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EVALUATION THE SWISS CHARD RESPONSE TO BIOCHAR APPLICATION

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Abstract

A study was made to determine the influence of incorporate carbonized plant residues, as a soil improver, on the growth and development of Swiss chard (Beta vulgaris subsp. vulgaris). A pot experiment was conduct on two soil types: Vertisols and Luvisol soils. Five variants were develop in three replicates, as follow: 1. Control – pure soil without fertilization; 2. Soil + biochar (BC); 3. BC+$N_{200}P_{200}K_{250}$; 4. BC+$N_{400}P_{200}K_{250}$; 5. BC+$N_{600}P_{200}K_{250}$ and the same variants (6, 7, 8, 9, 10) on Luvisol. Irrespective of the different starting supply of nutrients in two soil types, the highest yield of plant mass was recorded in the variant with BC+$N_{200}P_{200}K_{250}$, followed by the variant with BC+$N_{400}P_{200}K_{250}$. The fresh mass recorded on Vertisol significantly exceeds that on Luvisol.

Key words: *Swiss chard, fertilizer, biochar, pot experiment.*

INTRODUCTION

Applying organic residues to the soil is one of the main ways to improve soil fertility. It is also one of the strategies for soil management and part of the "circular economy". In this regard, in recent years there has been a growing interest in the use of safe products obtained through organic waste recycling technologies, such as biochar.

Biochar is a porous, carbon rich material produced by heating organic matter to temperatures between 300°C and 1000°C in an environment with limited or no oxygen (Verheijen et al., 2010).

These organic amendments are reported to mitigate climate change by atmospheric CO_2 sequestration, to improve soil physical (aggregation, density, root penetration) and chemical (pH and CEC) properties, water-holding capacity and nutrient retention, organic matter and nutrient cycling, to stimulate soil microbial, microfauna, and mesofauna communities, to reduce nutrient leaching, and to increase heavy-metal sequestration (Libutti et al., 2021).

Application of BC can positively affect plant nutrient uptake and facilitate the efficient use of fertilizers by keeping them on its surface and preventing their leaching from the soil (Gunarathne et al., 2017).

Leafy vegetables that require minimal processing are of great interest to consumers due to their ease of use. To increase the yield and quality of leafy crops, farmers often apply large amounts of nitrogen fertilizer.

Swiss chard is one of the leafy vegetables suitable for cultivation, through organic fertilization, and it is widely spread in the countries of Central and Western Europe. Swiss chard plants have been used for many years in traditional medicine to treat various diseases and conditions. Many of these medicinal plants are also excellent sources of phytochemicals, many of which contain powerful antioxidants. Nitrogen overdoses can have a negative impact on the environment and the taste qualities of raw and minimally processed vegetables. Studies conducted with Swiss chard show that plant has the ability to accumulate large amounts of nitrates in its leaf mass, which affects its quality (Colla et al., 2018).

Libutti (2020) mace the research on Swiss chard response to biochar and compost application, they apply organic amendment it in two doses, in order to provide 140 and 280 kg N ha^{-1}. Swiss chard responded positively to composts, particularly to those from animal wastes and to the higher N dose, showing a higher yield and a better product quality, while biochar did not lead to positive or negative effects. Castaldi et al. (2011) reported an increase in the exchange capacity of the soil due to the application of BC and an improvement in its ability to retain nutrients.

This study focuses on the evaluation of nitrogen rates in order to ensure high quality and environmentally friendly chard production and also to study the influence of imported carbonized plant residues as a soil amendment on the growth and development of Swiss chard.

MATERIALS AND METHODS

A pot experiment was conducted in 2018/2019 on two soil types: Vertisols and Luvisol soils. The experience is embedded in the glazed greenhouse. Plastic pots were used for the experiment. The pots was fill up with 2.5 kg of untreated or treated soil. Ten variants were developed in three replicates, as follows:

Variants	Vertisol
V1	Control- Pure soil
V2	Soil (S)+ biochar (BC)
V3	S+BC+$N_{200}P_{200}K_{250}$
V4	S+BC+$N_{400}P_{200}K_{250}$
V5	S+BC+$N_{600}P_{200}K_{250}$

Variants	Luvisol
V6	Control- Pure soil
V7	Soil + biochar (BC)
V8	S+BC+$N_{200}P_{200}K_{250}$
V9	S+BC+$N_{400}P_{200}K_{250}$
V10	S+BC+$N_{600}P_{200}K_{250}$

The tested crop is a leafy vegetable - Swiss chard (*Beta vulgaris* subsp. *vulgaris*). Chard was sown on 02.10.2018 with 20 seeds per pot.

