Use of binary agrocenoses to increase the stability of agroecosystems and obtain environmentally friendly products

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Abstract. Modern agriculture is characterized by the fact that the increase in agricultural production is focused on the widespread use of intensive soil cultivation and high pesticidal load, which is accompanied by pollution of ecosystems and deterioration of product quality. The solution to this urgent problem is possible only on the base of a comprehensive ecologization of land use processes. The objects of research are winter wheat Bezenchukskaya 380, potato Impala, hairy vetch (wheat) Glinkovskaya, segetal vegetation, straw of winter wheat, biomass of hairy vetch. Sowing hairy vetch into winter wheat agrocenosis was carried out in spring at the same time as top dressing of grain crops (ammonium nitrate 30 kg / ha active substance) with a seeding rate of 15 kg / ha. After harvesting the monoculture, straw was added into the soil together with the green mass of the vetch. The introduction of hairy vetch into the agrocenosis had a negative effect on the development of segetal plants and ensured an increase in the yield of winter wheat by 19.3-21.2%. The advantage of plowing straw with hairy vetch biomass compared with the introduction of straw into the soil along with fertilizer mineral nitrogen was found to be 8.9-12.6% faster for decomposing linen, 5.7% for mobile phosphorus and 6.3% for exchange potassium. The highest potato yields were formed with the use of green mass of vetch and straw of 20.9 t / ha, which exceeded the variant with straw together with mineral fertilizers by 23.7%.

1. Introduction

The problem of creating highly productive and environmentally sustainable agrophytocenoses is one of the most complex and least studied in agroecology. This is primary due to the issues of regulating the composition of agrophytocenoses, which provide for a certain ratio of cultivated and weed (segetal) plants in field communities [1,2,3].

The development of scientific research in this area is mainly aimed at the development of agrotechnical techniques and chemicals in order to completely destroy weeds. This path led to a deadlock, since weeds could not be destroyed as a component of agrophytocenosis. In addition, many of their species as a result of biocenotic adaptability at various levels (morphological, genetic, etc.) have become resistant to the herbicides used. In addition, it should be noted that most of the techniques aimed at the destruction of segetal plants are openly anti-ecological in nature. The herbicides that accumulate in soil, plants, water, and animals can cause deep and irreversible disturbances in the normal cycles of the biological cycle of substances and a decrease in the productivity of ecosystems. With increasing use of herbicides, their residues and metabolic products can accumulate in environmental objects, migrate along food chains and cause negative consequences, adversely affecting environmental quality and human health [4].

In this regard, it is important to develop an environmentally friendly system for managing the components of agrophytocenosis that increases the stability of agroecosystems and allows the production of environmentally friendly products.
The purpose of the work is to study the structure of agrophytocenosis of winter wheat when using an inoculum culture (hairy vetch) and the effectiveness of the subsequent introduction of its biomass into agroecosystem with cereal by-products.

2. Materials and methods
The studies were carried out in 2014-2017 on the basis of the agricultural enterprise “Rykanskoye” in Novousmansky district of the Voronezh region. The climate is temperate continental with unstable moisture. Meteorological conditions during the period of research were characterized by an increased temperature regime and uneven precipitation. The average annual temperature overall years exceeded the mean annual value by 6.1 °C, in the abnormally warm 2015 - by 2.6 °C. Precipitation deficit was observed in 2014 and 2015, with an average annual amount of 554 mm, they fell by 120 mm and 21 mm less, respectively. Abnormally humid weather conditions developed in 2016, with a norm of 579 mm - 787 mm, the bulk of rainfalls was in the spring - 311 mm, which is three times more than the average long-term value.

The soil of the experimental plot of chernozem is leached, heavy loamy, thin with humus content of 4.5 ... 5.1%, pH of salt extract - 5.38, mobile phosphorus – 149 mg/kg and exchange potassium – 120 mg/kg.

