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Microbiological Activity of Soil Under the Influence of Post-Harvest Siderates

Yurii Mishchenko[1], Ihor Kovalenko[1], Andrii Butenko[1*], Yuriy Danko[1], Volodymyr Trotsenko[1], Ihor Masyk[1], Mykola Radchenko[1], Zoya Hlupak[1], Andrii Stavytskyi[2]

[1] Sumy National Agrarian University, H. Kondratieva St., 160, Sumy, 40021, Ukraine

[2] Separate Structural Subdivision, Okhtyrka Professional College of Sumy National Agrarian University, Sumy region, Okhtyrka, Sumska St., 46, 42700, Ukraine

* Corresponding author's e-mail: andb201727@ukr.net

ABSTRACT

The results of research on the activation of the microflora by using post–harvest green manure crops were presented. As a result of the conducted studies, the positive effect of sidereal crops of *Raphanus sativum* and *Phacelia tanacetifolia* on activity increase of microflora in black soil with little humus was revealed. Application of post–harvest siderates increased the number of non-sporous species of bacteria and actinomycetales, contributed to improvement of soil environment under the influence of siderates, which had a positive effect on creating more comfortable conditions for growing potatoes. The usage of green fertilizers had a positive influence on microbiology activity of soil.

Keywords: siderates (green manure), media, *Phacelia tanacetifolia*, *Raphanus sativum*, *Fagopyrum sagittatum*, actinomycetales, *Lepidium sativum*.

INTRODUCTION

Development of agriculture requires an in-depth study of all soil properties, among which the biological one takes a leading place, because microflora plays a very a important role in soil formation, which gives soil the qualities of a living system [Svirskene, 2003; Iutinskaya, 2006; Santín-Montanyá et al., 2016; Mishchenko et al., 2019; Karpenko et al., 2020a].

Microorganisms are an integral and the most active part of any biogeocenose. They have a great variety of biochemical functions and high physiological activity [Van Der Heijden et al., 2016; Woźniak, 2019].

Due to the activity of microorganisms in soil, the following processes take place: decomposition of plant and animal residues into mineral compounds, synthesis and decomposition of humus, binding of atmospheric nitrogen, destruction of toxic substances, etc. Microorganisms synthesize various physiologically active compounds (antibiotics, plant toxins, stimulants and inhibitors of growth), take active part in conversion of physiologically active substances secreted by plants and microorganisms into compounds more active than the original ones [Bater, 1996; Fließbach et al., 2007; Araujo & Melo, 2010; Paz-Ferreiro & Fu, 2016; Karbivska et al., 2022]. They convert insoluble soil compounds into available forms of nutrition for plants, synthesize biologically active substances (vitamins, auxins, amino–acids), which promote better growth and development of plants, increase the yielding capacity of crops [Grodzinskiy et al., 1990; Bulyhin & Tonkha, 2018; Kvitko et al., 2021].

Growing post-harvest siderates has a multifaceted positive effect on soil properties (enriches the primer with nitrogen and organic matter). Post–harvest siderates reduce soil acidity, decrease the mobility of aluminum, and increase the buffer capacity of absorption [Karpenko et al., 2019; Karpenko et al., 2020b; Scherner et al., 2016]. When plowing the green mass of plants, the structure of the soil improves, the volume mass of the arable layer and the density of soil composition decrease. This is very important, because in this case the negative consequences of compaction of the arable soil layer by heavy agricultural techniques are eliminated [Steinweg et al., 2012; Tsyhanskyi et al., 2019; Kravchenko, 2020; Rieznik et al., 2021]. As a result of plowing of siderate manures, the water permeability and moisture capacity of soil considerably increase, as a result of which the superficial runoff of precipitations decreases and the moisture content in soil sharply increases [Grodzinskiy, 1990; Caldiz et al., 2016; Cerbari & Leah, 2021]. During the decomposition of postharvest siderates, soil and ground air are enriched with carbonic acid, which promotes the transition of soil phosphates and other mineral nutrients into digestible forms for plants. The rate of decomposition of plant mass depends on the depth of earnings, the age of the siderates, the particle size distribution of the soil [Coulson et al., 2015; Karbivska et al., 2020; Kwiatkowski et al., 2020; Yakupoglu et al., 2021]. The greater the depth of earnings and the older the plant, the heavier the particle size distribution of the soil, the slower the decomposition of green mass of siderates, and vice versa. [Armengot et al., 2016; Litvinov et al., 2019; Barczak et al., 2019].

