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INFLUENCE OF INTERCROPPING ON PHYSICO-CHEMICAL AND BIOLOGICAL SOIL PROPERTIES IN ORGANIC STRAWBERRY CROP

Andrei MOȚ[1], Mihai FRÎNCU[1], Ioan VLAD[2], Elena Ștefania IVAN[1], Oana-Crina BUJOR[1], Bogdan MIHALCEA[3], Maria-Mihaela ZUGRAVU[1], Liliana Aurelia BĂDULESCU[1, 2], Roxana CICEOI[1]

[1]Research Center for Studies of Food Quality and Agricultural Products, University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, 011464, District 1, Bucharest, Romania
[2]Faculty of Horticulture, University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, 011464, District 1, Bucharest, Romania
[3]Cooperativa Agricola Rodagria Produce, Ogoru, Str. Constructia C1, Călărași, Romania

Corresponding author email: oana.bujor@ qlab.usamv.ro

Abstract

The intercropping system promotes biological interactions, increasing plant resources efficiency such as nutrients, water and light use. The study was carried out in polytunnels using the organic Amandine® strawberry variety in the Baragan plain, in the southeast of Romania. Along the polytunnel's pole lines, Borago officinalis L. flower strip was seeded. For soil sampling were chosen two moments (April and October 2022) and were analysed the following physicochemical and microbiological parameters: pH, electrical conductivity, total soluble salts, total carbon and nitrogen and total number of bacteria and fungi. The results pointed out that the number of bacteria in the soil covered with flower strips increased significantly during the vegetation period for borage strips. In addition, Borage proved to be a companion species that inhibit weeds growth successfully, including in high infestation of Johnsongrass. After the first year, no significant differences regarding the soil physicochemical properties between the sampling periods were noticed.

***Key words**: flower strip, intercropping, soil health, strawberries, Borago officinalis L.*

INTRODUCTION

The strawberry (*Fragaria x ananassa* Duch.) is a fruit species cultivated worldwide, their fruits being highly appreciated not only for the unique taste but also for the height content in bioactive ingredients and nutrients, and health benefits (Dane et al., 2019; Giampieri et al., 2012; Tulipani et al., 2008; Yang et al., 2020; Mițoi et al., 2022). At the same time, the number of consumers looking for nutritious food and pesticide-residue-free or organically produced berries is increasing. As a result of the need to combat climate change and the demand for wholesome products, it is imperative for farmers to discover effective methods to create innovative and resilient agricultural strategies. These strategies should be focused on maintaining berry production while simultaneously minimizing detrimental environmental impacts and promoting the enrichment of functional biodiversity. In particular, it is known that along with global warming, extreme effects appeared and damaged the habitat both above and below the ground. Moreover, through monoculture technologies, pest control and intensive fertilisation, biodiversity has been greatly diminished (Geisen et al., 2019).

Intercropping is an agricultural practice that involves growing two or more crops in proximity. This method is part of polyculture farming and is used for several reasons, including to increase biodiversity, enhance productivity, make efficient use of resources. decreasing disease transmission, increasing soil quality, crop yield, land efficiency and above all it has an essential role in organic agriculture (Blessing et al., 2022). Organic farming is a growing sector in agriculture that uses fertilizers of organic origin such as compost manure, green manure, and bone meal and places emphasis on techniques such as crop rotation and companion planting or intercropping, with the aim to reduces carbon emissions, improves soil health, and reloads natural ecosystems for cleaner water

