The use of developed mushroom compost in crop cultivation technology

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Abstract. The scientific work analyzes experimental data on the cultivation of potatoes and rapeseed using elements of biologization in conditions of Ryazan region. Two-year studies have been carried out to study the effect of developed mushroom compost on the yield of potato tubers and rape of various varieties cultivated on dark gray forest soils of Ryazan region. The use of spent mushroom compost is a promising technique that allows to increase the productivity of crops and obtain environmentally friendly products. When cultivating potatoes and spring rape, first, bare fallow was used as a precursor, and then the introduction of 84 t/ha of fresh mushroom compost for the main processing of potatoes and 80 t/ha for spring rape, immediately after harvesting mushrooms in the form of developed blocks. In the second option, 95 t/ha of mushroom compost was used for potatoes and 89 t/ha was used for spring rape, after a year of storage of spent mushroom blocks. As a result of the use of two types of mushroom compost, the foliage of plants improved: on average, the largest increase in leaves was obtained in the option with fresh compost. Its use immediately after harvesting mushrooms exceeded the control by 12.8%, and the use of compost after a year of storage caused 7.6% increase. The highest average marketability of tubers for all varieties was noted in the option with fresh mushroom compost and averaged 80.8% for all varieties, which was 9.1% more than the control. The productivity of spring rape seeds increased when using mushroom compost as a fertilizer. The introduction of fresh compost under the main tillage increased the rape productivity by 2.9 dt/ha, and rotted compost by 1.9 dt/ha compared with the control. For all varieties of potatoes, the yield with fresh mushroom compost increased by 37.8 dt/ha or 20.1% compared to the control, and for the variant after a year storage of mushroom compost, the yield increased by 23.8 dt/ha or 11.3 %.

1 Introduction

One of the ways to improve the quality and productivity of potatoes and spring rape is the use of a mushroom substrate block including mycelium. The resulting organo-mineral fertilizer after picking mushrooms is safe for the soil and a crop, since it contains natural substances that help plants absorb useful elements [1;5].

It should be taken into account that trace elements being a part of the mushroom substrate in the form of mushroom compost (hereinafter referred to as mushroom compost) from developed blocks include calcium, potassium, phosphorus, nitrogen, etc. At the same time, mushroom compost reduces soil acidity and participates in moisture regulation in the soil. Mushroom substrate (compost) is very valuable in agriculture and has a low cost [6]. The fertilizer favorably affects the increase in the yield of crops, in particular, potatoes and spring rape. Plants are provided with trace elements at all stages of development, and are also resistant to diseases.

Consequently, the fertilizer will increase the fertility of the soil, its structure and the amount of the harvested crop, which has high quality indicators. The effect is achieved almost immediately: mushroom compost increases the yield in the first year of use.

It should be taken into account that the trend in potato production in certain areas of the country requires some reduction in the use of pesticides and a switch to biologics [7;11-12]. In this regard, mushroom composts obtained in advance in the process of known technologies, i.e. in the process of growing edible mushrooms, and representing blocks of developed waste, were previously considered a problem, taking into account environmental requirements and rules for the destruction of developed mushroom blocks. Biologists have found that mushroom compost is characterized by a rich organic composition, i.e. developed mushroom compost can be widely used in present agriculture, in particular, as an application for growing products in limited areas with intensive use of arable land, especially in suburban farms and for farmers with limited land plots. Here it is necessary to take into account the high content of organic substances, nitrogen and other elements noted above (K, Ca, P, Mg, Su, Fe) [3;8;10].

Science and practice have accumulated considerable experience in the technology of growing champignons and selecting the substrate. The production of champignons is associated with the creation of conditions in which they give a high yield. The profitability of mushroom growing depends not only on the organization of the growing process, but also on the quality of the planting material. Varieties (strains) of champignons are different in size, color and taste [9].

Organic materials are used as a substrate. They include pure manure, or the one with the addition of straw. Manure with sawdust is rarely used due to poor air permeability. Straw improves aeration, optimizes the content of nitrogen and carbon. Straw can be mixed with bird droppings and mineral fertilizers. Adding slurry improves soil quality [2].