The biochar was 6 g per pots in form of the powder mixed with the soil. The amount of biochar, phosphorus and potassium rates, are constant and serve as a background to track the impact of increasing nitrogen fertilization and the ability of the BC to absorb and release nutrients more slowly.

The introduction of mineral fertilizers was carried out with previously prepared working solutions. Norms of applied amounts of mineral fertilizers and biochar were determined based on literature data and preliminary research with chard and other leafy vegetables (Mikova et al., 2015; Stoimenov et al., 2015; Sarah et al., 2013).

The biochar used for the experiment was produced from wood chips. The pH 10.8 value of BC is strongly alkaline. It contains a large amount of carbon 61.8%, which confirms the ability of BC to deposit carbon in the soil, reducing its release into the atmosphere. The selected norms were introduced into each pot in the form of a fine powder fraction.

An optimal irrigation rate close to the field capacity was maintained through frequent watering with a small irrigation rate. The water was apply on every three day 150 ml per pots.

Phenological observations and biometric measurements were carried out during the growing season. During the chard growing season, when the rosette has reached full development, two measurements were made on 17.12.2018 and on 22.02.2019 at the end of experiment.

The nitrates, absolute dry matter in the experimental plants were determined.

Two soil types used for the experiment are Vertisols from the village of Bozhurishte (geographic coordinates: 42°45'48.59" N and 23°12'7.21" E.) and Luvisol from the village of Pozharevo (44°3′34.77 N and 26°42′23.95 E). The obtained pH data for both soil types defines them as slightly acidic. Vertisols are moderately stocked with absorbable nitrogen forms, well stocked with humus. Poorly stocked with P_2O_5 and well stocked with K_2O. The agrochemical analysis of the Luvisol from the village of Pozharevo defines it as moderately stocked with total N, slightly stocked with P_2O_5 and medium stocked with K_2O.

The following methods were used to determine the NPK in the soil:

- mineral nitrogen-extraction with 1M KCl (1:10) and distillation;
- available P and K extraction with ammonium acetate and potassium lactate with pH 4.2 (Ivanov, 1984)

Nitrates were determined from the crushed the leaves with a mortar and pestle leaf using a nitrochek meter Boeco.

RESULTS AND DISCUSSIONS

About a month after starting the experiment, the number of sprouted plants on the two soil types, according to variants, was record. The data are present in Table 1.

The largest number of sprouted plants was in variant 3 on Vertisol, and the least in variant 7 only with BC on Luvisol. In the rest of the variants, the number of sprouted plants varies from 12.26 to 14.3. The small numbers of sprouted plants in both soil types were recorded in the variants with the addition of BC only. Gomez-Eyles et al. (2013) reported that the application of biochar increased the cation exchange capacity of the soil, with NH_4 ions retaining on the BC surface (Table 1).

Table 1. Number of sprouted plants in pot experiment with Swiss chard

Variant	Number of plants per pot
Vertisols	
Var.1	13.3
Var.2	10.0
Var.3	16.7
Var.4	14.3
Var. 5	14.0
Luvisol	
Var.6	7.0
Var. 7	5.33
Var. 8	14.0
Var. 9	14.3
Var.10	13.0

The phenological development of the Swiss chard varieties was also observed. It is noticeable that growth is strongly suppressed in the different variants of Luvisol. Despite the increased nitrogen fertilization, the plants are still in the cotyledon phase, while the plants grown on Vertisol have entered the 3–4 leaf phase. In all variants, etiolating and cutting of the young plants were reported.

Variant 3 with nitrogen at 200 g/kg soil is the best on both soil types. Based on these results, we can assume that high nitrogen rates suppress the development of Swiss chard. The plants of variant 3 on Vertisol are the best developed, intensely green collared, and without lodging.

Table 2 shows the yields of fresh mass obtained in both samples. The data presented in the table correlates with the number of sprouted plants. The highest yield was reported again for var. 3 and var. 8 on both soil types, followed by var. 4. For the Luvisol, the differences in the masses of the variants fertilized with N_{400} and N_{600} are not clearly defined. The fresh mass obtained on Vertisol significantly exceeds that on Luvisol.

