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Effect of management practices on soil fauna in organic orchard in Plovdiv region

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Abstract

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Different management of apple orchards agrosystems affects soil biodiversity. Organic farming is beneficial for conserving soil fauna and stimulating the decomposition lead to biological activity of the soil and respectively soil fertility. A field study was conducted to examine the influence of agricultural practices on soil fauna. The study was realized on organically managed apple orchard at Agroecological centre of Agricultural University of Plovdiv for two year period (2019-2020). We obtained comprehensive information by monitoring of various agrometeorological factors and agro-technological practices (tillage, mowing, irrigation, pest management and soil analysis). Macro- and microfauna were observed. Ecological parameters were higher in sward orchard and buffer zone.

Keywords: apple orchard, soil biodiversity, organic farming.

Introduction

Apples are one of the most produced fruits worldwide (FAO).

According to the data from the Ministry of Agriculture, Forestry and Food, the South-East region (26.9%) and the South-Central region with 26.8% occupy the leading place in fruit production in Bulgaria. 38.2% of apple production is concentrated in the South-Central region. For apples in 2020, the average yield was reported by 1.2% higher (10,654 kg / ha) compared to 2019 (10,532 kg / ha). https://www.mzh.government.bg/bg/politiki-i-programi/otcheti-i-dokladi/agraren-doklad/, https://www.mzh.government.bg/bg/statistika-i-analizi/izsledvane-rastenievadstvo/danni/

One of the key elements of the healthy ecosystems is a healthy soil. Different management of apple orchards agrosystems affects soil biodiversity. Soil organisms are essential for agricultural ecosystems and food production. Organic farming is beneficial for conserving soil fauna and stimulating the decomposition lead to biological activity of the soil and respectively soil fertility (Doles et al., 2001, Sheik et al., 2016). Soil biota takes crucial role for soil formation and maintaining soil in good condition (Paraskevov & Trendafilov, 2000).

The aim of the current study is to analyze how the organic agricultural management influenced the soil fauna in apple orchard. The focus is on macro- and microfauna that can contribute to outlining the importance of ecosystem sustainability in agricultural production.

Materials and Methods.

The study was realized on the organically managed seven years old apple orchard with Florina cultivar – grafted on MM106 rootstock. The study was conducted in apple orchard at the Agroecological Centre of Agricultural University of Plovdiv (42.133845 N, 24.807315 E) for two year period (2019-2020). Comprehensive information by monitoring of various agrometeorological factors and agro-technological practices (tillage, mowing, irrigation, pest management and soil analysis) were obtained. Soil pH was measured using pHotoFlex Set, 2512000, WTW-Germany (ISO 10390), and the soil conductivity was measured using Multiset, F340, WTW- Germany (ISO 11265). Soil texture (pipette method by Wigner), humus content (by Turin) has been analyzed in the Laboratory of the Department of Agroecology & Evironmental Protection and Department of Soil Science & Agrochemistry, Agricultural University of Plovdiv.

Soil fauna was extracted via Tullgren funnels (Tullgren, 1917, Phillipson, 1971). Soil cores for microfauna were collected once during the spring (in April/May) from soil cores of 50 mm diameter and 400 mm tall of the 25 – 30 cm which was sampled from each subplot. Sampling was done along transects (of 5 soil cores) in fallow (subplot 1), sward (subplot 2) and buffer zone (subplot 3). Samples were placed in labeled plastic bags and stored in fridge until processing. After extraction, macro- and micro-fauna was preserved in 70 % ethanol. The soil samples were observed under steriobinocular microscope Zeiss, sorted and counted, and determined to taxonomic level.

In order to establish the faunal similarity between the soil communities in the three subplots, they are compared two by two. The following formula is used:

$$QS = \frac{2S}{A + B}.100$$

where:

QS – Sorensen similarity index;

A – number of species (taxa) found in habitat A;

B – number of species (taxa) found in habitat B;

C – number of species (taxa) that are common to both habitats.

Simpson's Diversity Index (S) and Simpson's Equality index (E) were established.

The raw data were processed using Statistical Software Statistica 7.0.

Results and Discussion.

Fig. 1. Organic apples orchard – Fallow (photo credit: Manol Dallev)

Management practices

The following agrotechnological operations were performed in the experimental field in the organic apples orchard: – **Fallow** (fig.1) – 2 deep cultivations with a mounted plow at 25 cm, respectively in spring and autumn, as well as 3 disks with an asymmetric disc harrow at a depth of 8-10 cm. **Sward** (turf) (fig.2) – 5 mowing with a mulcher (the grass is crushed and spread on the field surface), at a height of 2-3 cm, 2 sprays with a fan sprayer and 4 waterings.