In the process of growth, siderates enrich the soil with nitrogen (*Lupinus* L., *Vicia sativa* L., *Trifolium pratense* L.), sulfur and phosphorus (*Sinapis* L., *Raphanus sativus* L., *Brassica napus* L.), potassium (*Fagopýrum esculéntum*, *Secale cereale* L.). They also release into the soil substances that can suppress the spread of certain pests (*Raphanus sativus* L., *Phacelia tanacetifolia*) or pathogens (*Sinapis* L.) [Mishchenko et al., 2019; Karpenko et al., 2020b; Lopushniak et al., 2021; Hryhoriv et al., 2021].

That is why studying the ways of improving the development of microflora and microbiological processes in order to increase soil fertility is one of the urgent tasks of modern agriculture. A promising way of solving this problem is enrichment of soil with fresh organic matter of post-harvest siderates [Kranzler et al., 2016; Van Der Heijden et al., 2008; Cerdà et al., 2020; Chețan et al., 2021].

MATERIAL AND METHODS

The influence of post–harvest siderates on environment of typical black soil and their acting effectiveness were studied under the conditions of Left-Bank Forest-Steppe in experimental field of Sumy National Agrarian University during 2017–2021. The scheme of the experiment involved growing the potatoes of Slovyanka variety on the following backgrounds: (1) post–harvest residues of winter wheat 4.6 t ha^{-1} – background (control); (2) background + post-harvest siderate of *Raphanus sativum* 29.1 t ha^{-1}; (3) background + post– harvest siderate of *Phacelia tanacetifolia* 23.3 t ha^{-1}; (4) background + post–harvest siderate of *Fagopyrum sagittatum* 4.6 t ha^{-1}; (5) background + litter manure 25 t ha^{-1};

The area of accounting plot is 66 m^2. The placement of plots in the experiment is randomized. The experiment was repeated three times.

Post-harvest siderates were sown in the first decade of August, and their mass was plowed at the end of the third decade of October. The technology of potato growing was generally accepted for Left-Bank Forest-Steppe zone of Ukraine.

The study of siderate effect on microbiological activity of typical low-humus medium loam black soil was conducted by taking samples from 0–30 cm of soil layer before enfolding siderates with the soil and at the time of planting and flowering of potatoes.

The biological testing of soil was conducted by using the method of Grodzinsky (1990), and microbiological analysis of freshly selected soil samples – according to the generally accepted methods [Segi, 1983; Tepper, *et al.,* 1979]. Group composition of microflora was determined in Petri dishes by sowing soil suspension on appropriate nutrient media. Bacteria were counted by surface sowing of 0.05 ml of soil suspension from the fourth dilution on cabbage medium. Microscopic fungi were counted on Chapek's medium acidified to pH 4.5 (the third dilution, 0.1 ml). Especially sensitive to external environment conditions, the group of nitrogen-fixing bacteria (*Azotobacter chrooeoccuin)* were determined on Eshbi's medium by the level of relative biofouling of soil clods with this crop.

RESULTS AND DISCUSSION

The composition of soil microflora is quite diverse, it includes: microscopic fungi, actinomycetes, bacteria and other organisms. The activity of this biota significantly intensifies siderate growing in post-harvest sowings and the following usage of siderates for sowing crops, in particular, in this study – potatoes (Fig. 1, 2).

