Scientific Papers. Series A. Agronomy, Vol. LXIII, No. 1, 2020
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

THE INFLUENCE OF BIOCARBON ON THE AVAILABILITY OF SOIL NUTRIENTS DURING ZUCCHINI CULTIVATION

Vera PETROVA, Milena YORDANOVA

University of Forestry, Faculty of Agronomy, 10 Kliment Ohridski Blvd, Sofia, Bulgaria

Corresponding author email: vera_zamfirova@abv.bg

Abstract

The purpose of the experiment is to study the influence of incorporated carbonised plant residues on the nutrient storage in soil during the zucchini vegetation. The experiment was carried out in the experimental field on University of Forestry - Sofia (42° 7′ N, 23° 43′ E), on fluvisols. Six variants have been developed: 1) V1- pure soil; 2) V2 - with manure (4 t/da); 3) V3 - with biochar (500 kg/da); 4) V4 - manure (4 t/da) + biochar (250 kg/da); 5) V5 - manure (4 t/da) + biochar (500 kg/da); 6) V6 - manure (4 t/da) + biochar (750 kg/da). The highest N content in the experimental variants was reported in V6 - (manure 4t/da + BCh 750 kg/da), which was found to be optimal for the development of zucchini. The lowest NPK values were reported in V1 and V3. Positive effects on soil nutrients, organic matter and zucchini yield indicates that biochar could partly replace chemical fertilizers.

Key words*: biochar, manure, N, soil nutrients.*

INTRODUCTION

Maintaining soil productivity and improving soil quality are one of the key elements for sustainable agriculture. In recent years, in the context of climate change, there is a great interest in studying biochar (BC) use in agriculture (Lehmann, 2007). Several studies have reported that biochar can adsorb nitrogen (as NH_4^+-N, NO_3-N, and Urea), phosphorus (as orthophosphate), potassium, and organic matter (Kasozi et al, 2010; Takaya, 2016; Kizito et al., 2019). As a soil amendment, biochar has been reported to offer several benefits, which include increased soil texture, soil carbon, nutrient retention, and cation exchange capacity, beside support to microbial diversity that increases mineralization and availability of nutrients in amended soils (Kizito et al., 2019). The incorporation of carbonized plant residues into the soil increases the efficiency of nitrogen uptake from plants grown on sandy soil (Zwieten et al., 2010). Thereby, seed germination, growth, development and yield of some plants are significantly increased by the application of biochar (Glaser et al., 2002).

The increasing interest in recent years on the fresh zucchini taste has leads to necessitated of study its growth and development.

Zucchini is an annual herbaceous plant of the family *Cucurbitaceae*, of the genus *Cucurbita*, to which the zucchini (*Cucurbita pepo* var. *Giromontia Dutch*) belongs.

A number of researches have considered the zucchini yield obtained on different soil types after biochar application. According to some authors, application of biochar increases the yield of zucchini over the control variant by 2.2 t/ha (Zwieten et al., 2009). Other authors report a *Cucurbita pepo* crop increase ranging from 20% to 140% over control variants. There are also data that do not show a significant difference in zucchini yield (Joseph SD. et al., 2008), and those that report a decline in yield compared to control variants in a one-year experiment (Gaskin et al., 2010).

A very few studies about BC application and its effect on soil properties and nutrition uptake have been conducted in Bulgaria.

The aim of the experiment is to study the influence of incorporated carbonised plant residues on the nutrient storage in soil during the zucchini vegetation.

MATERIALS AND METHODS

The experiment was carried out on the experimental field of the University of Forestry - Sofia *(42° 7′ N, 23° 43′ E)*. The soil is fluvisol, slightly stony, slightly acidic. This area came under a continental climatic sub region, in a mountain climatic region.

The experiment was set with two ameliorants - biochar and manure (used as a background). During the spring cultivation, the two ameliorants were incorporated into the soil at 15 cm depth. Six variants were developed: 1) V1- pure soil; 2) V2 - with manure (4 t/da); 3) V3 - with biochar (500 kg/da); 4) V4 - manure (4 t/da) + biochar (250 kg/da); 5) V5 - manure (4 t/da) + biochar (500 kg/da); 6) V6 - manure (4 t/da) + biochar (750 kg/da). The experiment was carried out by randomized complete block design with four replications and protection zones.

