead to significant changes in the biomass of a number of vegetable crops with an aboveground product, including and zucchini, while significantly affecting the root vegetables.

There are also data that report a decrease in zucchini yield compared to control variants in a one-year experiment (Gaskin G. et al., 2010).

Spokas et al. (2012) in their review they summarize that the increase in crop yields is reported mainly in degraded or weathered soils, while the negative or neutral effects of biochar on yields are in fertile soils. (El-Naggar et al, 2019).

To the similar conclusion are reached and Ippolito et al. (2012), pointing out that due to their low retention capacity for nutrients or water, it would be much more beneficial to use biochar in degraded and sandy soils than in high-yield soils.

Vista and Khadka (2017) found that biochar has a great effect on changes in soil properties such as: pH, organic carbon, phosphorus, but is highly effective at increasing the potassium content. However, it has been found that nitrogen content has been reduced to a great extent, and that an overdose of biochar is not beneficial for vegetable crops.

The aim of this study was to investigate the effect of incorporated low rates carbonized plant residues as ameliorant on the growth on fluvisols. In this context, the article presents data on the impact of biochar on phenological development and yield of zucchini.

MATERIALS AND METHODS

The experiment was conducted on the experimental field of the Faculty of Agronomy at the University of Forestry - Sofia (42° 7′ N, 23° 43′ E). The experiment is conducted on fluvisol, an area of 150 m^2.

For the purpose of the experiment, two ameliorants were used - biochar and manure. Six variants have been developed as follows:

1) control (C) - no ameliorants;
2) manure control (M) - 4 t/ha^{-1};
3) biochar control (BC) - 500 kg/ha^{-1};
4) combination with manure - 4 t/ha^{-1} and biochar - 250 kg/ha^{-1} ($M+BC_{250}$);
5) combination with manure - 4 t/ha^{-1} and biochar - 500 kg/ha^{-1} ($M+BC_{500}$);
6) combination with manure - 4 t/ha^{-1} and biochar - 750 kg/ha^{-1} ($M+BC_{750}$).

The experiment was carried out by randomized complete block design with four replications and protection zones.

In combination variants the manure is as a basic background - with the same optimum amount and biochar with reduced, optimal and increased rate. The ameliorants were incurporated one month before the sowing of the zucchini (at the end of March), by spreading them over the surface, followed by rotary cultivation to a depth of 15-20 cm.

For the field experiment was carry out the zucchini variety Izobilna, which is the standard variety in the country. Three beds are formed and the sowing of zucchini was by a standard two-row cultivation scheme (100 cm+60 cm x 50 cm).

The following phenological phases from the development of the zucchini were monitored: - beginning of germination; - beginning of formation of the first leaf; - the beginning of flowering of female flowers; - the first harvest.

The total yield was calculated in kilograms per $hectare^{-1}$, by variants, and for each variant the dynamics of harvests was monitored. Data were analyzed statistically by Anova.

RESULTS AND DISCUSSIONS

Meteorological conditions

During the experimental period (from the last ten days of April to the first ten days of July), the meteorological conditions were favourable for the growth and development of the zucchini. Only on the day of sowing, the average daily temperature was below 10°C (7.4°C) and till the end of April, on average for the period, daytime temperature was around 15°C (Figure 1).

The first ten days of May are relatively cool - with an average temperature of 14°C. In the following period, the temperature rises, with several cooler days again combined with rainfall at the end of May. Average daily temperatures in June range from 17°C to 24.4°C, with a rise in average daily temperatures above 25-27.1°C and 26.5°C at the end of the month. There is a uniform distribution of rainfall during the zucchini vegetation, ranging from 0.2 mm to 21.9 mm.

The total rainfall is 63.1, with more than two-thirds falling in the first half of the month (Figure 1).

