The use of bird droppings, mineral and organomineral fertilizers in solving the issue of increasing productivity of agricultural lands of the Trans-Urals

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Abstract. Studies conducted to study the effect of the use of combinations of bird droppings and mineral fertilizers, organic fertilizers on the yield of grain crops in a crop rotation showed that this technique can significantly increase the productivity of arable land. On average, over three years of research, the increase in the use of mineral fertilizers and bird droppings was 45.3–46.6 % higher than in the variant without fertilizers. The use of organic mineral fertilizers obtained on the basis of bird droppings with mineral enrichment highly effective intake, grain productivity of spring wheat and oats even in adverse weather conditions exceeded the control options by 44–47 %. Conducted comparative analysis of the options with mineral fertilizers and organomineral fertilizers showed that the latter are not inferior in direct effect, and in some cases even superior to the mineral counterpart. Comparative production tests have confirmed the significant economic efficiency of using complex organomineral fertilizers compared to its industrial mineral counterpart.

1 Introduction

The priority direction in improving the efficiency of agricultural production is based on solving issues of intensification, improving economic methods of managing, processing and selling agricultural products. The solution to the problems of increasing production volumes and improving the quality of products, both in crop production and in animal husbandry, must be considered taking into account maintaining and improving soil fertility [1–3].

It is known that long-term use of arable soils with increasing intensification of agriculture affects soil-forming processes. The use of organic and mineral fertilizers, as well as chemical ameliorants in low volumes, has recently led to a significant decrease in soil fertility [4–6].

The systematic use of organic fertilizers contributes to the accumulation of humus, improves the physicochemical properties of the soil, increases the supply of nutrients, lowers acidity, increases the content of absorbed bases, absorption capacity and buffering, and creates optimal conditions for the mineral nutrition of plants [7, 8].

Currently, in the Russian Federation and in the Trans-Urals, bird droppings are one of the most common types of raw materials for the production of organic and organomineral fertilizers. By the amount of nutrients and the positive effect on soil fertility parameters, the fertilizers obtained are not inferior to the manure obtained from cattle and small cattle. These types of fertilizers can be used as the main, row and top dressing of plants. The raw material for their preparation can be the droppings of various farm birds, including geese. Fresh litter contains useful elements and minerals that contribute to the development of plants and their growth [9, 10].

It is believed that litter fertilizers are most appropriate and more efficiently used for row crops, winter crops and annual grasses. But in our opinion, in the fertilizer system of spring crops, they are no less effective provided that they are combined with mineral fertilizers, especially in the framework of grain-crop rotations or their links.

It should be agreed that in the classical case of their application, the greatest increase in the yield of early spring grain and vegetable crops gives the use of fertilizers for the main plowing [11–13]. This is the basis for most of the recommended and used in the Urals Ural fertilizer systems of crops, including cereals [14, 15]. Research on the improvement of fertilizer systems for crops, including organic and organomineral fertilizers obtained from bird droppings, was carried out in the forest-steppe zone of the Trans-Urals, within the territories of the Kurgan and Chelyabinsk regions.

The purpose of the research was to study the efficiency of using rotted goose droppings and mineral fertilizers in grain-crop rotation, as well as organomineral fertilizers obtained on the basis of chicken droppings on black soil leached in the Trans-Urals.

To achieve this goal, it was necessary to solve the following tasks: to evaluate the agrochemical parameters

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of the experimental plots; conduct a medium-term field experiment; set the yield of wheat and oats in the experiments.

2 Materials and methods

The study was carried out at the Kurgan State Agricultural Academy (KSAA) in 2017–2019. Field studies, laboratory analyzes, mathematical processing of the results were performed as part of the research plan of the department "Land Management, Agriculture, Agricultural Chemistry and Soil Science". Research on the experiment of using organic fertilizers obtained from bird droppings was conducted in the Chelyabinsk region.

