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CHANGES IN CROP YIELD AND QUALITY OF CROP PRODUCTS AGAINST THE EFFECTS OF SEWAGE SLUDGE FROM URBAN WASTEWATER AND THEIR COMBINATIONS WITH ZEOLITE-CONTAINING AGRO-ORE

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Abstract

The most important task of agriculture at the present stage of its development is to increase the production of high-quality crop products. In this regard, the development of technological methods for the use of local raw materials in order to increase the yield and quality of crop products is relevant. The purpose of the research was to study the aftereffect of urban sewage sludge and their combinations with zeolite-containing agro-ore on crop yields and the quality of crop production in the conditions of the forest-steppe of the Middle Volga region. It has been established that the complex aftereffect of increased norms of urban sewage sludge (160 and 180 t/ha) and zeolite-containing agricultural ore increased the yield of Jackpot peas in 2019 by 1.12-1.14 t/ha, or by 48.9-49.8%, protein content in pea grain by 2.3-2.7%,

Key words*: sewage sludge, zeolite-containing agro-ore, productivity, gluten, protein.*

INTRODUCTION

In modern agriculture, the most important task is to increase the scale of crop production with high quality. Currently, the productivity of agricultural crops remains low due to the lack of means of intensification and to their high cost. The needs of crop production are especially poorly met by means of chemisation, which are the main factor in the growth of crop productivity (Arefiev et al., 2020a; Grishin et al., 2007). One of the promising methods for increasing the yield and the quality of agricultural products against the backdrop of constantly rising prices for mineral fertilizers is the use of cheaper local raw materials. Of the local raw materials in the Penza region (Russia Federation), sewage sludge (SS) can be used in large volumes as organo-mineral fertilizers, and zeolite-containing agricultural ore can be used as a chemical amendment. The use of SS in the form of organo-mineral fertilizers for agricultural crops is an environmentally safe method of their disposal. Thus, the use of SS as a fertilizer allows solving not only agronomic and environmental, but also resource problems (Grishinet al., 2009; Arefiev et al., 2020b; Vuaille et al., 2022).

At present, considerable foreign experience has been accumulated in the use of local non-traditional organic fertilizers (OSV) in the cultivation of agricultural crops (Tran et al., 2021; Wydro et al., 2021; Piersa et al., 2021). In the Russian Federation, the use of SS as an organo-mineral fertilizer when growing crops is limited, so there is a need for scientific justification for the development and application of methods for using sewage sludge in agriculture in the Volga forest-steppe region (Stelmakh et al., 2021; Kuzin et al., 2019).

According to numerous studies, the effectiveness of the effect of sewage sludge on soil fertility, crop yields, and crop production quality increases when sludge is used in combination with chemical amendments (Kuzin et al., 2013; Kuzina et al., 2021).

The purpose of the study was to study the aftereffect of the ameliorative norms of sewage sludge of urban wastewater (SS) in Penza (Russia) and their combinations with zeolite-containing agro-ore on crop yields and the quality of crop products.

MATERIALS AND METHODS

To achieve the aim of the current research, in 2014, a field experiment was established on a meadow-chernozem leached low-humus medium-thick medium-loamy soil according to the following scheme: 1. Without SS and zeolite-containing agricultural ore (control); 2. Zeolite-containing agricultural ore; 3. SS 100 t/ha; 4. SS 120 t/ha; 5. SS 140 t/ha; 6. SS 160 t/ha; 7. SS 180 t/ha; 8. SS 100 t/ha + zeolite-containing agricultural ore; 9. SS 120 t/ha + zeolite-containing agricultural ore; 10. SS 140 t/ha + zeolite-containing agricultural ore; 11. SS 160 t/ha + zeolite-containing agricultural ore; 12. SS 180 t/ha + zeolite-containing agricultural ore. The experiment was organized in three replicates, and the variants in the experiment were placed by the method of randomized repetitions. Each plot had 4 m^2. In the experiment, SS from the city of Penza was used, which is characterized by the following indicators: pHCL value - 6.0 units; hydrolytic acidity - 2.4 mg-equiv/100 g of precipitation, the amount of exchangeable bases - 31.6 mg-equiv/100 g of precipitation.. The content of nutrients: nitrogen (N)- 291%, phosphorus (P)- 116%, and potassium (K)- 120 mg/100 g of precipitation; carbon of organic matter - 21.2%. The concentration of heavy metals in the dry matter of sewage sludge, in the city of Penza, was significantly below the maximum permissible concentration. Zeolite-containing agricultural ore from the Luninskoye deposit with a clinoptilolite content of 41% was used as a chemical amendment in the experiment. Sewage sludge and zeolite-containing agricultural ore were introduced into the fallow field in 2014 for the main tillage. The dose of the amendment (zeolite) was calculated according to the content of clinoptilolite in the agricultural ore and was equal to 24.4 t/ha. Jackpot peas, winter wheat Moskovskaya 56, maize hybrid Ladoga 191 MV were cultivated in the experiment. Agrotechnics for the cultivation of peas, winter wheat and corn was generally accepted for the Penza region.