It should be noted that the method suits well for the cultivation of potato and rape varieties. The substrate is characterized by a high content of organic matter, micro- and macroelements used in agricultural production to increase soil fertility and reduce the anthropogenic impact on the environment [4].

Consequently, the technology of cultivating potatoes and oilseeds in conditions of Ryazan region with the use of mushroom composts is not studied.

In this regard, the purpose of the research was to study the reaction of potato and rape varieties to the introduction of mushroom compost into the soil in the form of production waste after mushroom harvesting with appropriate processing and improvement of methods for increasing crop yields, as well as plant development, which is manifested in increased growth of the vegetative mass and leaf surface on all studied varieties in conditions of Ryazan region, taking into account getting environmentally friendly products.

2 Materials and methods

The studied varieties had production testing in agro-climatic conditions in the period from 2020 to 2021 at the experimental site of the Federal State Budgetary Educational Institution of Higher Education Ryazan State Agrotechnological University.

Agrochemical parameters of the used composts according to the results of analyzes at the agrochemical station of Federal State Budgetary Institution SAS "Podvyazyevskaya" were as follows: the organic matter was 65.4% when fresh compost and 29.3% when one year-old compost; the ash content was 8% when fresh compost and 74.1% when one year compost; pH was 8.0 when fresh compost and 7.3 when one year-old compost; the organic matter was 66.3% when fresh compost and 25.9% when one year-old compost; natural moisture content of total elements NPK was 0.5%, 0.63%, 0.44% when fresh compost and 0.45%, 0.51%, 0.39% when one year compost.

When cultivating potatoes and spring rape, first bare fallow was used as a precursor, and then 84 t/ha fresh mushroom compost was used for potatoes and 80 t/ha for spring rape for the main processing, immediately after harvesting mushrooms in the form of developed blocks. For comparison, the option of one year-old mushroom compost had a dose of 95 t/ha for potatoes and 89 t/ha for spring rape, after a year of storage of developed mushroom blocks, where the agrotechnics corresponded to zonal recommendations. Mushroom compost in the form of blocks was natural. It included mycelium of mushrooms, which was processed in the process of decay of the introduced organic elements in the form of components when cultivating mushrooms.

These mushroom substrates were used for research in the form of mushroom compost in the technology of growing potatoes of varieties Vympel, Velikan, Kolobok, Favorit, Ilyinsky, Zhigulevsky, Vostorg, Vasilek, Ivan da Marya, Lukyanovsky, Krasa Meshchery, Sineglazka, Nikulsky. Thus, the experiments included the following options (scheme):

- Without organic mushroom compost (substrate).
- The introduction of fresh mushroom compost into the soil after total mushroom harvesting at a dose of 84 t/ha.
- Introducing mushroom compost into the soil after storing it for a year, after mushroom harvesting at a dose of 95 t/ha.

For research, these mushroom substrates were used in the form of mushroom compost in the technology of growing spring rape varieties Rif, Ratnik, Rubezh.

The experiments included the following options:

- Without organic mushroom compost (substrate).
- The introduction of fresh mushroom compost into the soil after total mushroom harvesting at a dose of 80 t/ha.
- Introducing mushroom compost into the soil after storing it for a year, after mushroom harvesting at a dose of 89 t/ha.

An example of a specific implementation of the method of cultivation of the above varieties of potatoes was as follows. Records and observations during the growing season were carried out on the basis of "Methodology of state variety testing of agricultural crops" (1985). Mathematical processing of the results was performed according to B.A. Dospekhov (1985).

The studies were carried out in Ryazan region on gray forest soils in 2020 and 2021. Agrochemical analysis of the soil of the experimental plot was carried out at Federal State Budgetary Institution Station of the Agrochemical Service "Ryazanskaya".