To test the impact of BC, a field experiment with the zucchini variety Izobilna was carry out, this variety was chosen as the standard variety in the country. The sowing was done at the end of April. Three beds were formed on which the sowing of zucchini was carried out according to the standard scheme for growing two-row tape. The sowing is in nests, with a row spacing of 60 cm and 50 cm inside the row (two row row diagram: 100 + 60/50).

Plants are irrigated by a drip irrigation system; the tape drip hose used has the following characteristics: I-Tape 8 mil/distance between drippers 20 cm/5.3 lh. The irrigation rate is 40 mm.

Samples of used ameliorants (biochar and well-decomposed manure) were taken before conducting the experiment. Laboratory analyzes in beginning and in the end of the experiment was carried out. The content of basic nutrients, heavy metals and pH was obtained from soil and plants.

RESULTS AND DISCUSSIONS

Samples of used ameliorants were taken prior to the laying of the field experiment.

In the experiment well decomposed cow manure was used.

The pH reaction is slightly alkaline. The manure contains a high amount of organic

carbon, well stored with total N and medium stored with P and K, the values of the mobile forms being approximately equal to the reported total amounts of P-0.89 and K-1.31. The ratio of ammonium to nitrate forms indicates that the mineralization process is not fully complete (NH_4 - 79.9 and NO_3 - 0.9).

Table 1. Nutrient content of manure

Indicator	Unit	Method	Value
pH		BS EN 15933	7.51
Organic C	%	BS EN 13137	16.92
N Kjeldahle	%	BS EN 13342	2.06
K	%	BS EN 16170	1.40
P	%	BS EN 16170	1.39
K mobile	%	BS EN 16170	1.31
P mobile	%	BS EN 16170	0.89
NH_3	%	BS EN 16177	0.90
NH_4	mg/kg	BS EN 16177	79.9

The biochar used to conduct the experiment was made from wood chips. Table 2 presents the chemical analysis of used BC.

Table 2. Chemical characteristics of BC obtained from wood chips

pH	ELCD mS/m	C%	N%	P%	K%	Ca%	Mg%	$CaCo_3$
10.8	45	61.8	0.39	0.22	0.85	2.18	0.23	5.4

The pH reaction in the analysed sample from BC is highly alkaline. It contains a large amount of carbon, which confirms the ability of BC to deposit carbon into the soil, reducing its release into the atmosphere. The mineral content of NPK is minimal. The presence of $CaCo_3$ is one of the causes of the highly alkaline reaction of the substrate.

Agrometeorological and phenological observations are a valuable source of information on the relationship between climate and plant development during the growing season.

During the experimental period (April-July), the weather conditions are favourable for the growth and development of zucchini (Figure 1). With average seasonal temperatures close to normal, no temperature anomalies are observed.

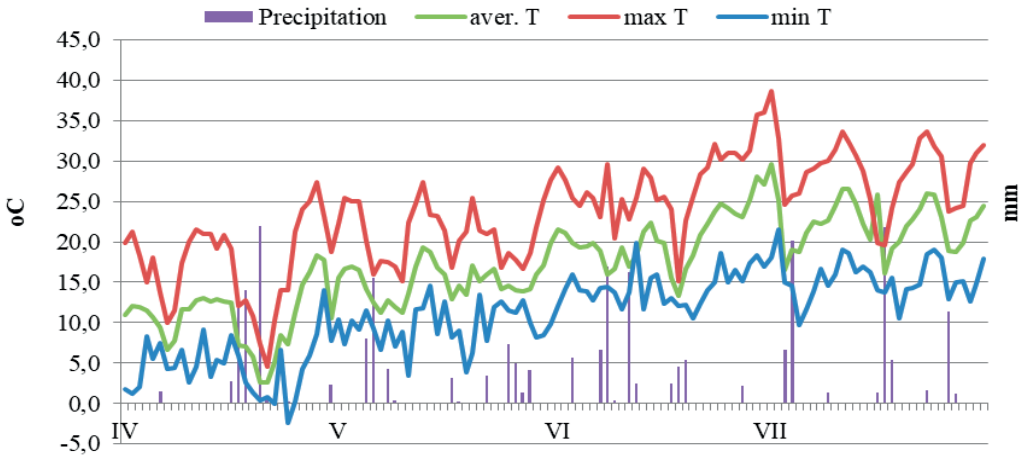

Figure 1. Temperatures and precipitation during the growing season of the zucchini

Only at the beginning and at the end of the second week of May lower positive temperatures (3.5°C and 3.8°C) were recorded, but average daily temperatures during this period did not fall below 12°C, which did not lead to a negative effect on the vegetative plant growth.