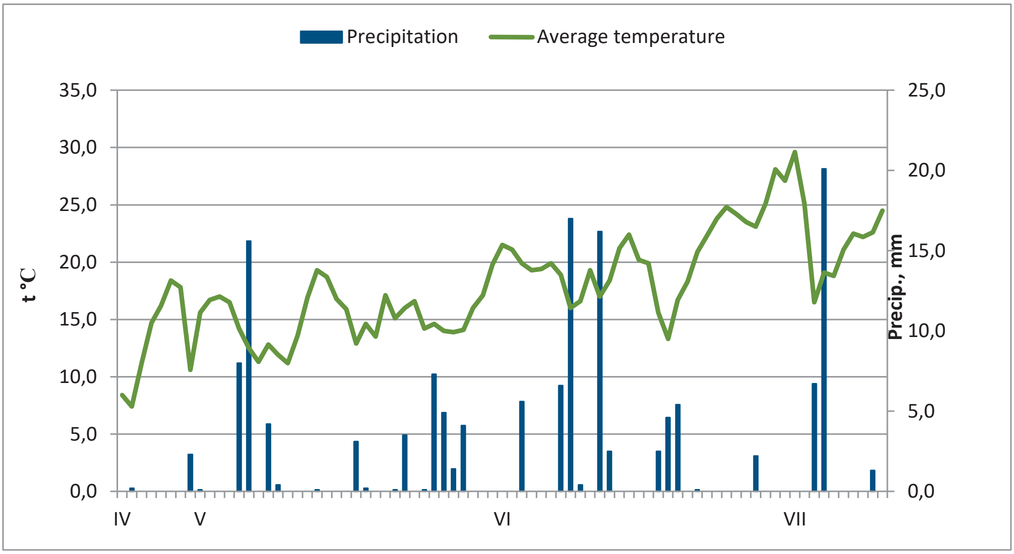

Figure 1. Average daily temperature and precipitation during the experimental period of the zucchini

Phenological monitoring

The sowing was carried out on 24 of April, with the average daily temperatures below 15°C for the first three days.

This affected the germination of plants and up to 5-day such was not registered.

On day 9, the beginning of the germination was reported in all six variants (Figure 2).

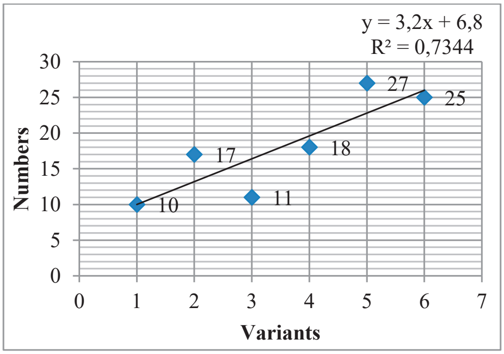

Figure 2. Number of plants in the cotyledon phase by variants (beginning of germination)

In two of the variants - control (1) and treatment only with biochar (3) the germination is less. In all variants with included manure, the number of germination plants was higher as compared with these two variants. After another 9 days (on the 18th day) the next phase was reported - the first leaf (Figure 3).

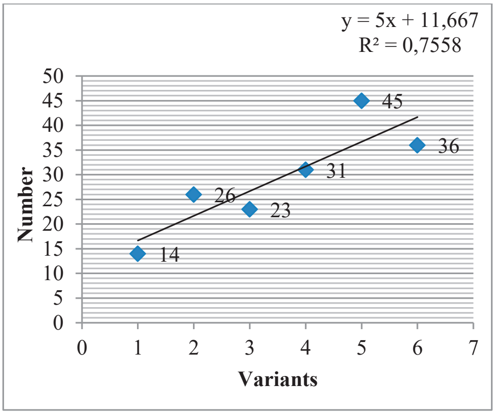

Figure 3. Number of plants in the formation phase of the first true leaf of variants

The trend persists - again the combined variants are with more plants with the first formed leaf. In the biochar-only variant (3), the number of plants in this phase exceeds that of the manure-only variant (2).

The beginning of flowering of female flowers in the individual variants, was reported between the 46th and the 48th day after sowing, with minor differences between different variants (Figure 4).

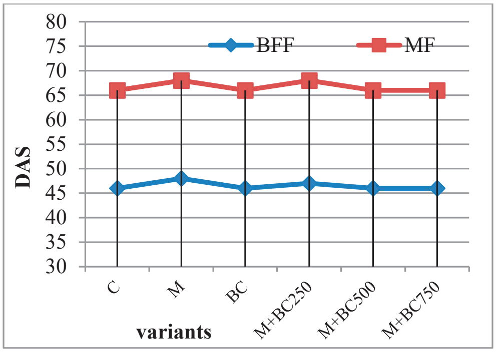

Figure 4. Number of days after sowing (DAS) to the beginning of flowering and mass flowering of female flowers in variants

No effect of the application of ameliorants (alone or in combination) was observed on the beginning of flowering of the female zucchini flowers.