Table 2. Fresh mass in a pot experiment with Swiss chard

Variant	Plants mass per pot	Plants mass per pot
	I sample (g)	II sample (g)
Vertisol		
Var.1	13.81	12.60
Var.2	13.91	8.48
Var.3	55.14	15.06
Var.4	18.31	25.51
Var.5	10.47	4 .94
Luvisol		
Var.6	1.99	5.55
Var.7	3.54	10.31
Var.8	15.27	13.74
Var.9	4.08	6.74
Var.10	2.67	4.04

It is clear that with an increase in the nitrogen rate, the yield of fresh mass decreases, and in the second sampling, it is even lower than in the control variant. This clearly confirms the suppressive effect of higher nitrogen rates on chard development.

I crush the leaves with a mortar and pestle content of absolute dry matter (ADM) from the first sample for the different variants is in the range of 6.16% to 7.49% for the plants grown on Vertisol and 5.38% to 8.11% for those grown on Luvisol (Figure 1). In the second sampling, an increase in the ADM was observed for both soil types, with the same varying from 5.89% to 9.32% for Vertisol and from 7% to 7.96% for Luvisol.

The second reading of ADM at Vertisol shows the highest content in var. 2 with BC only, this probably due to the better water and air soil regime (Figure 1)

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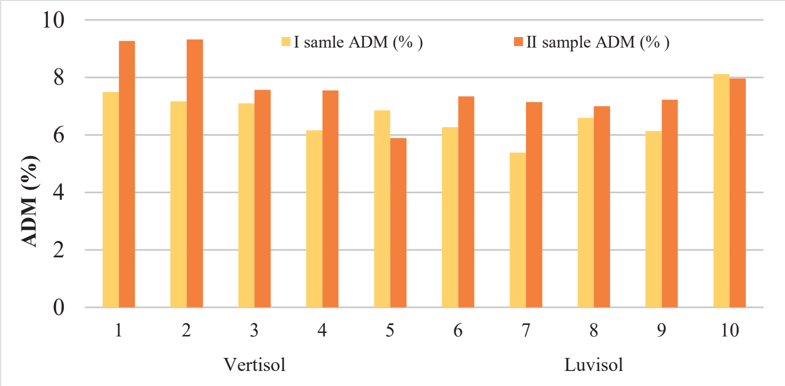

Figure 1. Absolute dry matter in chard plant samples

Mineral nutrition in plants is a process dependent on metabolism, growth, and development. During the growth processes, the supply of mineral substances to the plant increases.

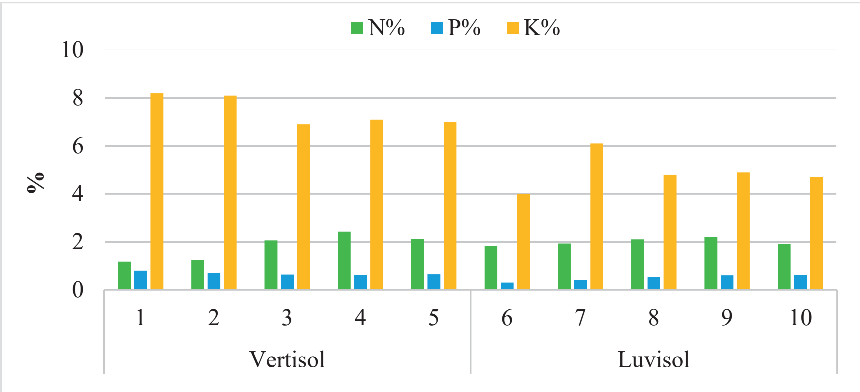

Figure 2. Percent nutrient content of Swiss chard leaves

It is clear (Figure 2) that with the increase in the nitrogen rate by variants, the nitrogen content in the leaves of Swiss chard also increases on Vertisoil. Reported values ranged from 1.18% for var. 1 to 2.4% for var. 4. The leaf N content of plants grown on Luvisol varied insignificantly between variants. This may be due to the ability of BC to equalize soil fertility and absorb nitrogen ions.

Although phosphorus is very mobile, with a constant flow from older to younger leaves, the results obtained show little variation in phosphorus content among the tested varieties. The lowest values were obtained for var. 1 control in Luvisol soils.