RESULTS AND DISCUSSIONS

In the conditions of 2019, the pea yield on the control variant was 2.29 t/ha. Against the background of the aftereffect of zeolite-containing agricultural ore, the pea yield was 2.67 t/ha. The increase in relation to the control variant was significant and amounted to 0.38 t/ha, or 16.6% (Table 1).

Table 1. The yield of Jackpot peas

Indicator	Yield (t/ha)	Deviation from control	
		t/ha	%
1. Without SS and zeolite-containing agro-ore (control)	2.29	-	-
2. Zeolite-containing agro-ore	2.67	0.38	16.6
3. SS 100 t/ha	2.69	0.40	17.5
4. SS 120 t/ha	2.71	0.42	18.3
5. SS 140 t/ha	2.85	0.56	24.5
6. SS 160 t/ha	3.08	0.79	34.5
7. SS 180 t/ha	3.09	0.80	34.9
8. SS t/ha + zeolite-containing agricultural ore	2.90	0.61	26.6
9. SS 120 t/ha + zeolite-containing agricultural ore	3.08	0.79	34.5
10. SS 140 t/ha + zeolite-containing agricultural ore	3.10	0.81	35.4
11. SS 160 t/ha + zeolite-containing agricultural ore	3.41	1.12	48.9
12. SS 180 t/ha + zeolite-containing agricultural ore	3.43	1.14	49.8
NSR_{05}		0.18	

Source: Compiled by the authors on the basis of the results obtained

The aftereffect of ameliorative norms of SS in combination with zeolite-containing agricultural ore had the highest effect on the impact on pea yield. The yield of peas in these variants varied from 2.90 (SS 100 t/ha + zeolite-containing agricultural ore) to 3.43 t/ha (SS 180 t/ha + zeolite-containing agricultural ore).

The protein content in pea grain in the variant without the use of sewage sludge and zeolite-containing agricultural ore was 20.5%. Against the background of a unilateral aftereffect of zeolite-containing agro-ore and urban sewage sludge with a norm of 100 t/ha, there was a

tendency to increase the protein content in pea grain (20.8-21.4%).

The unilateral aftereffect of urban sewage sludge with norms from 120 to 180 t/ha significantly increased the protein content in pea grain by 1.2 (SS 120 t/ha) - 2.3% (SS 180 t/ha). The protein content against the background of their aftereffect varied in the range from 21.7 to 22.8%.

Against the background of the aftereffect of SS in combination with zeolite-containing agro-ore, the protein content in pea grain varied from 21.7 (SS 100 t/ha + zeolite-containing agricultural ore) to 23.2% (SS 180 t/ha + zeolite-containing agricultural ore), significantly exceeding the control by 1.2-2.7%.

According to the research results, in the variant without the use of urban sewage sludge and zeolite-containing agricultural ore, the yield of winter wheat in 2020 was 4.71 t/ha (Table 2).

Zeolite-containing agro-ore against the background of its unilateral aftereffect significantly increased the yield of winter wheat by 0.33 t/ha, or 7.0%.

Despite the background of a unilateral aftereffect of urban sewage sludge, the yield of winter wheat varied from 5.05 (SS 100 t/ha) to 5.97 t/ha (SS180 t/ha). The deviation from the control variant was significant and amounted to 0.34-1.26 t/ha, or 7.2-26.8%.

The aftereffect of SS in combination with zeolite-containing agricultural ore significantly increased the yield of winter wheat by 0.68 (SSUW 100 t/ha + zeolite-containing agricultural ore) - 1.62 t/ha (SSUW 180 t/ha + zeolite-containing agricultural ore), or by 14 .4-34.4%.

Table 2. Yield of winter wheat variety Moskovskaya 56

Indicator	Yield (t/ha)	Deviation from control	
		t/ha	%
1. Without SSUW and zeolite-containing agro-ore (control)	4.71	-	-
2. Zeolite-containing agro-ore	5.04	0.33	7.0
3. SS 100 t/ha	5.05	0.34	7.2
4. SS 120 t/ha	5.31	0.60	12.7
5. SS 140 t/ha	5.49	0.78	16.5
6. SS 160 t/ha	5.90	1.19	25.3
7. SS 180 t/ha	5.97	1.26	26.8
8. SS t/ha + zeolite-containing agricultural ore	5.39	0.68	14.4
9. SS 120 t/ha + zeolite-containing agricultural ore	5.64	0.93	19.7
10. SS 140 t/ha + zeolite-containing agricultural ore	5.87	1.16	24.6
11. SS 160 t/ha + zeolite-containing agricultural ore	6.28	1.57	33.3
12. SS 180 t/ha + zeolite-containing agricultural ore	6.33	1.62	34.4
NSR_{05}		0.24	

Source: Compiled by the authors on the basis of the results obtained

The content of gluten in the grain of winter wheat in the control variant was 22.4%. A significant increase in the gluten content against the background of a one-sided aftereffect of urban sewage sludge was noted in variants with aftereffect of sludge at rates of 120-180 t/ha. The content of gluten in the grain against the background of their aftereffect varied from 23.6 to 26.0%, exceeding the control by 1.4-3.6%.

