Binary plantings as a factor of reducing the technogenic load of agrocnosis

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Abstract. The results of research conducted by Voronezh State Agrarian University to determine the effect of binary sunflower plantings in combination with postharvest sideration on the content of plant residues in the soil, on the number of soil microorganisms, on the dynamics of detritus, sunflower infestation and yield are presented. The positive effects of the studied complex of biological function was well established to increase the content of organic matter sources in soil (by 4.64 of 5.67 t/ha), contributing to the increase in the content in the soil detritus (4.7 and 9.9%) on the growth of soil microorganisms, which in combination with the reduction of planting infestation (by 9-18 pcs/m²) has led to significantly higher yields of sunflower (0.18-0.51 in t/ha) compared with the traditional technology of cultivation. As binary components of sunflower, it is recommended to use perennial legumes of yellow melilot and purple alfalfa, and oil radish as a postharvest sideral crop.

1. Introduction

In pursuit of meeting the growing needs, humanity has always sought to obtain high yields of agricultural crops through various means of influencing the agroecosystem: scientists and practitioners around the world have been engaged in the development of agriculture intensification. The scientific justification of agriculture on a biological basis, the scientific principles of ecological agriculture, developed in the XVIII century, were forgotten.

Traditional intensive agriculture, which has become widespread, is characterized today by rather high indicators, but at the same time by a number of significant disadvantages, expressed not only in the degradation of soil fertility and environmental pollution, but also in a decrease in the biological quality of the products obtained, based on their attractive appearance, taste, size, and ability to maintain human and animal health.

Today, more than ever, the question of changing the agrochemical direction of agriculture development to agrobiological one, based on the laws of nature, on a reasonable reduction of anthropogenic impact on agroecosystems, on creating the most favorable conditions for the full use of its own biopotential, has become acute. Although it is worth admitting that even in ancient times many thinkers were attracted by the idea of farming on the principles suggested by nature, and in the early 60s of the XX century a new direction was formed in Europe, called alternative agriculture, based on the principles of "ecologization" and "biologization".

One of the main concepts of alternative agriculture is the development of biologized crop rotations with their saturation with highly productive medium-improving crops, ensuring maximum reduction of soil organic matter deficit, and the orientation of all agrotechnical measures to reproduce and increase
soil fertility by activating the soil microorganisms. For a long time, research in this area has been conducted in various regions of our country [1-10], but, nevertheless, this topic remains relevant.

To develop the main elements of the cultivating technology of crop plants in the conditions of the Central Chernozem region, the Department of Agriculture of the Voronezh State Agrarian University in 2010 laid the experiment on determining the influence of various methods of biologization on the main indicators of soil fertility. This article will present the results of studies conducted on sunflower plantings – the main oil crop of the Central chernozem region.

2. Methods of research

Studies to determine the effect of a complex of biologization techniques on the amount of plant residues entering the soil, the rate of their decomposition, the quantitative and species composition of soil microorganisms and the content of organic matter in the soil were carried out from 2013 to 2016, which, according to the degree of moisture content of the growing season, were both excessively moist (2013 and 2016: HTC according to Selyaninov, respectively 2.3 and 1.8) and arid (2014 and 2015: HTC, respectively 0.7 and 0.8).

The experiment is laid on a flat surface with a slope up to 1°. The soil is typical chernozem, clay, medium-sized. The humus content in the soil layer of 0-30 cm at the time of the experiment was 5.3%. The soil supply with exchangeable potassium is very high (184 mg/kg of soil according to Chirikov), mobile phosphorus is increased (113 mg/kg of soil according to Chirikov). The reaction of the soil solution is slightly acidic (pHsol - 5.6).

Within the framework of the scientific research program, the following options were studied:

1. Background (postharvest-root residues + barley straw) + Single-species sunflower planting (F+Op)
2. Background (postharvest-root residues + barley straw) + Postharvest sideration (oil radish) + Binary sunflower planting with yellow melilot (F+Ps+Bd)
3. Background (postharvest-root residues + barley straw) + Crop sideration (oil radish) + Binary sunflower planting with purple alfalfa (F+Ps+Bl).