This means that by this stage of development, the plants of the control variant have reached the rate of development of the plants of the other variants.

Nine harvests were carried out, according to variants and replications, which form the total yield (Figure 5).

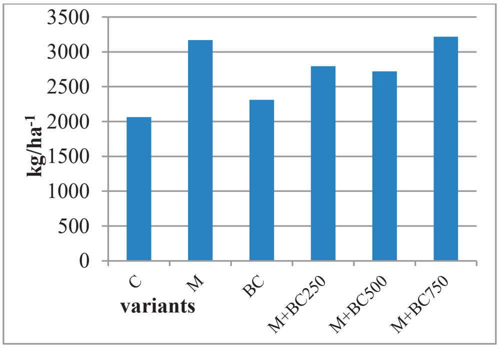

Figure 5. Average zucchini yield obtained by variants

There remains a tendency that the variants involving manure (M, M+BC$_{250}$, M+BC$_{500}$, M+BC$_{750}$) to be better than those without manure (C and BC).

It was found that the variant with individual use of biochar (BC), also has a higher yield than the control variant (C). This result shows that adding only biochar to the soil as a soil ameliorant (although it does not contain nutrients) leads to an increase in yield compared to the control, which confirms the conclusions of Zwieten et al. (2009).

The highest yield was obtained at two variants – M+BC$_{750}$ and M (Figure 5).

The second soil ameliorant - manure, incorporated on its own, leaded to higher yields. Compared to the control (no ameliorants and no fertilizers) and compared to incorporated biochar alone, the total yield of this variant (among the tree control variants) was highest, because the manure contains nutrients and can be used both as a soil improver and as a fertilizer (Figure 5).

For the other three variants (with combined incorporation of the two ameliorants), the obtained yields were also higher than the two controls (without ameliorants - C and with the incorporation of biochar - BC), which is in agreement with the findings of other researchers (Spokas et al., 2012; Ippolito et al., 2012; El-Naggar et al., 2019) that the use of biochar in light and sandy soils leads to improved yields.

Among the three combined variants (M+BC$_{250}$, M+BC$_{500}$ and M+BC$_{750}$) with the highest obtained yield was the variant with highest applied rate of biochar (M+BC$_{750}$).

Nine harvests during which realized yields of zucchini were grouped into three harvesting periods (Figure 6).

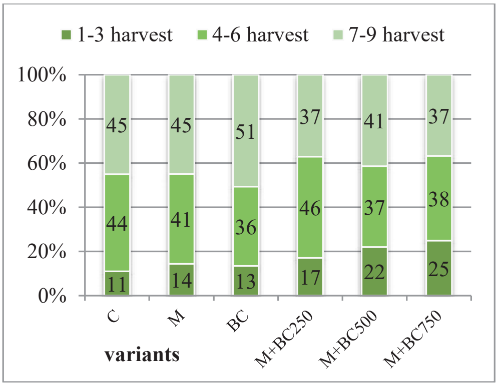

Figure 6. Percentage distribution of the yield obtained in the three harvesting period for each variant

The first of these included the beginning of the harvest (on the 59th day after sowing), as harvests were obtained only from variants with a combination of ameliorants.

This is clearly seen in the percentage of the first harvest of the individual variants, with the other harvests (Figure 6).

In the three combined variants, the yield of the first three harvests was higher due to an earlier first harvest.

In the biocarbon-only variants (BC), yield from different harvests groups increased gradually and was highest during the last harvesting period, covering the 7-9th harvest, which was in early July.

Probably the impact of biochar was initially to retain nutrients and then to gradually mineralize and release the plants in the later stages of their development. This effect is not noticeable in the other three combined variants because manure is also fertilizer and feeds the plants throughout all stages of their development.

In variant M+BC_{750}, the final yield is distributed almost evenly between the three harvest periods and is the highest yield achieved.

CONCLUSIONS

Of the two ameliorants, with a more pronounced influence on the growth, development and yields of zucchini was manure, regardless of the way of its application - alone or in combination with biochar.

Self-applied biochar has no effect on growth and yield of zucchini.

The combination of biochar (750 kg/ha^{-1}) with manure, applied to light soils, resulted in the highest yield obtained from zucchini.

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