and air (Mihalache et al., 2015; Gamage et al., 2023).
Accordingly, studies regarding the agrochemical quality of the soil, have shown that intercropping can reduce the leaching of some nutrients from the soil and increase their absorption in the current or future crop (Mocanu et. al., 2016; Moghbeli et al., 2019; Astiko et al., 2021; Romaneckas et al., 2020). Many studies have also noted an increase in soil organic carbon and total nitrogen, depending on the plants used as companions. In particular, clover has proven to be beneficial for maintaining a high level of nitrogen in the soil. A study carried out in 2021 by Li et al. demonstrated the effectiveness of nitrogen absorption by the main crop, intercropped with clover. Other studies that tested intercropping between strawberries and perennial plants showed benefits in terms of weed suppression, water use efficiency, soil biological activity (Dane et al., 2016; Laugale et al., 2023). Another study also demonstrated significant changes on soil biological properties after a period of 3 years of intercropping (Dane et al., 2017).
Intercropping usually leads to a pH decrease, but it depends on the plants used for intercropping (Lian et al., 2019; Romaneckas et al., 2020). Considering that strawberries prefer a moderately to slightly acidic soil (Milosevic et al., 2009), intercropping is a good way to improve soil pH for this crop. Also, the slightly acidic pH solubilizes certain micronutrients, improving their absorption (Ritchey et al., 2014). In addition to phosphorus, potassium, magnesium, strawberries are a great source of iron, zinc, manganese, i.e. the elements that are accessible at a slightly acidic pH (Tulipani, 2012).
At a microbiological level, the soil experiences more pronounced changes than chemical alterations. Research has highlighted substantial variances between monocultures and intercrops, especially when evaluating biodiversity indicators like microbial and enzyme activities, along with the total microbial population (Gong et al., 2019; Lu et al., 2023). For strawberry crops, monocropping is one of the biggest problems, because it generally requires protected spaces that cannot be changed easily. Relevant studies showed a major decrease of soil bacterial community after several years of monocropping (Li et al., 2018; Lovaisa et al., 2017). Using companion plants in open or protected spaces proved to be beneficial for strawberry crop. Companion planting strawberries with borage led to a notable rise in yield and market quality of the strawberries, indicating enhanced insect pollination per plant. The strawberries grown alongside borage showed an average increase of 35% in fruit production and a 32% increase in yield by weight (Boeckmann, 2023; Griffiths-Lee et al., 2020; Kellogg Garden Products, 2020).
This study's objective was to assess the impact of intercropping strawberries with *Borago officinalis* L. in high tunnels, focusing on the physico-chemical properties of the soil and the composition of soil bacterial and fungal communities.

MATERIALS AND METHODS

The experiment was conducted in 2022 at Cooperativa Agricola Rodagria Produce, an organic farm located in Calarasi County, in the south-east of Romania.
Strawberry plants (cv. 'Amandine') were planted in April, in high polytunnels, with 5 raised double-rows per tunnel. *B. officinalis* was intercropped with strawberry being sown in May 2022 along the poles lines of the tunnel, next to strawberry rows, in 60 cm wide strips.
The soil samples were collected in April 2022 (untreated/control) before planting strawberry runners (stolons) and sowing the *B. officinalis* as well as in October 2022. Each sample was homogenized on the spot and was divided into separate containers for physico-chemical and microbiological analyses. The samples were transported to the laboratory in cool boxes (3 hours from the sampling). The soil samples were analysed for the physico-chemical and microbiological parameters: pH, electrical conductivity, total carbon and nitrogen and total number of bacteria and fungi.

Physico-chemical analyses of soil samples

For the physico-chemical analyses, the samples were dried at room temperature for 3 days, after which they were ground in a soil mill (Humboldt, USA) to a size of 2 mm.
The pH of the soil was determined potentiometrically in aqueous extract (SR ISO 10390:2015) and the electrical conductivity

(EC) of the soil was determined conductometrically in aqueous extract (SR ISO 11265:1994), using a multiparameter analyzer (Mettler Toledo Seven Excelence.

The total content of soluble salts was calculated conductometrically, based on EC value (Ilie and Mihalache, 2013).

For the analysis of total nitrogen and total carbon, the soil samples were sieved through a 250 µm sieve (Haver & Boeck, ISO 3310-1:200, Germany). The analysis was carried out by dry combustion method (Moț et al., 2022), using the CHNS elemental analyzer (Elemental Analyzer EA 3100, Eurovector, Italy). All analyzes were performed in triplicate.