Sunflower cultivation was carried out in a field crop rotation: fallow (pure dead, green-manured, seeded) - winter wheat - barley - sunflower/corn. With binary plantings, the seeding rate of sunflower was 50 thousand germinating seeds per 1 ha (seed depth 5-6 cm), legumes - 5 kg/ha (sowing depth 2-3 cm). Measures for the care of joint oilseed crops consisted in carrying out two inter-row treatments. Fertilizers and plant protection products were not used. After harvesting the sunflower, the remaining stems of the crop and the vegetative mass of legumes were crushed by a cutter. The next year, the growing legumes formed fallow fields: yellow melilot – green-manured fallow, purple alfalfa - seeded. The technology of cultivation of other crops of crop rotation is generally accepted for the CCR.

Soil sampling was carried out in layers every 10 cm to a depth of 30 cm in the following phases of sunflower development: seedlings, beginning of flowering, full ripeness. All analyses were carried out according to generally accepted methods: the content of plant residues - according to N.Z. Stankov, detritus – according to the TLC method, the number of soil microorganisms – according to the method of the All-Russian Research Institute of Agricultural Microbiology by seeding soil suspension on elective nutrient media: cellulose-destroying microorganisms – on agarized Hutchinson medium with filters; ammonifiers – on meat-peptone agar (MPA); bacteria assimilating mineral forms of nitrogen and actinomycetes – on starch-ammonia agar (SAA); aerobic nitrogen fixators – on Ashby medium; soil micromycetes – on Chapek medium acidified with lactic acid; weed infestation of crops – by quantitative-species method.

3. Research results

When developing individual elements of crop cultivation technologies, special attention is paid to optimizing the soil organic matter as a determining factor in improving its properties, supplying energy material to plants and soil microbiota, increasing the resistance of agriculture to adverse environmental manifestations.
The technology of sunflower cultivation, the agrocenosis of which is represented by single-species annual plants, is characterized by intensive measures for the care of its plantings, which is accompanied by a predominance of the rates of mineralization of organic matter over its neoplasm. To form a deficiency-free balance of humus under sunflower, it is necessary to carry out such agrotechnical measures that will ensure, first, an increase in the intake of fresh organic matter into the soil. Such agricultural practices in this study were the use of postharvest sideration for sunflower planting and cultivating it in an interspecific agrocenosis with leguminous grasses.

The use of postharvest sideration after harvesting barley provided additional intake of fresh organic matter into the soil in the form of biomass of oil radish, as a result of which the content of plant residues in the soil layer 0-30 cm in the phase of sunflower seedlings amounted to 7.27 t/ha, which exceeded this indicator by 2.64 t/ha. During the growing season of interspecific agrocenosis, the accumulation of plant residues occurred, as a result of which their mass by the phase of full ripeness of the oilseed crop was 9.55 t/ha in the variant with yellow melilot and 10.4 t/ha in the variant with purple alfalfa. During the same period, the content of plant residues under single-species sunflower sowing decreased to 3.11 t/ha (Table 1).

In total, the complex of biologization techniques studied allowed to increase the content of plant residues in the soil by 4.64-5.67 t/ha, while the absence of these techniques led to a decrease in the amount of plant residues in the soil by 1.3 t/ha.

The intensity of plant material destruction, determined by the biological activity of the soil, i.e. the totality of various biological processes carried out by soil biota, the most numerous and biologically active part of which is represented by microorganisms, is important in increasing soil fertility, along with the amount of plant residues entering the soil.

**Table 1.** The content of plant residues in the soil layer 0-30 cm, depending on the studied techniques.

| Variant | after harvesting the precursor (barley) | sunflower seedlings | full ripeness of sunflower | Dynamics, +, - |
|---------|--------------------------------------|---------------------|---------------------------|----------------|
| F+Op   | 4.41                                 | 4.63                | 3.11                      | -1.3           |
| F+Ps+Bd| 4.91                                 | 7.06                | 9.55                      | +4.64          |
| F+Ps+Bl| 4.73                                 | 7.48                | 10.40                     | +5.67          |

The biological activity of the soil is determined by a set of indicators, among which, in agriculture, the orientation and activity of biological processes characterizing individual stages of the transformation of substances, expressed in the number of individual physiological groups of microorganisms, is of the greatest importance.