In general, with the process of utilizing non–humic organic soil matter by microorganisms, the number of microflora under potato crops decreased both in the variants with siderates and with manure. A more detailed species examination of microorganisms showed that there was an increase in the number of non-sporous bacteria in the soil under the influence of sidereal crops, compared to the control without plant residues (Table 1). The number increase of bacteria which do not form spores is stipulated by the fact that they are the first to decompose the organic soil residues received with introduced mass of organic manure. Sporous bacteria were less sensitive to post-harvest sideral crops. This can be explained by the fact that the development of bacteria forming spores is generally connected with the presence of half-decomposed organic matter in soil. Post-harvest siderates of *Raphanus sativum* and *Phacelia* also stimulated most of all development of actinomycetales – microorganisms responsible for soil-forming process and producers of physiologically active substances, as well as cellulose-destroying microorganisms. The influence of post-harvest siderates on the biological activity of the soil was defined by accounting the growth of *Lepidium sativum* roots and the spread of azotobacter.

Currently, the ecology of nitrogen holder – Azotobacter is well studied. It develops in the soils rich in available phosphorus compounds, with close to neutral pH medium as well as sufficient amount of organic matter and water. Azotobacter,

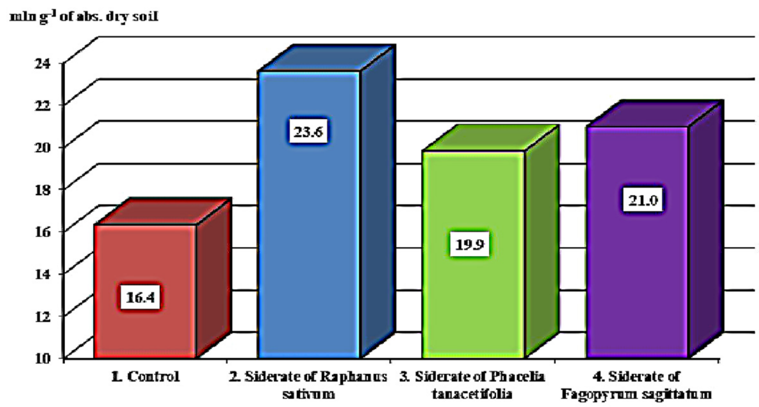

Figure 1. Number of bacteria in the soil at the time of enfolding siderates in the soil layer 0–30 cm, average for 2017–2020

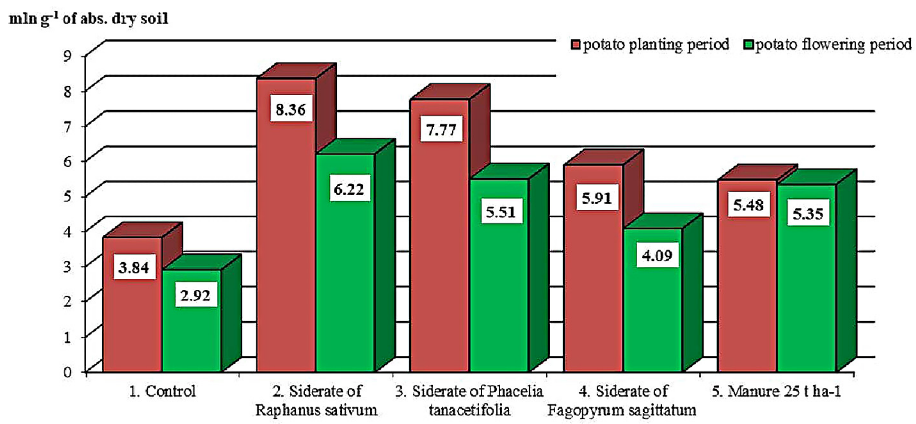

Figure 2. Influence of post-harvest siderates and manure on the number of bacteria in soil layer 0–30 cm under potato crops, average for 2018–2021

as well as many cellulose–decomposing bacteria, can be used as an indicator of valuable agronomic qualities of soils. As one can see in Table 1, the number of azotobacter was higher in the soil with the application of siderates of *Raphanus sativum* and *Phacelia tanacetifolia*. The data of plant biotests (growth of *Lepidium sativum* roots) also indicate better improvement of the soil with these siderates. Against the background of *Fagopyrum sagittatum* and manure, the number of Azotobacter and growth of *Lepidium sativum* roots were slightly smaller, although they prevailed the control variant.