The aftereffect of SS in combination with zeolite-containing agro-ore significantly increased the gluten content in winter wheat grain by 1.8-4.7%. The content of gluten against the background of their aftereffect varied in the range from 24.2 to 27.1%.

In the conditions of 2021, the yield of corn grain in the variant without the use of urban sewage sludge and zeolite-containing agricultural ore was 4.82 t/ha. Against the background of a unilateral aftereffect of the zeolite-containing agro-ore, the yield of corn grain was 5.19 t/ha, exceeding the control by 0.37 t/ha, or 7.6% (Table 3).

Table 3. Productivity of corn hybrid Ladoga 191 MB

Indicator	Yield (t/ha)	Deviation from control	
		t/ha	%
1. Without SSUW and zeolite-containing agro-ore (control)	4.82	-	-
2. Zeolite-containing agro-ore	5.19	0.37	7.6
3. SSUW 100 t/ha	5.22	0.40	8.3
4. SSUW 120 t/ha	5.47	0.65	13.5
5. SSUW 140 t/ha	5.66	0.84	17.4
6. SSUW 160 t/ha	5.93	1.11	23.0
7. SSUW 180 t/ha	5.96	1.14	23.6
8. SSUW t/ha + zeolite-containing agricultural ore	5.69	0.87	18.0
9. SSUW 120 t/ha + zeolite-containing agricultural ore	5.90	1.08	22.4
10. SSUW 140 t/ha + zeolite-containing agricultural ore	6.00	1.18	24.5
11. SSUW 160 t/ha + zeolite-containing agricultural ore	6.47	1.65	34.2
12. SSUW 180 t/ha + zeolite-containing agricultural ore	6.68	1.76	36.5
NSR_{05}		0.36	

Source: Compiled by the authors on the basis of the results obtained

The yield of corn grain against the background of a one-sided aftereffect of SS with dose from 100 to 180 t/ha varied in the range from 5.22 to 5.96 t/ha, exceeding the control by 0.40-1.14 t/ha, or by 8.3-23.6%.

The aftereffect of urban sewage sludge in combination with zeolite-containing agro-ore increased the yield of corn grain by 0.87-1.76 t/ha, or by 18.0-36.5%. The maximum yield of corn grain was obtained against the background of the aftereffect of urban sewage sludge at rates of 160 and 180 t/ha, both in pure form and in combination with zeolite-containing agricultural ore.

The yield of corn grain against the background of one-sided aftereffect of urban sewage sludge with norms of 160 and 180 t/ha was 5.93-5.96 t/ha, and in combination with zeolite-containing agricultural ore 6.47-6.68 t/ha, exceeding the control in in the first case by 23.0-23.6%, in the second by 34.2-36.5%.

The results of the study showed that the unilateral aftereffect of SS and their aftereffect in combination with zeolite-containing agro-ore had a positive effect on the protein content in corn grain.

In corn grain without the use of SS and zeolite-containing agricultural ore, the protein content was 8.91%, and its collection was 429.5 kg/ha. Against the background of a one-sided aftereffect of zeolite-containing agro-ore, the protein content in corn grain was 9.22%, and its collection was 478.5 kg/ha. The deviation from the control in the first case was 0.31%, and in the second one was 49.0 kg/ha.

The aftereffect of SS, depending on their dose, increased the protein content in corn grain by 0.43 (SSUW 100 t/ha) - 1.00% (SSUW 180 t/ha), protein collection by 58.0- 161.1 kg/ha. The protein content in the unilateral aftereffect of urban sewage sludge varied from 9.34 (SSUW 100 t/ha) to 9.91% (SSUW 180 t/ha), and its collection from 487.5 to 590.6 kg/ha.

The protein content in corn grain against the background of the aftereffect of SS in combination with zeolite-containing agricultural ore varied from 9.50 (SSUW 100 t/ha + zeolite-containing agricultural ore) to 10.21% (SSUW 180 t/ha + zeolite-containing agricultural ore), significantly exceeding control by 0.59-1.30%.

The content of protein in these variants of the experiment varied from 540.6 to 682.0 kg/ha. The increase in relation to the control was of 111.1-252.5 kg/ha, or 25.9-58.8%.

CONCLUSIONS

From the above, it follows that the most significant impact on the yield of Jackpot peas, winter wheat Moskovskaya 56, maize hybrid Ladoga 191 MV, protein and gluten content, and the collection of digestible protein had a complex aftereffect of urban sewage sludge with zeolite-containing agricultural ore.

The aftereffect of increased norms of urban sewage sludge in combination with zeolite-containing agro-ore increased the yield of peas by 48.9-49.8%, the protein content in pea grain - by 1.2-2.7%, the yield of winter wheat by 33.3-34%. 4%, gluten content in winter wheat grain - by 4.5-4.7%, corn grain yield - by 34.2-36.5%, protein harvest - by 227.1-252.5 kg/ha.

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