Of all the nutrients, potassium usually has the highest content. The large amount of potassium is associated with the carbohydrate metabolism and the water regime of the plants. In the variants grown on Vertisol, the values vary from 6.9% to 8.2%, the highest ones were recorded in var. 1 and 2, in the variants with mineral fertilization, and the values are very close. The higher rates in the first two variants are probably due to the ability of BC to change the cation exchange capacity of the soil. The other likely reason is that BC contains significant amounts of potassium in its composition. The obtained results correspond with those presented by other authors, who report that after the application of BC, the content of K in the plant biomass increased by 57%, while when manure was applied, the increase was only 43% (Lentz and Ippolito, 2012).

In the variants grown on Luvisol soil, the reported K values are smaller, varying between 4% and 6.1%, and in this soil type, the highest value was reported for var. 2 with BC only.

Based on the obtained data, it can be said that Swiss chard is a potassium-loving plant that accumulates carbohydrates in its leaf mass.

Nitrate accumulation in plants results from the uptake of nitrate ions and subsequent assimilation. Leafy vegetables do not have the nitrate-reducing ability of the roots, and this reduction takes place mainly in the leaves. Since they are used for direct consumption, Regulation (EC) No. 1881/2006 of the Commission determines the permissible amount of nitrates in the tissues to determine the concentration limit of pollutants in food. The regulation does not mention the permissible content for Swiss chard, but the specified levels for spinach and lettuce are 3500 mg NO_3/kg (Figure 3).

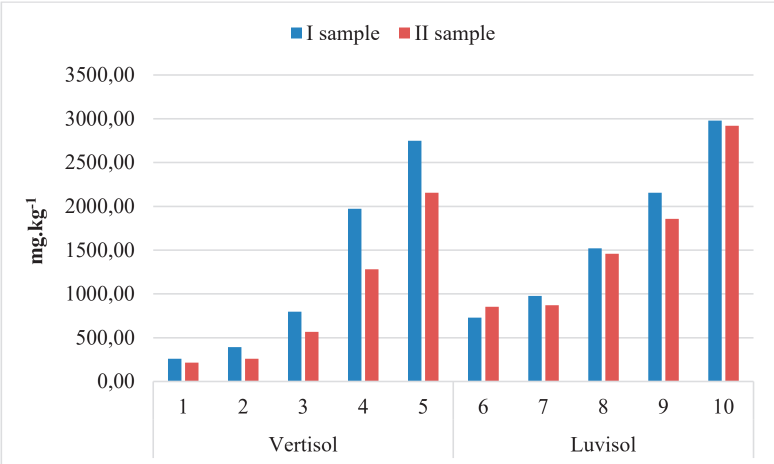

Figure 3. Nitrate content of Swiss chard leaves

In both samples on two soil types, there is a trend toward increasing nitrate content with increasing nitrogen rates. The lowest values were evaluated in the control variant, followed by the one with BC without mineral fertilization.

A gradual increase in nitrate content was reported in the Luvisol this was probably due to the acidic reaction of the soil.

Despite the detected presence of nitrates in the fresh chard leaves, the concentration does not exceed the concentration limit mentioned in Regulation 1881, which defines the product as good for consumption.

CONCLUSIONS

Based on the biometric measurements, phenological observations, and plant analyses, the following conclusions can be made:

The largest number of sprouted plants was recorded in the variant with BV+N200P200K250 on Vertisol. The fewest sprouted plants in both soil types were in the variants with biochar only and the variants with increasing rates of nitrogen fertilization.

On the Luvisol soil, plant growth is suppressed despite increasing nitrogen fertilization.

Regardless of the different starting supplies of nutrients in both soil types, the highest yield of plant mass was evaluated in the variant with BC+N200P200K250, followed by the variant with BC+N400P200K250. The fresh leaf mass recorded on Vertisol significantly exceeds that on Luvisols soil. Higher nitrogen rates have a suppressive effect on the development of Swiss chard.

As the nitrogen rate increases, so does the nitrogen content in the leaves of Swiss chard grown on Vertisol soil. The leaf N content of plants grown on Luvisol soil has a small variation. The obtained results show a slight variation in the phosphorus content in the tested variants. The lowest values were recorded for the control variant of Luvisol. The control and those with BC have the highest potassium contents. While in the versions with mineral fertilization, the values are very close. In the plants grown on Luvisol, the reported values of K were lower, with the highest content measured in the variant with only BC.

In both soil types, the nitrate content increases with the increase in the nitrogen rate, however, the concentration remains below the permissible limit.

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