There is an even 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.

The agrochemical characteristics of the Fluvisols from experimental field (Vrajdna) are presented in Table 3. The sampling depth is consistent with the main root zone of the zucchini.

Table 3. Agrochemical characteristics of the soil before conducting the experience with zucchini

Depth cm	Humus %	pH H_2O	N, %	P_2O_5 mg/100 g	K_2O mg/100 g
0-20	1.73	7.3	0.160	79.2	18.1
20-40	1.64	7.2	0.154	94.81	19.9

Soil data obtained before ameliorants incorporation, show a good degree of storage of K_2O, a very high content of P_2O_5, which increases in depth. The soil reaction is slightly alkaline, approaching a depth-neutral layer.

The soil is poorly humus with humus content varying between 1.73% for the arable horizon and 1.64% for the sub arable horizon. The obtained data are common for this kind of soil type.

After the end of zucchini vegetation, soil samples were taken again and give for agrochemical analysis. The obtained data are presented in Table 4.

Table 4. Soil analysis after zucchini vegetation

Variants	Humus (%) BBM	pH (H_2O) ISO 10390	N (%) Keldal	P_2O_5 (mg/100g) BBM	K_2O (mg/100g) BBM
Var.1	1.36	7.2	0.165	53.60	10.0
Var.2	1.33	7.3	0.173	68.45	10.8
Var.3	1.30	7.3	0.143	51.05	11.0
Var.4	1.82	7.1	0.189	81.60	14.1
Var.5	1.91	7.3	0.194	84.32	17.8
Var.6	1.90	7.3	0.203	81.84	19.3

The soil samples were taken from a depth of 0-30 cm. It is obvious that the humus content increases in variants with higher BC content in combination with manure. The reduced content of total N in Var. 3 with biochar probably is due to the adsorption of NH_3 or organic N onto its surface by cations or anion exchange reactions and the increased immobilization of N, as a consequence of the additional C incorporate in soil with BC.

A decrease in P_2O_5 content in variant 3 is observed with BC alone, this is most likely due to the ability of BC to absorb phosphorus and nitrogen anions on its surface. The combined introduction of BC and manure has a positive effect on the potassium content of the soil as the soil storage of K increases from medium to very good. This is due to the ability of BC to increase

cation exchange capacity. Many authors report for increasing levels of K in soil after BC application (Cheng et al., 2008; Lentz and Ippolito, 2012). It is considered that available K in the BC composition can be rapidly absorbed by plants (Karer et al., 2013). However, some researchers have suggested that the high availability of K for plants may not continue beyond the year of application (Steiner et al. 2007).

It is noteworthy that despite the highly alkaline reaction of BC (pH = 10.8), when is combined with manure, it has no effect on soil acidity.

Mineral plant nutrition, along with photosynthesis, is a piece of plant-specific autotrophy. Mineral nutrition is closely related to soil fertility. Regulation of mineral nutrition is one of the most powerful factors for managing the physiological processes and productivity of agricultural plants.

The nutrient content of zucchini fruits is shown in Figure 2.

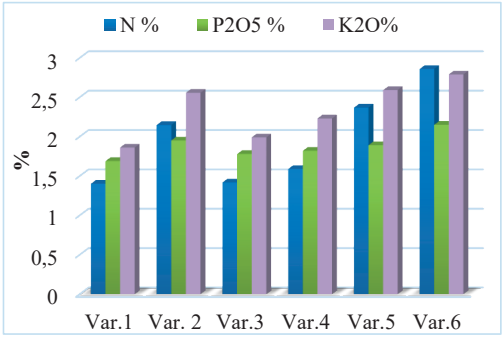

Figure 2. Percentage of nutrients in zucchini fruits

The lowest NPK values were again reported in Var. 1 clean soil and Var. 3 only with added BC. For BC variants, the N and K content increases with the increase the rate of imported carbonated plant residues. The highest nitrogen content in the experimental variants was reported in variant 6 - (manure 4 t/da + BC 750 kg/da), which is found to be optimal for the development of zucchini.