Shampion VP – 0.15% (at the end of November) and Funguran ON – 0.3% (contact broad-spectrum, containing 77% cupper hydroxide) combined with Colloidal sulphur –

Fig. 2. Organic apples orchard Sward (turf). (photo credit: Manol Dallev)

1:400. Trifolio S Forte 0.3% (50% vegetable oil + 50% emulsifier) and Acarzin 3% (85% mineral oil + 15% emulsifier) were used against the hibernating forms of aphids and apple fruit worms. Postblossom treatments in May was performed against apple diseases and the pests mainly target *Venturia inaequalis, Podosphaera leucotricha*, aphids and apple fruit worm with uses of the antifungal agent Kuore 200 g/dka (contains 10% Cu and 1.1% Zn, Colloidal sulphur – 1:400, Nimazal T/C – 200 ml/dka (a bioinsecticide) + Trifolio S Forte – 0.3%. Pheromone trapping was used to control apple fruit worm (Dobrevska et al., 2020).

Soil properties

In the organic apple orchard, the soil is Gleysols. The mechanical composition of the soils in the studied organic orchard is medium sandy-clayey. Carbonates are not observed. The pH of the soil is slightly acidic to neutral. According to the Capability soils classification, the studied soils are characterized by low to medium humus stock (Table 1).

The studied soils are characterized by low to medium supply of nitrogen, phosphorus and potassium (Table 2).

Various agrometeorological factors were monitored of and the data are presented in Table 3.

Soil fauna

The 9 taxa collected in this study belonged to Acarina, Porcelionidae, Pseudoscorpiones, Colembola, Protura, Diplura, Oribatidae, Diptera and Hymenoptera (Table 4). By comparison the common species in the three subplots, it was found that only three of all identified taxa are present in all of

Table 1. Soil features 2019-2020.

Sample/Depth, cm;	pH (H_2O)	Humus %	Total $CaCO_3$ %	Active $CaCO_3$%	Mechanical composition of the soil ≤ 0,01 mm%	Humidity %
1. Fallow 0–60	7.2	3.02	–	–	36.50	10.4
2. Sward 0–60	7.1	2.96	–	–	36.25	11.2
3. Buffer zone 0–60	6.9	2.91	–	–	37.50	16.1

Table 2. Agrochemical features average for the 2019-2020.

Sample/ Depth, cm;	NH_4 mg/1000g	NO_3 mg/1000g	$NH_4 + NO_3$ mg/1000g	P_2O_3 mg/100g	K_2O mg/100g
1. Fallow 0–60	15.3	12.8	28.1	6.9	15
2. Sward 0–60	13.8	13.9	27.7	7.8	17
3. Buffer zone 0–60	14.9	14.6	29.5	9.8	19

Table 3. Meteorological data.

Month	Average month T°C		Average month rainfall, mm		Average monthly air humidity %	
	2019	2020	2019	2020	2019	2020
April/May	15.4	14.4	48.9	76.8	67	70

Table 4. Established taxa from the soil fauna in an organic apple orchard.

Taxon	2019				2020			
	Subplot 1 (fallow)	Subplot 2 (Sward)	Subplot 3 (Buffer zone)	Total	Subplot 1 (fallow)	Subplot 2 (Sward)	Subplot 3 (Buffer zone)	Total
Collembola	25	25	8	58	5	3	11	19
Oribatidae	14	9	15	38	0	0	12	12
Protura	6	17	7	30	0	1	0	1
Diptera	0	9	9	18	1	0	1	2
Acari	3	4	0	7	0	0	2	2
Pseudoscorpiones	1	0	0	1	1	0	0	1
Diplura	1	2	0	3				
Hymenoptera	0	0	10	10				
Oniscus	1	0	0	1				
Total number of individuals	51	66	49	166	7	4	26	37
Total number of taxa	7	6	5	–	3	2	4	–

it – Collembola, Oribatidae and Protura. The most numerous and with the highest frequency of occurrence were Collembola on fallow (with 49%) and sward (37%) of total individuals, while in buffer zone, Oribatidae were predominant with 42% (figs. 3,4,5).

Regarding the species diversity of the soil fauna (2019) and based on the values of the Simpson Diversity Index, the studied sites form the following descending order: subplot №1 (51 individuals, 7 taxa)> subplot №2 (66 individuals, 6 taxa)> subplot № 3 (49 individuals, 5 taxa).