Microbiological analyses of soil samples

For the microbiological analyses, the samples were analyzed within 24 hours of collection.

The total number of bacteria (TNB) and the total number of fungi (TNF) was determined by the serial dilution method on PDA medium (Mwangi, 2023; Martin et al., 2012). As a method of determination, the number of colonies were calculated based on colony counting at 1, 3, 5 and 7 days after inoculation, taking into account the dilution and soil moisture (Brugger et al., 2012). All analyzes were performed in triplicate.

Statistical analysis

The statistical processing of the results was carried out using the statistical functions of Excel - Office 2010 program (Pomohaci and Vâşca, 2017). Also, Duncan test (IBM SPSS - statistical analysis software) was used for univariate variance analysis at the P≤0.05 level to determine the significance between all groups of the variants used in experiments.

RESULTS AND DISCUSSIONS

B. officinalis strip, as it showed very good resistance to competition from weeds in the area. Being a plant with rich foliage, with a relatively well-developed root system, with fairly fast growth and adapted to any type of soil, that is, a plant with a special ecological plasticity that immediately adapted to the respective conditions.

It has been observed that the influence of companion plants is very complex and determines a multitude of effects on some parameters, which in many situations do not have a typical or predictable evolution.

Although some studies did not observe significant changes in chemical parameters (Suri et al., 2019; Gikonyo et al., 2022), our results are rather similar to those of Mansaray et al., (2023) and Romaneckas et al., (2020).

As in the studies mentioned above, it is observed that the pH of the soil had a tendency to decrease in the case of the use of companion plants. At the beginning of the experiment, the soil reaction was neutral. In the case of the control variant (monoculture), an increase in the pH value was observed at the end of the experiment. In the variant of intercropping with *B. officinalis*, a significant decrease of pH by 9.09% was observed (Figure 1).

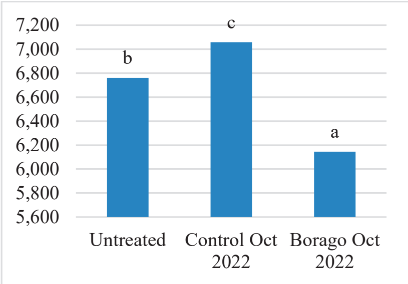

Figure 1. pH evolution from the beginning to the end of the experiment

Regarding soil EC and TSS, a significant decrease is observed from spring to autumn. This decrease is due to the fact that the monitoring areas are located on the edge of the tunnel, in the place where the rainwater drains from the surface of the entire tunnel. Due to this fact, the soil was repeatedly subjected to leaching processes, and the mineral content decreased (Figure 2).

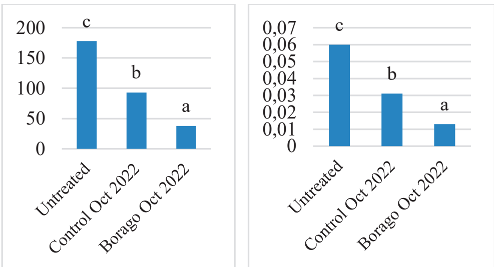

Figure 2. EC and TSS evolution from the beginning to the end of the experiment

It is a known fact that intercropping enhances C and N sequestration, thus improving soil fertility but also contributing to reducing greenhouse gas emissions (Cong et al., 2014; Chen et al., 2023). Soil total nitrogen had a significant increase when *Borago* was used for intercroping, compared to the control (monocropping). It can be noted that on the control version the content was similar both in spring and autumn, without major changes. On the control variant, there was a significant decrease of total carbon, which means a decrease of organic matter and implicitly, a decrease of microorganisms number (Figure 3).