Nitrogen substances are found in the form of proteins, amino acids, amides, ammonia compounds and more. Their quantity in fruits is low and ranges from 1.41% to 2.86%.

The increase in nitrogen content in the variants with imported BC can be explained by biological nitrogen fixation due to the favourable development of microorganisms in the soil.

According to (Xu et al., 2014), the use of biochar for fertilization increases plant growth, soil pH, total carbon and nitrogen forms, C/N ratio and cation exchange capacity. Their results show that the application of biochar significantly increases the diversity and alters the relative abundance of some microbes that are associated with the carbon and nitrogen cycle. Overall nitrification and denitrification processes are stimulated while reducing N_2O emissions.

Despite the high values of P_2O_5 in soil samples, the content in zucchini fruits range between 1.69 to 2.15%. This is probably due to the fact that the majority of phosphorus compounds are poorly soluble in soil solution, which is one of the major difficulties in supplying plants with phosphorus. Highest values were reported for variant 2 (manure only) and variant 6, no significant difference was observed between the other variants.

Phosphorus, like nitrogen, is easily redistributed between the organs of the plant, moving from the old leaves to other parts of the plant (Kimenov, 1994). Phosphorus uptake by plants occurs mainly in two periods when the seeds germinate and when the fruit ripens, when a large number of organophosphorus compounds are formed, therefore the content of P_2O_5 in the fruits is higher than that of N.

Of all nutrient content in plants, potassium generally reaches the highest content. A large amount of potassium is associated with carbohydrate metabolism and plants water regime. The highest percentage of potassium was again reported in variant 6 - 2.79%, followed by variant 2 by 2.55%. It is noteworthy that as the rate of imported BC increases, the content of K_2O increases as well, due to the ability of the BC to capture positively charged cations through its negative charge, which develops on its surfaces, and this negative charge can buffer acidity in soil, as well as organic matter in general fertility. The low content in variant 3, which is almost equal to that in the control variant can be explained by the fact mentioned above, as well as by the minimum nutrients contained in biochar.

Nine harvests were made from the zucchini. They were obtained by variants and replicates. Data are averaged and equated to kilograms per decare at a planting density of 2,500 plants per hectare. The results obtained are shown in Figure 3.

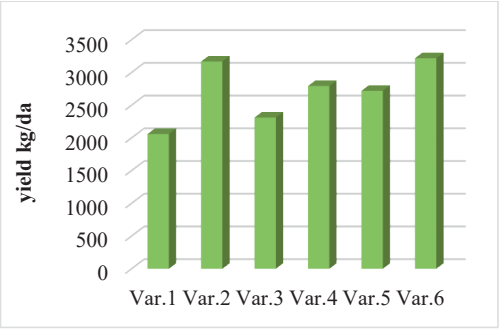

Figure 3. Average zucchini yield obtained by variants

The highest yield was reported in variant 6 - 3219 kg/da, followed by that in variant 2 with manure-3168 kg/da. The yield of zucchini fruits improves with the addition of BC, increasing with increasing of bio carbon application level. The increase in yield is probably due to the accumulation of nutrients and the improved microbiological activity of the soil that is associated with nitrogen fixation.

CONCLUSIONS

Based on the experiment the results demonstrate the positive effect of BC on soil organic matter content, water-physical properties and zucchini yield.

The soil and climatic conditions of the experimental year are favorable for the cultivation of zucchini. Uniform rainfall combined with a moderate irrigation rate is an indicator of optimum moisture content for their development.

For variants with higher BC content in combination with manure, humus content increases. The reduced content of total N in variant 3 probably is due to the adsorption of NH_3 or organic-N onto its surface by cationic or anion exchange.