The soil contained 3.3% humus. Its largest amount was in the 0-10 cm layer, and it decreased with depth. The content of P2O5 varied in soil layers from 10.5 to 14.6 mg/100 grams of soil, and K2O varied from 14.1 to 15.6 mg/100 grams of soil, respectively. The reaction of the soil environment was slightly acidic. The climate of the site was temperate continental, with moderately cold winters, warm summers and well-defined transitional seasons (spring and autumn).

According to the duration of the growing season the cultivation of the studied potato varieties was 175-185 days with a temperature above +5° C and 135-145 days with a temperature above +10° C. The average annual amount of precipitation was 510 mm. The

area of experimental plots was located in the zone of unstable and sometimes insufficient moisture, hydrothermal coefficient (HTC) was 1.2-1.3. In general, the weather conditions for the growing seasons of 2020 and 2021 amounted to HTC-0.95 and HTC-1.10, which were satisfactory for growth and development of potato varieties. The replication of options in the experiment was fourfold.

3 Results

As a result of adding fresh mushroom compost the number of leaves was on average 0.5 pieces more, and at the background of one year-old compost it was 0.3 pieces more.
The foliage of plants improved in the process of using two types of mushroom compost (substrate) and the largest increase in leaves was obtained in the option with fresh compost. Its use immediately after harvesting mushrooms gave 5.4 pieces or exceeded the control by 12.8% and the use of one year-old compost gave the increase of 3.2 pieces or exceeded the control by 7.6%.

The leaf-area duration in the control was 39.8 thousand m2/ha, while in the area with fresh mushroom compost it was 46.1 thousand m2/ha that exceeded the control by 15.8%, and with the one-year-old compost it was 44.0 thousand m2/ha that exceeded the control by 10.5%. Thus, a positive effect was revealed from the use of mushroom compost from developed mushroom blocks left after mushroom harvesting. The average number of tubers on one bush at the time of harvesting was 5.6 pieces in the control, 9.1 pieces when fresh compost and 7 pieces when one year-old compost.

The highest average marketability of tubers for all varieties was noted in the option with the use of fresh mushroom compost (immediately after harvesting mushrooms) and averaged 80.8% for all varieties, which was 9.1% more than the control. The marketability of the tuber itself was associated with a decrease in the content of the fine fraction by 25.9% compared to the control, while the proportion of the coarse fraction increased by 10.6%. When applying one year-old mushroom compost, marketability was 76.8%, which exceeded the control by 3.7%. However, these indicators could have been even more, since they were specifically related to weather conditions of 2021. The period of May - August 2021 was dry and hot.

Data on potato yield in the applied compost options are presented in table 1.

Table 1. The yield of potato varieties, dt/ha, average for 2020-2021.

Variety	Control	Fresh compost	% to the control	One year-old compost	% to the control
Vympel	235.0	279.6	119.0	256.5	109.1
Velikan	278.9	319.3	114.5	291.9	104.7
Kolobok	95.8	112.1	117.0	108.6	113.4
Favorit	109.7	147.4	134.4	140.9	128.4
Ilyinsky	221.1	265.3	120.0	230.8	104.4
Zhigulevsky	99.5	116.6	117.2	106.3	106.8
Vostorg	98.5	122.6	124.5	115.0	116.8
Vasilek	142.4	174.5	122.5	158.7	111.4
Ivan da Marya	129.4	164.6	127.2	148.3	114.6
Lukyanovsky	247.4	288.6	116.7	263.1	106.3
Krasa Meshchery	235.6	273.5	116.1	257.9	109.5
Sineglazka	123.5	144.4	116.9	139.2	112.7
Nikulsky	205.5	236.0	114.8	222.8	108.4

LSD_{05} dt/ha, AB interactions: 2020 – 2.17; 2021 – 3.38.

The yield in the control option was 170.9 dt/ha for all varieties and in the option with fresh mushroom compost the yield was higher by 37.8 dt/ha or 20.1%, and in the option with one year-old mushroom compost the yield was higher by 23.8 dt/ha or 11.3%.
Data on the yield of spring rape depending on the applied compost options are presented in table 2.