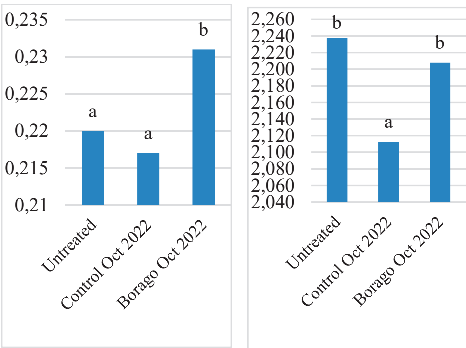

Figure 3. Total nitrogen (N_{tot}, %) and total carbon (C_{tot}, %) evolution from the beginning to the end of the experiment

Although from a statistical point of view the C:N ratio had a significant decrease from spring to autumn, from 10.17 to 9.74 (untreated) and to 9.56 (*B. officinalis* intercropping), from an agrochemical point of view the value remained within the limits of a normal soil (Swangjang, 2015) which means that the microbiological balance has not changed. The fact that both carbon and nitrogen had higher values means that the soil provided more nutrients, which causes a significant increase in microbial activity (Figure 4).

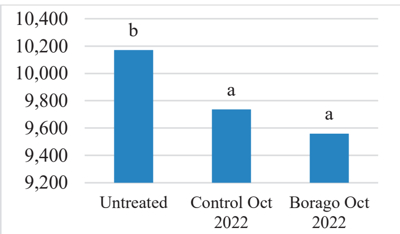

Figure 4. C: N ratio evolution from the beginning to the end of the experiment

Microbiological analyses showed an increase in the number of bacterial colony-forming units (CFU) from April to October 2022, from 15 $*10^6$ CFU/g soil to 1689.33 $*10^6$ CFU/g soil for the control variant, as it included plant species already adapted to specific environmental conditions. In the case of the *Borago* flower strips it was observed an increase in the number of CFU from $15*10^6$ CFU/g soil to 245.66 $*10^6$ CFU/g soil, which indicates the beneficial effect for the organic-maintained soil in the strawberry plantation (Figure 5).

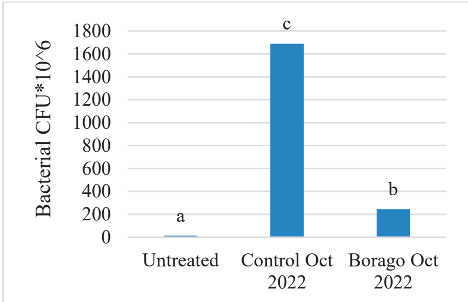

Figure 5. Bacterial CFU evolution in soil samples

In the case of the fungal community in the organic soil in the flowering strips of the strawberry plantation, an increase from 0.33 *106 UFC/g soil to 2 *106 UFC/g soil for the control variant and to 2.67 *106 UFC/ g soil for the version with *B. officinalis* (Figure 6).

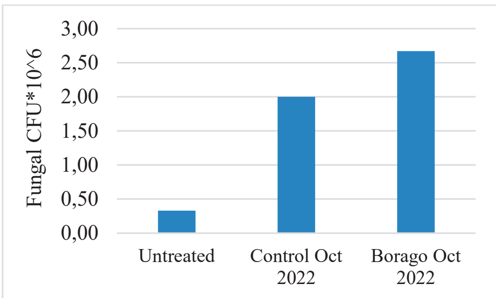

Figure 6. Fungal CFU evolution in soil samples

CONCLUSIONS

The results pointed out that the number of bacteria in the soil covered with flower strips increased significantly during the vegetation period for borage strips. In addition, borage proved to be a companion species that inhibit weeds growth successfully, including in high

infestation of johnsongrass. After the first year, a significant decrease of soil pH was observed, bringing this parameter much closer to the optimal value for strawberry crop. Also, using borage as a companion plant, the amounts of soil carbon and nitrogen increased significantly, which led to an intense microbial activity.
The number of fungal CFU was very low compared to bacterial CFU, but the fact that *Borago* positively influenced the increase in the number of microorganisms in the soil is a strong point of this experiment.

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