The lowest NPK values were reported in variant 1 clear soil and variant 3 with only BC added. In the variants of BC, as the rate of imported carbonated plant residues increases, the NPK content also increases. The highest N content in the experimental variants is reported in variant 6 (manure 4 t/da + BV 750 kg/da), which is found to be optimal for the development of zucchini.

The obtained yield in the experiment exceeds the national average values, with the reported yield even in the control variant 1- 2031. 45 kg/da within the maximum yields reported worldwide. The highest yield was reported for variant 6- 3219 kg/da, followed by variant 2 - 3168 kg/da.

ACKNOWLEDGEMENTS

This research work was carried out with the support of: Project №158 / 2017 Investigation of the influence of biochar on soil fertility and agricultural crop development.

REFERENCES

Cheng, C.H., Lehmann, J., & Engelhard, M.H. (2008). Natural oxidation of black carbon in soils: Changes in molecular form and surface charge along a climosequence. *Geochimica et Cosmochimica Acta, 72*. 1598–1610.

Gaskin G., Julia W., R.A. Speir, K. Harris, K.C. Das, R. D. Lee, A. Lawrence, S. Dwight, D. Fisher (2010). "Effect of Peanut Hull and Pine Chip Biochar on Soil Nutrients, Corn Nutrient Status, and Yield. *Agronomy Journal, 102*(2), 623–633.

Glaser, B., J. Lehmann, W. Zech, (2002). Ameliorating physical andchemical properties of highly weathered soils in the tropics withcharcoalVA review. Biol. Fertil. Soils 35:219Y230.

Joseph, M., Lehmann, J., Solomon, O., Ngoze, D., Mugendi, N., James, M., Kinyangi, M., Riha, S., Verchot, L. John, W. (2008). Recha, and Alice N. Pell. "Reversibility of Soil Productivity Decline with Organic Matter of Differing Quality Along a Degradation Gradient. Ecosystems, 11.5, 726–39.

Kasozi, G.N., Zimmerman, A.R., Nkedi-Kizza, P., Gao, M.B. (2010). Catechol and humic acid sorption onto a range of laboratory-produced black carbons (biochars). *Environ. Sci. Technol*., *44.* 6189–6195.

Kimenov G., (1994). Plant Physiology. Univ. St. Cl. Ohridski, Sofia, 567 p.

Kizito, S.; Luo, H.; Lu, J.; Bah, H.; Dong, R.; Wu, S. (2019). Role of Nutrient-Enriched Biochar as a Soil Amendment during Maize Growth: Exploring Practical Alternatives to Recycle Agricultural Residuals and to Reduce Chemical Fertilizer Demand. *Sustainability*, *11*, 3211.

Lehmann, J. (2007) Bio-energy in the black. *Frontiers in Ecology and the Environment*, *5*, 381–387.

Lentz, R., & Ippolito, J. (2012). Biochar and manure affect calcareous soil and corn silage nutrient concentrations and uptake. *Journal of Environmental Quality*, *41*(4), 1033–1043.

Steiner, C., et al. (2007). Long term effects of manure, charcoal and mineral fertilization on crop production and fertility on a highly weathered Central Amazonian upland soil. *Plant and Soil*, *291*(1-2), 275–290.

Takaya, C.A., Fletcher, L.A., Singh, S., Anyikude, K.U., Ross, A.B. (2016) Phosphate and ammonium sorption capacity of biochar and hydrochar from different wastes. *Chemosphere*, *145*, 518–527.

Xu Hui J., X. Wang, H. Yao, J. Su, Y. Zhu, (2014). Biochar Impacts Soil Microbial Community Composition and Nitrogen Cycling in an Acidic Soil Planted with Rape. *Environ. Sci. Technol*., *48*(16), 9391–9399.

Zwieten L., S. KimberS, A. Downie, S. Morris, S. Petty, J. Rust, K. Y. Chan, (2010). A glasshouse study on the interaction of low mineral ash biochar with nitrogen in a sandy soil. *Australian Journal of Soil Research*, *48*, 569–576.

Zwieten L., S. KimberS, A. Downie, S. Morris, S. Petty, J. Rust, K. Y. Chan, (2010). A glasshouse study on the interaction of low mineral ash biochar with nitrogen in a sandy soil. *Australian Journal of Soil Research*, *48*, *569–576.*