Field experiments were carried out in the link of grain-crop rotation of winter wheat - potatoes. The crops were cultivated according to the generally accepted agrotechnology in the zone. We used winter wheat Bezenchukskaya 380, Impala potatoes, and Glinkovskay hairy vetch. The vetch was sown in the agroecosystem of winter wheat in the spring period at the same time as root top dressing of grain crops (ammonium nitrate 30 kg / ha active substance), sowing rate of 15 kg / ha.

In the potato agroecosystem, studies were carried out according to the following scheme: control (without fertilizers); straw with nitrogen compensation with ammonium nitrate 10 kg active substance per 1 ton of straw; straw together with the green mass of hairy vetch. Shredded straw (5 ... 7 cm), the biomass of hairy vetch were planted into the soil in the autumn by disking to a depth of 8 ... 10 cm.

The accounting plot area is 100 m², the repetition in the experiment is four times and the placement of options is systematic. The species composition and abundance of segetal plants were determined using a reference frame with an area of 1 m²; the number and weight of nitrogen-fixing nodules - by digging up a monolith of 30 x 30 x 15 cm in size with subsequent washing of the nodules; cellulolytic activity of the soil – by the application method.[5]

Mobile forms of phosphorus and potassium in the soil were found according to Chirikov in the modification of Central Research Institute of Agrochemical Service of Agriculture; pH of salt extract, nitrate nitrogen content - by potentiometric method. The results of experiments and analyzes were statistically processed by analysis of variance. [6]

3. Discussion of results
It was found that overseeding hairy vetch in agroecosystem of winter wheat has a significant influence on the formation of populations of segetal plants. In the phase of winter wheat tillering, the numeral strength of this component of agrophytocenosis amounted to 41.5 p/m², in monospecific planting it reached 77.5 p/m². Introduction of hairy vetch to agro-ecosystem influenced the development of segetal plants such as Echinochloa crusgalli L., Setaria viridis L. Beauv., Capsella bursa-pastoris L., Thlaspi arvense L., Matricaria perforate Merat, Viola arvensis Z., Gallium aparine L., Stellaria media L. Their number in comparison with annual sowing was reduced by 60.0; 58.3; 55.6; 40.0; 25.0; 42.4; 61.5; 35.0 % respectively. The distribution of Chenopodium album L. and Centaurea L. uganus at this stage of development of winter wheat in agrophytocenosis was not received.

The decrease in the number of segetal plants is associated with the high allopathically activity of hairy vetch seeds. In the work [3] and others it was noted that the vetch hairy seeds contain physiologically active substances that can cause sharp inhibition of seed germination and growth of primary roots of many weeds.
In the future, hairy vetch plants being in the lower tier of agrophytocenosis fill an ecological niche and with high competitiveness hinder the development of segetal plants. So, in the earing phase of winter wheat the composition of the segetal plants expanded at the expense of late spring plants, such as *Cirsium arvense*, *Amaranthus retroflexus* L., *Solanum nigrum* L. The number of weeds also increased. But it was the same as in the previous period of accounting in the variant with sowing in the agrocenosis Vetch hairy and accounted for 65.0 p/m², which is less than monospecific farming for 53.9 %. The same pattern continued in the maturing stage of winter wheat (tab. 1).

Table 1. Composition of segetal plants in the vegetation phases of winter wheat seeds p/m²