Table 2 shows that the smallest seed yield was got in the control and averaged 18.3 dt/ha. When using fresh compost for the main tillage, it increased the rape yield by 2.9 dt/ha, and rotted compost increased the yield by 1.9 dt/ha compared to the control.

Table 2. The yield of spring rape varieties, dt/ha, average for 2020-2021.

Variety	Control	Fresh compost	% to the control	One year-old compost	% to the control
Rif	19.2	22.1	115.1	21.3	110.9
Favorit	18.3	21.4	116.9	20.1	109.8
Ratnik	17.3	20.1	116.2	19.3	111.6

LSD_{05} dt/ha, AB interactions: 2020 – 1.16; 2021 – 2.24.

The technical result was achieved by the following facts: the method of using developed mushroom compost in the technology of growing potatoes and rape, including the preparation of compost and the source of adding the grown mycelium; the use of bare fallow as a precursor; nutrients used from organomineral fertilizers in the form of developed mushroom compost left after harvesting mushrooms in the form of champignon blocks; the substrate, which included the mycelium of mushrooms processed in the process of decay of organic fertilizers, was applied under the main tillage for potatoes at 84 t/ha and for spring rape at 80 t/ha of fresh compost immediately after harvesting the mushrooms, or in the form of 95 t/ha for potatoes and 89 t/ha for spring rape after one year-old compost, while planting potatoes was carried out when the physical ripeness of the soil was reached at a temperature of 8° C to a depth of 8-10 cm, and spring rape at 6°C to a depth of 1-2 cm.
The use of mushroom compost (substrate) in the form of fresh mushroom compost, immediately after mushroom harvesting, as well as mushroom compost after storage of used mushroom blocks for a year, affect all biometric indicators of each of the potato varieties in the direction of increasing the share of marketable potato yield.

The number of tubers against the background of fresh mushroom compost increased by 62% and against the background of one year-old mushroom compost increased by 60% compared to the control.

The maximum yield was noted according to the variety application: Velikan - 319.3 dt/ha, Lukyanovsky - 288.6 dt/ha, Vympel - 279.6 dt/ha, Ilyinsky - 265.3 dt/ha, Krasa Meshchery - 273.5 dt/ha, Nikulsky - 236 dt/ha. Favorit variety was next with 134% of the control against the background of fresh mushroom compost and 128.4% when using one year-old compost. Ivan da Marya variety was next in terms of the yield: it had 127.2% of the control against the background of fresh mushroom compost and 114.6% of the control against the background of mushroom compost after a year of storage. Vostorg variety was next with 124.5% of the control against the background of fresh mushroom compost and 116.8% of the control against the background of mushroom compost after a year of storage.
It should be noted that against the background of fresh mushroom compost and taking into account the climatic phenomena of that year marketability of some varieties was as follows: "Vympel" - 89.6%, "Nikulsky" - 88.3%, "Favorite" - 88, 0%, "Ilyinsky" - 86.5%. Thus, timing of phenological phases depends on weather conditions and the influence of organic mushroom compost.

The research results demonstrate a positive trend in increasing the productivity of spring rape seeds depending on the use of mushroom compost as a fertilizer. The smallest

yield of seeds was in the control averaging 18.3 dt/ha. The introduction of fresh compost under the main tillage increased the productivity of rape by 2.9 dt/ha, and rotted compost caused 1.9 dt/ha increase compared with the control. The maximum yield of 22/1 dt/ha among the studied varieties was in Rif variety when fresh compost was applied.

The use of organo-mineral fertilizers from developed mushroom blocks left after mushroom harvesting, and having a rich composition of nutrients, is a promising technique that allows to increase the yield of crops with environmentally friendly products in the form of potato tubers and spring rape oil seeds in conditions of Ryazan region.

The introduction of fresh mushroom compost for the main processing when cultivating potatoes in the amount of 84 t/ha and when cultivating spring rape in the amount of 80 t/ha ensured an increase in potato yield by 37.8 dt/ha and spring rape by 2.9 dt/ha.

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