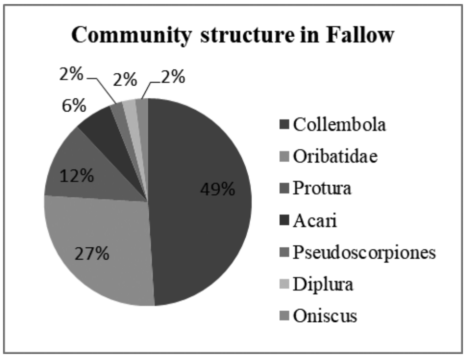


Fig. 3. Community structure of soil fauna in fallow 2019

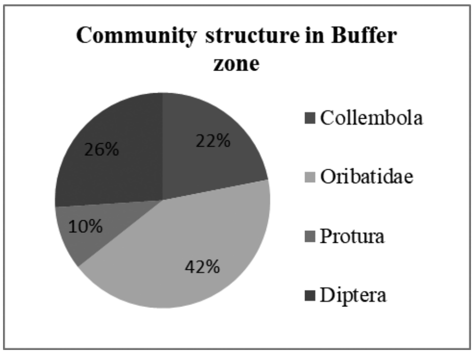


Fig. 5. Community structure of soil fauna in buffer zone 2019

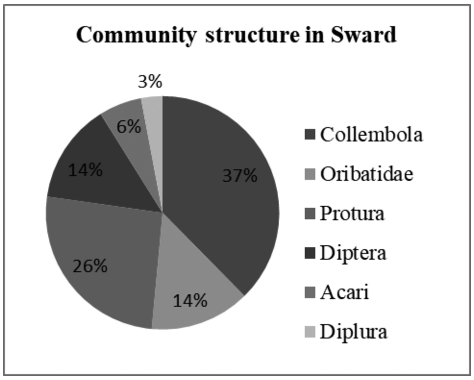


Fig. 4. Community structure of soil fauna in sward 2019

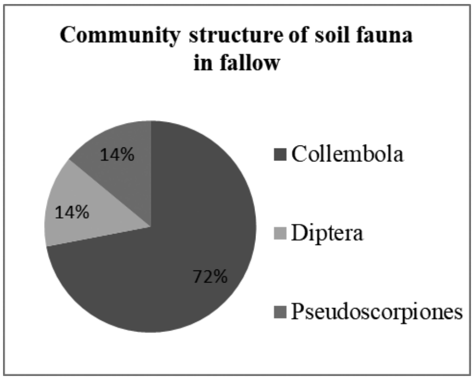


Fig. 6. Community structure of soil fauna in fallow 2020

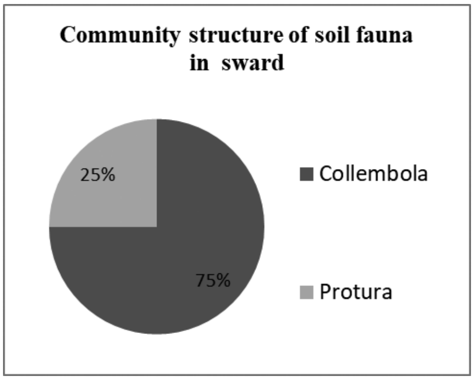


Fig. 7. Community structure of soil fauna in sward 2020

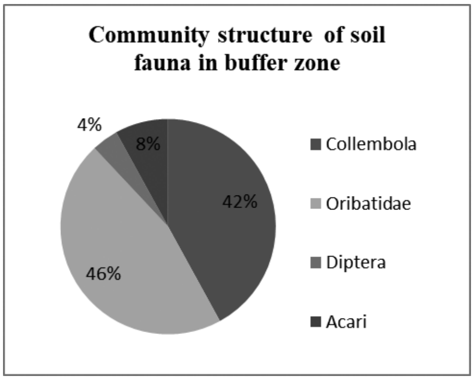


Fig. 8. Community structure of soil fauna in buffer zone 2020

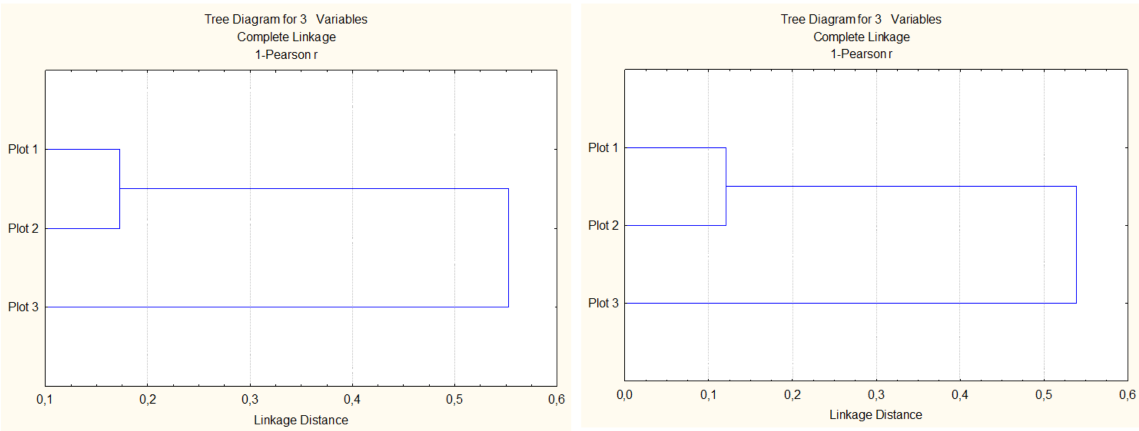
Regarding the distribution of individuals among the identified taxa in all three subplots, similar values of the Simpson's Equality Index are reported in 2019 – about 0.04, which indicates a significant unevenness in the distribution and the presence of 1 (or 2) dominant taxa.

Based on the obtained results for the faunal similarity between the soil communities, it is reported that the similarity between fallow and sward is 38%, between sward and buffer zone is 36%, and between fallow and buffer zone is 33%.

Comparing the frequency of species in the three subplots, it was found that only one of all identified taxa was present in all of it – Collembola. The most numerous and with the highest frequency of meeting in fallow and sward and in the second year (2020) are again the representatives of Collembola – respectively 72% and 75% of all listed individuals, while in buffer zone again dominated by representatives of Oribatidae with 46% (figs. 6,7,8).

The findings above are supported from (Doles et al., 2001; Eni et al., 2014; Sheikh et al., 2016) who established that, from the total soil arthropods Collembola dominated in faunistic community structure studied in different agoecosystems.

Regarding the species diversity of the soil fauna in 2020 and based on the values of the Simpson Diversity Index, the studied subplots form the following descending order: buffer zone (26 individuals, 4 taxa)> fallow (7 individuals, 3 taxa)> sward (4 individuals, 2 taxa). Regarding the distribution of individuals among the identified taxa according to