| Plant                        | Tillering | Earing emergence | Maturation |
|------------------------------|-----------|------------------|------------|
|                              | Single – species agrocenosis | Vetch hairy reseeding | Single – species agrocenosis | Vetch hairy reseeding | Single – species agrocenosis | Vetch hairy reseeding |
| *Echinochloa crusgalli* L.  | 7.5       | 3.0              | 9.0        | 3.5        | 9.5        | 3.0        |
| *Setaria viridis* L. Beauv. | 6.0       | 2.5              | 26.5       | 14.5       | 28.0       | 15.5       |
| *Amaranthus retroflexus* L. | -         | -                | 4.5        | 1.5        | 7.5        | 3.0        |
| *Capsella bursa-pastoris* L. | 9.0       | 4.0              | 14.0       | 5.5        | 14.0       | 6.0        |
| *Thlaspi arvense* L.        | 7.5       | 45               | 10.5       | 7.0        | 11.0       | 9.0        |
| *Sonchus arvensis* L.       | 2.5       | 2.0              | 3.0        | 2.0        | 4.0        | 2.5        |
| *Matricaria perforata* Merat.| 2.0       | 1.5              | 2.0        | 1.5        | 2.0        | 1.5        |
| *Viola arvensis* Z.         | 16.5      | 9.5              | 23.0       | 14.5       | 27.5       | 15.5       |
| *Poligemma aviculare* L.    | 4.0       | 3.5              | 6.0        | 4.0        | 7.0        | 5.5        |
| *Fallopia convolvulus* L.   | 3.0       | 5.0              | 5.5        | 5.5        | 5.5        | 6.0        |
| *Chenopodium album* L.      | 2.5       | -                | 4.0        | -          | 5.0        | 0.5        |
| *Cirsium arvense*           | -         | -                | 1.5        | -          | 2.0        | 0.5        |
| *Solanum nigrum* L.         | -         | -                | 0.5        | 1.5        | 1.5        | 1.5        |
| *Centaurea uganus* L.       | 1.5       | -                | 2.0        | 0.5        | 2.0        | 0.5        |
| *Galliurn aparine* L.       | 6.5       | 2.5              | 8.5        | 4.0        | 9.0        | 5.5        |
| *Stellaria media* L.        | 10.0      | 6.5              | -          | -          | -          | -          |
| The total number of plants  | 78.5      | 44.5             | 120.5      | 65.0       | 135.5      | 75.0       |

The structure change in agrocenosis has had an impact not only on the composition of the weed component of planting but on microphytoclimatic conditions agrophytocenosis as well. So, the amount of productive moisture in the upper soil layer (0...20 cm) at the option of using the vetch hairy excess monospecific farming was 5.2% (2014), 7.2 (2015) and 6.5% (2016).

The change in microphytoclimatic conditions in binary sowing is connected with a change in agrophytocenosis structure as a legume crop forms already at early stages of development of a closed sward, which is located in the lower tier of the planting, thereby reducing the evaporation of moisture from the soil. Moreover, uniform distribution of roots in the soil profile promotes a more rational use of moisture from all soil horizons, compared with single –species sowing.

In the maturing stage of winter wheat winter vetch forms a well-developed symbiotic apparatus. Over the period of the studies the number of tubercles per plant ranged from 14.5 to 15.3 pieces, their weight from 46.0 to 49.8 mg.

The yield of winter wheat when seeding the vetch hairy was 33.7 dt/ha (LSD<sub>0.95</sub> 1.1) in 2014, in 2015 – 33.8 dt/ha (LSD<sub>0.95</sub> 3.2), in 2016 – 31.9 dt/ha (LSD<sub>0.95</sub> 1.6) and exceeded the one-species farming at 19.3, 17.6 and 21.2%, respectively.
Vetch hairy vegetation did not end after the harvesting of winter wheat, the formation of biomass and the time of tillage was increased to 0.7...1.1 t/ha, the content of nitrogen in it ranged from 3.39 to 4.43%. It is established that the ratio of winter wheat straw and biomass of vetch hairy was 5.8:1 (2014), 3.9:1 (2015), 4.3:1 (2016), in this case between the carbon and nitrogen it approached to the optimum – 18:19. Therefore, vetch biomass application together with the straw provides effective decomposition of by-products cereal component and has a positive effect on soil biotic complex.

