Use of straw in organic farming

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Abstract. The article describes the results of a study on the use of crop residues (straw) as a fertilizer in the organic farming system. The studies were carried out in two farms of Ryazan region and consisted in disposing of crop residues as a fertilizer using a special machine. It is a device for utilizing the non-grain part of the crop as a fertilizer and using the standard technology with the addition of biological products with the help of a sprayer. The design of the developed machine allows selection and grinding of the plant material with its simultaneous treatment with a working solution of biopreparations or stubble destructors. Recycled plant residues were treated with various biopreparations: Agrinos-1 1.2-2 l/ha, Sterinfag SP 80 g/ha, Ecorost 0.4 l/ha and Biocomplex BTU 1 l/ha. As a control, the straw was crushed and embedded in the upper soil layers without treatment with biopreparations. From the moment of disposal of crop residues and until the beginning of spring barley sowing in April 2019, the activity of cellulose-degrading bacteria in the soil was recorded (using the linen method). Content of the main micro and macro elements was established by a comprehensive chemical analysis. Before harvesting in August 2019, biological productivity was recorded (it was 15.2% higher on variants using biopreparations for stubble destruction) and the quality was assessed by the protein content in the grain.

1. Introduction

Straw (crop residues or non-cereal crop) is a by-product of crop production. For example, grain crops have up to 2/3 of the total biological yield [1, 2], while it serves as an energy source for soil microflora, which is a determining factor controlling the activity of microorganisms in the soil [1–5]. However, when plant residues are embedded in the soil, a long, up to 3-5 years, period of its humification follows, which is accompanied by the release of phenolic compounds that inhibit the development of subsequent plants [3, 6, 7]. One can also note that the straw accumulated in fields after harvesting the main products can interfere with the operation of machine and tractor units that perform the next technological operations, for example soil tillage, which can cause some violation of agrotechnological periods (for example, winter sowing).

The use of plant residues as a fertilizer is most interesting and promising and it fits the organic farming system. To accelerate the process of their humification, it is promising to use biopreparations (for example, Agrinos-1, Sterinfag SP, Ecorost, Biocomplex BTU, etc.), which demonstrate physiological activity. In ultra-low doses, they stimulate plant growth and development, inhibit the action of pathogens and increase the utilization rate of the main mineral fertilizers, accelerating the decomposition and transformation of by-products in the soil, reducing the activity of heavy metals and harmful chemical compounds. In addition to the direct effect on the plant, preparations also have an
indirect effect on improving the water-physical, mechanical and biological properties of the soil, activate soil biota and reduce the intake of radionuclides and nitrates in plants.

2. Materials and methods
The studies were carried out in the URC “Agrotehnopark” FSBEI HE Ryazan State Agrotechnological University (FSBEI HE RSATU) and Agrochim LLC in Starozhilovskiy district of Ryazan region. The crop residues were disposed with two different technologies, shown in Figure 1. In the first case, the combine harvester harvested the entire biological crop. The grain was threshed and collected in a bunker and the non-grain part was laid behind in the form of a roll. Then it was picked up, crushed and processed with a working solution of a biopreparation for stubble destruction. It was evenly distributed over the field surface using a device for utilization of the non-grain part of the crop as a fertilizer [1, 2] (this machine, depending on the configuration, can carry out the incorporation of a ready-made biological fertilizers in the soil). In the second case, the combine harvester crushed the non-cereal part of the crop and scattered it over the field surface. Then, using a sprayer, the plant residues were treated with a working solution of a stubble destructing biopreparation, followed by soil tillage with a disk implement.

The following biopreparations were used to prepare the working solution: Agrinos-1 (1.2 l/ha), Sternifag SP (80 g/ha), Ecorost humic product (0.4 l/ha) and Biocomplex BTU (1 l/ha). The straw in the control plot was crushed and embedded into the upper soil layers without treatment with biopreparations. This experimental design was used at URC "Agrotehnopark" FSBEI HE RSATU from August 2018 to the present (utilization is carried out using the unit for utilization of the non-grain part of the crop as a fertilizer). In this design, wintering of linen of one sample was provided for evaluating the effect of biopreparations in winter (at freezing temperatures). At Agrochim LLC, the experimental design (2019) was as follows: Agrinos 1 (2 l/ha), Sternifag SP (80 g/ha), Ecorost (0.4 l/ha) and the control was without treatment (treatment with a sprayer). Sowing and laying the
experiment were in May and harvesting was in September. Next spring barley of brewing variety "Laurica" of German breeding was sown. Then plates covered with linen were dug into the soil. The change in the mass of the linen compared with the initial one was used to evaluate the activity of cellulose-degrading bacteria in the soil (linen method). A comprehensive agrochemical analysis of the soil was carried out for each treatment option according to the following indicators: pH, K2O, P2O5, NO3, Zn, Cu, B, organic matter. Throughout all time, the average daily air temperature and the amount of precipitation were monitored. Three sheaves were collected from 1 m² each to record biological productivity in each experimental plot. Then, the number of plants, the number of all and productive stems were determined in each sheaf. From each sheaf, 25 ears were taken, for which the length, the total number of grains in the ear, the number of undeveloped grains in the ear and the weight of grain from the ear were determined. The quality of the crop was evaluated by protein content, which was determined using an infrared analyzer Spectran-119M. The unit for utilization of the non-cereal part of the crop as a fertilizer was made on the basis of the Kverneland fx-230 serial shredder-cutter. It was used in the field work at URC "Agrotehnopark" FSBEI HE RSATU without a complex for embedding the ready-made fertilizer into the soil.

3. Results
The results of the agrochemical analysis of the soil were obtained (Table 1) at URC "Agrotehnopark" FSBEI HE RSATU. Figure 2 shows the rate of decomposition of linen at URC "Agrotehnopark" FSBEI HE RSATU and Figure 3 presents the rate of decomposition of linen at Agrochim LLC.