Our analyses showed that in the soil layer 0-20 cm under sunflower plantings, the quantitative composition of microorganisms varied markedly depending on the biologization techniques used (Table 2).
Table 2. The number of microorganisms of various physiological groups, depending on the studied methods of biologization in sunflower cultivation, average for 2013-2016.

| Phase          | Variant        | assimilating mineral nitrogen | oligonitrophils | ammonifying fungi | actinomycetes | azotobacter | bacteria | fungi | actinomycetes | total |
|----------------|----------------|-----------------------------|----------------|-----------------|---------------|-------------|----------|-------|--------------|-------|
| after harvesting the barley | F              | 11.2                        | 6.4            | 6.3             | 38.5          | 1.0         | 0.6      |       | 1.320        | 0.042 | 65.362 |
|                | F+Ps            | 9.9                         | 8.3            | 7.2             | 28.4          | 1.0         | 0.7      |       | 1.470        | 0.065 | 57.035 |
|                | F+Ps+Bd         | 10.8                        | 8.0            | 6.8             | 28.3          | 1.0         | 0.6      |       | 1.636        | 0.043 | 57.179 |
|                | F+Ps+Bl         | 5.6                         | 7.9            | 5.0             | 28.2          | 1.1         | 0.6      |       | 2.110        | 0.194 | 50.809 |
| full ripeness  | F+Op            | 10.5                        | 7.6            | 5.8             | 39.4          | 1.0         | 0.7      |       | 1.286        | 0.045 | 66.331 |
|                | F+Ps+Bd         | 10.8                        | 8.1            | 6.4             | 30.6          | 0.9         | 0.8      |       | 1.401        | 0.078 | 59.079 |
|                | F+Ps+Bl         | 11.0                        | 8.6            | 6.5             | 28.8          | 0.8         | 0.7      |       | 1.667        | 0.183 | 58.250 |

The influence of biologization techniques was already visible after the application of postharvest sideration. If during the period from harvesting the precursor (barley) to sowing sunflower in the control variant, the number of microorganisms decreased by $14.958 \times 10^5$ CFU/g of soil, i.e. by 22.9%, then in the variants with the use of postharvest sideration (oil radish), this decrease was less pronounced and amounted to 10.5-11.1%. At the same time, groups of microorganisms showed a different reaction to the entry of the sideral mass into the soil. For example, during the period under review, there was a decrease in the number of ammonifying microorganisms, microorganisms assimilating mineral nitrogen, oligonitrophils and an increase in the number of cellulosolytic bacteria and actinomycetes in the variants with postharvest sideration; the content of azotobacter remained virtually unchanged.

As a result, at the time of germination of oilseed crop cultivated using traditional technology, the total number of groups of microorganisms determined by us in the soil layer 0-20 cm was $50.404 \times 10^5$ CFU/g of soil. The use of postharvest sideration, an increase in the amount of plant residues entering the soil activated the growth of the number of soil microorganisms to an average of $50.920 \times 10^5$ CFU/g of soil.
The number of microorganisms, $1 \times 10^5$ CFU/g of soil

1) ammonifying microorganisms
2) assimilating mineral nitrogen
3) cellulosolytic bacteria
4) cellulosolytic actinomycetes
5) oligonitrophils
6) actinomycetes
7) fungi
8) azotobacter

- after harvesting the precursor; - sunflower seedlings; - full ripeness of sunflower; 1, 2, 3 - variants (see the experiment scheme)

**Figure 1.** The number of different groups of microorganisms in the soil layer 0-20 cm under the sunflower.
At the time of sunflower germination, cellulosolytic microorganisms had the greatest predominance over the indicators of the control variant: the number of cellulosolytic bacteria on average exceeded the control indicators by $0.501 \times 10^5$ CFU/g of soil, and cellulosolytic fungi - by $0.015 \times 10^5$ CFU/g of soil. In addition, the number of oligonitrophils (by $0.05 \times 10^5$ CFU/g of soil), ammonifying microorganisms (by $1.05 \times 10^5$ CFU/g of soil), fungi (by $0.45 \times 10^5$ CFU/g of soil) was higher than the control values. The number of microorganisms assimilating mineral nitrogen, actinomycetes, azotobacter and cellulosolytic actinomycetes was less than in the control variant.