The determination of the soil biological activity by the intensity of linen decomposition in the potato agroecosystem have clearly shown a significant superiority of the straw use together with hairy vetch biomass in the case of straw introduction in combination with nitrogen fertilizer, the ratio was 8.9...12.6%. The greatest activity cellulose-digesting microorganisms was noted in 2015...24.9 36.5 and in 2017 – 28.5 38.9%. Linen bed decayed less intensively by 21.6 ... 30.5% in 2016, largely due to significant rainfall deficit in summer (table. 2).

| Table 2. Intensity of linen decomposition, %. |
|---------------------------------------------|
| Option                                      | 2015   | 2016  | 2017  |
| Control (without fertilizes)                | 17.1   | 13.3  | 21.4  |
| Straw + NH₄NO₃ (10 kg/t a.v.)               | 24.9   | 21.6  | 28.5  |
| Straw + vetch green mass                    | 36.5   | 30.5  | 38.9  |

It was found by the research of authors dealing with this problem that the straw in the first year of application deteriorates nutrient status of the soil due to active microbial decomposition and the use primarily of soil nitrogen. It is known that cellulose-digesting organisms experience relatively high demand for nitrogen and with a small amount of it in the straw microorganisms consume mineral nitrogen from the soil. This is the process of immobilization of this element.

In our studies the straw incorporation into soil did not lead to decreasing the content of nitrate nitrogen, moreover, the introduction of the straw had the advantage of the control to 10.6...18.7 %. Therefore, the deterioration of potatoes nitrogen nutrition when making straw occurred. The use of straw in conjunction with hairy vetch biomass provide improved phosphorous-potassium regime of soil, the excess of phosphorus with respect to the straw in combination with mineral nitrogen was 5.7, exchange potassium – 6.3%.

When straw introduced together with ammonium nitrate, a slight increase in the acidity up to 5.32 was noted. It was due to acidic nitrogen fertilizer while the introduction straw with hairy vetch biomass did not change pH (table. 3).

| Table 3. Agrochemical properties of leached Chernozem. |
|------------------------------------------------------|
| Option                                               | pH_KCl | N-NO₃, mg/kg | P₂O₅, mg/kg | K₂O, mg/kg |
| Control (without fertilizes)                         | 5.42   | 7.5          | 149         | 121        |
| Straw + NH₄NO₃ (10 kg/t )                            | 5.32   | 8.3          | 158         | 128        |
| Straw + vetch green mass                             | 5.40   | 8.9          | 167         | 136        |

The improvement in the nutrition of plants primarily affects the increase in leaf area, which in this case has a decisive influence on yield. The lengthening of the active period of their life plays a main role.

The use of vetch green mass in combination with straw provides the greatest leaf area of potato agroecosystem that was as follows: 9.6 in shoots; 24.6 in budding; 36.9 thousand m²/ha in flowering, and was higher on 9.1; 24.2; 14.6 %, respectively in the case of straw and nitrogen fertilizer application.

The use of straw together with mineral fertilizer and hairy vetch green mass ensured a reliable yield increase with regard to the control option of 5.9 t/ha and 9.9 t/ha respectively.
The largest yield of potatoes was obtained by applying the green mass and straw that exceeded the option with incorporation of straw together with mineral fertilizer at 23.7% (table 4).

### Table 4. Potato yield in different options t/ha

| Option                        | 2015 | 2016 | 2017 | Average over three years |
|-------------------------------|------|------|------|--------------------------|
| Control (without fertilizers) K | 11.1 | 9.5  | 12.8 | 11.0                     |
| Straw + NH₄NO₃ (10 kg/t a.s.)  | 15.9 | 16.3 | 18.6 | 16.9                     |
| Straw + vetch green mass      | 20.8 | 18.6 | 23.5 | 20.9                     |
| HCP₀.₉₅                        | 4.8  | 2.1  | 3.4  |                          |

### 4. Conclusion

Thus, overseeding vetch hairy (winter) in agrocenosis of winter wheat provides a change in the composition and abundance of segetal population, improving microphyto-climatic conditions of agrocenosis, which in turn increases the harvest of winter wheat. Incorporation into the soil vetch hairy biomass jointly with winter wheat straw has a positive effect on biological, agrochemical properties of the soil and provides favorable conditions for the growth and development of potatoes.

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