Table 1. Results of agrochemical analysis of the soil November 11, 2018 (86 days) April 6, 2019 (236 days)

| Parameter                   | Option                      | Control      | Agrinos-1 | Sternifag, SP | Ecorost | Biocomplex, BTU |
|-----------------------------|-----------------------------|--------------|-----------|---------------|---------|-----------------|
| pH (salt extract)           |                             | 5.2 / 5.1    | 6.1 / 5.8 | 5.7 / 5.6     | 4.9 / 5.2 | 4.9 / 4.8       |
| K2O mg/kg of soil           |                             | 135 / 160    | 162 / 181 | 205 / 220     | 208 / 186 | 99 / 112        |
| P2O5 mg/kg of soil          |                             | 178 / 165    | 234 / 231 | 245 / 246     | 212 / 201 | 225 / 241       |
| NO3 mg/kg of soil           |                             | 10.46 / 3.36 | 5.28 / 6.04 | 9.21 / 6.03  | 36.13 / 9.16 | 24.32 / 19.08  |
| Organic matter, %           |                             | 2.72 / 2.63  | 2.31 / 2.76 | 2.58 / 2.70   | 2.55 / 2.71 | 2.37 / 2.63     |

Trace elements

| Parameter        | Option                   | Control      | Agrinos-1 | Sternifag, SP | Ecorost | Biocomplex, BTU |
|------------------|--------------------------|--------------|-----------|---------------|---------|-----------------|
| Zinc (Zn), mg/kg of soil | 1.09 / 14.29 | 1.33 / 16.29 | 1.33 / 29.29 | 0.96 / 23.57 | 0.84 / 30.71 |
| Copper (Cu), mg/kg of soil | 6.05 / 6.67 | 7.89 / 6.36 | 6.84 / 7.58 | 6.58 / 7.27 | 6.05 / 6.36 |
| Boron (B), mg/kg of soil   | 0.60 / 0.79 | 0.80 / 0.81 | 1.02 / 0.66 | 0.63 / 0.65 | 0.68 / 0.71 |
| Sulphur (S), mg/kg of soil | 5.3 / 3.3 | 2.7 / 4.1 | 4.2 / 4.8 | 7.1 / 4.8 | 3.9 / 3.8 |
Figure 2. The rate of decomposition of linen at URC "Agrotehnopark" FSBEI HE RSATU, 2018-2019

Figure 3. The rate of decomposition of linen at LLC Agrochim

Quantitative and qualitative indicators of harvested spring barley were obtained. The best results were shown by the "Vladimir" variety of the Russian selection in the second reproduction of fodder barley production in August 2019 (Table 2). Here, maximum protein content is considered best in
quality. Results for the German brewer’s barley variety Laurika for September 2019 are presented in Table 3. The main task when growing brewer’s barley is to have protein level between 9% and 11%.

**Table 2.** Quantitative and qualitative indicators of the harvested crop at URC "Agrotechnopark" FSBEI HE RSATU

| Parameter                  | Option          | Agrinos-1 | Sternifag, SP | Ecorost | Biocomplex, BTU | Control |
|----------------------------|-----------------|-----------|---------------|---------|-----------------|---------|
| Biological yield, dt/ha    |                 | 40.60     | 38.28         | 29.75   | 33.00           | 27.70   |
| Protein, %                 |                 | 13.6      | 12.8          | 13.3    | 12.5            | 11.0    |

**Table 3.** Quantitative and qualitative indicators of the harvested crop at Agrochim LLC

| Parameter                  | Option          | Agrinos-1 | Sternifag, SP | Ecorost | Control |
|----------------------------|-----------------|-----------|---------------|---------|---------|
| Biological yield, dt/ha    |                 | 34.89     | 29.35         | 26.37   | 25.73   |
| Protein, %                 |                 | 10.9      | 10.3          | 10.7    | 10.9    |

4. Discussion

Treating crop residues with biopreparations contributes not only to their accelerated decomposition, but also to an increase in the yield of agricultural crops.

The experiment at URC "Agrotechnopark" FSBEI HE RSATU showed a high increase in the activity of bacteria that are part of Agrinos-1 for 100 days. The same acceleration was also observed with Sternifag SP, which might indicate the work of bacteria in the low temperature range. Ecorost and Biocomplex BTU preparations slowed down the decomposition rate in the winter period. So, after wintering (236 days of the experiment), more than 22% of linen had decomposition in the variants with Agrinos-1 and Ecorost, more than 18% of linen were decomposed with Sternifag SP.

The experiment at Agrochim LLC showed that sufficient moistening at high temperatures contributes to a more intensive decomposition of crop residues.

5. Conclusion

As a result of the studies, it was found that:

There is high efficiency of biological fertilizers and humic preparations to improve the microbiological parameters of the soil and accelerate the decomposition of crop residues. The greatest efficacy was shown by Agrinos-1 and Sternifag SP.

The yield increase in options with the use of spring barley straw as a fertilizer according to the technology with the proposed machine (the device for utilization of the non-grain part of the crop as a fertilizer) in combination with biopreparations was on average 15.2% higher compared to the classical technology (biopreparations are applied by a sprayer). The highest performance was shown by samples treated with Agrinos-1 and Sternifag SP.

Options with Agrinos-1 and Sternifag SP significantly accelerated the decomposition of crop residues in winter, which was reflected in an increase in the content of mobile forms of potassium by 13.5% and phosphorus by 1.2%. Options with Ecorost and Biocomplex BTU for the winter period did not contribute to the acceleration of the humification process, which was reflected in a decrease in the content of mobile forms of nitrogen, potassium and phosphorus in the soil.

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