Microscopic fungi – the most ferentatively active group of micro biocenosis. It is characterized by ferentative feature of transforming organic substances, including cellulose and biosynthesis of physiologically active substances. Fungi decompose fiber, lignin and, thus, play an important role in the formation of humus and increase of soil fertility. While analyzing the number of microscopic fungi, it can be noted that among siderates, *Raphanus sativum* harder activate development of micromycetes and this indicator is close in efficiency to the action of manure. The data of potato yielding capacity indicate the most positive effect of sidereal crops of *Raphanus sativum* and *Phacelia tanacetifolia* among other backgrounds of organic fertilization (Table 2).

The highest yield of potato tubers was obtained when applying *Raphanus sativum* as a post–harvest siderate, followed by – in descending order – the variants with manure, *Phacelia tanacetifolia* and *Fagopyrum sagittatum*.

Table 1. Influence of siderates and manure on the dynamics of soil microorganisms in the layer 0–30 cm, average for 2017–2021

Variants of applied siderates	Growth of *Lepidium sativum* roots, % to control	Micro-mycetes (Chapek's medium), thousand/g of soil	Non-sporous bacteria (medium KA), million/g of soil	Sporous bacteria (medium Mishustin), thousand/g of soil	Azotobacter (Eshbi's medium), %	*Actinomycetales* (medium KA), thousand/g of soil	Cellulose-decomposing (Hetchinson's medium), thousand/g of soil
siderate ploughing period							
Without siderates	100	47.7	16.1	289	77.3	377	65.3
Raphanus sativum	134	45.5	23.4	253	82.4	318	99.4
Phacelia tanacetifolia	128	49.6	19.6	221	83.4	297	80.9
Fagopyrum sagittatum	120	47.3	20.7	255	80.3	342	76.7
Potato planting period							
Without siderates	100	34.2	3.5	385	87.5	116	49.6
Raphanus sativum	117	28.2	8.0	328	92.5	238	53.4
Phacelia tanacetifolia	115	23.6	7.5	244	94.6	179	51.6
Fagopyrum sagittatum	113	25.8	5.6	317	88.5	149	47.7
Manure 25 t ha^{-1}	111	28.8	5.3	191	91.5	166	45.8
Potato flowering period							
Without siderates	100	37.8	2.5	377	74.2	54	194
Raphanus sativum	109	40.1	5.9	319	78.3	58	303
Phacelia tanacetifolia	107	29.0	5.4	119	77.3	62	254
Fagopyrum sagittatum	105	30.0	3.8	330	7.3	56	232
Manure 25 t ha^{-1}	106	57.7	5.1	265	76.3	56	297

Table 2. Influence of organic fertilizers on potato harvest, average for 2018–2021

Experiment variants	Yielding capacity		Yield increase, t ha^{-1}
	t ha^{-1}	%	
1. Control	24.7	100	–
2. Siderate of *Raphanus sativum*	30.8	125	6.1
3. Siderate of *Phacelia tanacetifolia*	28.7	116	4.0
4. Siderate of *Fagopyrum sagittatum*	26.2	106	1.5
5. Manure 25 t ha^{-1}	30.1	122	5.4
LSD_{05}			1.4

CONCLUSIONS

The application of sideral crops increased soil biogenicity, improved soil-microbiological conditions of growing plants and, as a result, increased the potato yield significantly. Among siderates, *Raphanus sativum* better activate development of micromycetes and this indicator is close in efficiency to the action of manure.

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