the values of the Simpson's Equality Index, it can be stated that a more pronounced unevenness in the distribution and the presence of 1 (or 2) dominant taxa exists in buffer zone and fallow. Regarding the faunal similarity between the soil communities in the individual habitats in 2020, it is reported that the similarity between subplot 1 (fallow) and subplot 2 (sward) is 20%, between subplot 2 and buffer zone is 16.7%, and between subplot №1 (fallow) and buffer zone is 28.6%.



A **B**

Fig. 9. Cluster analysis of the soil fauna in three studied subplots in organically managed apple orchard in 2019 (A) and 2020 (B)

A significant positive correlation was proved between the soil communities in both years 2019 and 2020 of subplot 1 (fallow) and subplot 2 (sward) ($r = 0.83$ at $p <0.05$) and ($r = 0.88$ at $p <0.05$) respectively.

T-test shows that there are no statistically significant differences in the composition of soil fauna between different subplots in both study years.

The results achieved in the Cluster analysis of the similarity between the three studied subplots in organically managed apple orchard in 2019 and 2020 based on the described soil fauna are presented at figure 9. Statistically significant similarity was proved between the composition of the soil fauna in subplot 1 (fallow) and subplot 2 (sward) ($p <0.05$).

Conclusion

In agroecosystems, the soil biota activity is strongly influenced by management practices (cultivation, irrigation, the application of fertilizers etc.) which cause changes in the soil environment. This study provides a data of soil fauna in organically managed apple orchard. Organic farming is beneficial for the biological activity of the soil. Ecological parameters were higher in sward orchard and buffer zone. This can be due to the higher accumulation of plant litter and organic matter and higher soil moisture in soil under sward farming practice, which is in synchrony with findings of Doles et al., 2001 in USA.

A better understanding of the role of soil micro- and macrofauna in orchards can be a key factor in determining the best soil management strategies in these agrosystems.

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