During the growing season of sunflower, the number of soil microorganisms increased and by the full crop ripeness was $66,331 \times 10^5$ CFU/g of soil on the variant of single-species sowing (+31.6%) and $58.250...59.079 \times 10^5$ CFU/g of soil - on variants with binary plantings (+14.6...15.8%). As we can see from Table 2 and Figure 1, the control variant is characterized by the highest growth rates of the total number of soil microorganisms - 31.6%, which was ensured by an increase in the number of groups such as ammonifying microorganisms (by 45%), microorganisms assimilating mineral nitrogen (by 84.2%) and fungi (by 37.8), including pathogenic ones. At the same time, there was a decrease in the number of cellulosolytic microorganisms (by 26.5 and 90%), oligonitrophils (by 1.3%), actinomycetes (by 16.7%) and azotobacter (by 12.5%).

In the variants with the use of biologization techniques, the increase in the number of microorganisms in the soil was primarily due to an increase in the number of ammonifying microorganisms (by 25.5-30%), microorganisms assimilating mineral nitrogen (by 96.4-170%), cellulosolytic actinomycetes (by 74.3%), oligonitrophils (by 6.6-8.9%), azotobacter (by 14.3-16.7%) and fungi (by 2.1-2.3%). The number of cellulosolytic bacteria decreased by 21-41.4%, and the number of actinomycetes - by 10-27.3% to the full ripeness of sunflower.

Thus, the applied methods of biologization provide an increase in the number of soil microorganisms that play an important role in the decomposition of plant residues, in the formation of soil fertility.

An increase in the rate of decomposition of plant residues due to the joint use of barley straw and sideral mass for fertilizer ensures an increase in the detritus content in the soil to the full ripeness of sunflower. If during the cultivation of oil cvrop without the use of biologization techniques (control), the detritus content in the soil during the period from harvesting the precursor to full ripeness of the crop decreased by 28.6%, then during sunflower cultivation in binary plantings with perennial legumes on the background of joint use for fertilizing barley straw and postharvest sideration the detritus content increased significantly (by 4.7-9.9%).

Agrotechnical and biological measures to control weeds play an important role in reducing the anthropogenic load on the agrocenosis. In our studies, both postharvest sideration and binary components of oil crop had a positive effect on reducing the weed infestation of sunflower plantings.

Oil radish, used as a postharvest siderate, during the intensive growth of vegetative mass provided a depressing effect on weed vegetation, and after embedding in the soil, due to substances released during decomposition, it had an inhibitory effect on germinating seeds of weed plants, which ensured the least weed infestation of sunflower plantings during the germination phase.

During the growing season, binary sunflower plantings showed a restraining effect against weeds. Yellow mellilot and purple alfalfa growing in the same row with sunflower, providing significant competition to weeds for the main life factors, provided a more intensive reduction in the contamination of plantings during the growing season of oil crop. thus, on average, during the growing season, the number of weeds in binary sunflower plantings was 9-18 pcs./m² less than with its single-species planting. In addition, in these variants, the biomass formed by weed vegetation was 18-35 kg/ha less than in the control.

The effectiveness of reducing weed infestation when cultivating sunflower in binary plantings with legumes without the use of herbicides, as well as improving the main indicators of soil fertility under the influence of biologization techniques was expressed in a significant increase in the yield of oilseeds. On average, over the years of research, the maximum yield of sunflower was obtained when it was cultivated in binary planting with purple alfalfa by postharvest sideration of oil radish - 3.07
t/ha. The sunflower yield was formed insignificantly less (by 0.15 t/ha at LSD05 = 0.168 t/ha) with binary planting with yellow melilot: 2.92 t/ha. The yield of oilseeds with single-species planting turned out to be the lowest - 2.74 t/ha (deviations from the studied variants are significant).

Thus, the cultivation of sunflower in binary plantings with leguminous grasses on the background of joint use for fertilization of barley straw and postharvest sideration of oil radish provides an increase in the content of plant residues in the soil, an increase in the number of soil microorganisms, an increase in detritus content, a decrease in the weed infestation of plantings, which in combination provides a significant increase in sunflower yield.

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