The soil of the KSAA experimental field is leached chernozem, low-humus, low-power, medium loamy, deep boiling according to the main parameters of effective fertility, and can be classified as cultivated types. It is formed on parent rocks related to yellow-brown carbonate loams of Quaternary age, eluvial origin (Table 1).

In 2017, in the experimental field of the Kurgan State Agricultural Academy on leached chernozem, stationary experiment was held to study the effect of goose droppings in combination with nitrogen-phosphorus fertilizers on the yield of grain crops in a grain-crop rotation.

Table 1. Soil characteristics of the experimental plot, 2016 (experimental field of KSAA)

Index		Genetic horizon	
		Ап	AB
1. Power, cm		0-20	20-36
2. Granulometric composition, particle content, %	less than 0.01 mm	38.5	36.9
	less than 0.001 mm	57.7	57.1
3. Soil density, g/cm^3		1.09	1.14
4. Acidity, pH of the extract	water	6.42	6.35
	saline	5.62	5.56
5. Hydrolytic acidity, Ng	mg · eq. per 100 g of soil	3.21	1.25
6. Absorption capacity, CEC	mg · eq. per 100 g of soil	28.4	16.5
7. The degree of saturation with bases, V, %		88.7	92.5
8. Absorbed base, mg · eq per 100 g of soil	Ca^{2+}	18.5	12.8
	Mg^{2+}	6.7	2.5
9. Content, %	N_{total}	0.264	0.264
	P_2O_5	0.135	0.135
	K_2O	2.22	2.22
	Humus	4.63	3.26

The placement of options in the experiment is randomized, it includes four repetitions. The total area of the plot in the experiment is 15 m^2, accounting 12 m^2 (2 m x 6 m). Fertilizers were applied in the following doses: mineral fertilizers annually before sowing in a scatter method based on 20 and 40 kg of active substance nitrogen (ammonium nitrate) and phosphorus (simple superphosphate); organic – bird droppings in doses of 5 and 10 t/ha. Bird droppings were added to the stock for 3 years. The forerunner of the first wheat is black steam. Spring wheat was sown on May 28 (2017) and June 8 (2018), oats on June 5 (2019) with the SZP-3.6 seeder. Wheat of the Omskaya 36 variety and oats of the Skakun variety with a sowing rate of 5 million germinating seeds per 1 ha. Harvesting of wheat was carried out in the phase of full ripeness on September 4 and 25, and oats on September 20 with a TERRION SR2010 brand small-plot experiment harvester. Yields were adjusted to standard humidity and converted to t/ha. Weather conditions during the research period corresponded to long-term average indicators.

The experiment scheme included 9 options: 1. Control (without fertilizers); 2. N20P20; 3. N40P40; 4. Bird droppings, 5 t/ha; 5. Bird droppings, 5 t/ha + N20P20; 6. Bird droppings, 5 t/ha + N40P40; 7. Bird droppings, 10 t/ha; 8. Bird droppings, 10 t/ha + N20P20; 9. Bird droppings, 10 t/ha + N40P40.

Statistical processing of crop accounting results was carried out by the method of variance analysis of three-factor experience, as well as linear correlation according to B. A. Dospekhov [16].

The technology of cultivation of grain crops and the used doses of mineral fertilizers correspond to those recommended for the forest-steppe zone of the Trans-Urals.

For field research in the Chelyabinsk region, we obtained a batch of organic fertilizers using the technology of stabilization and enrichment of fresh bird droppings [17]. In this case, the moisture content of the obtained fertilizer was achieved through active drying, which allows it to be applied in a scattering manner. A number of technological and agrochemical parameters of the fertilizer are presented in the table (Table 2).

Table 2. Brief description of the organic fertilizers obtained, 2016

Fertilizer composition		Bird droppings, phosphorite flour, ammonium sulfate, filler (coal dust)
The content of batteries, in % of dry matter	N_{total}	12.5
	P_2O_5	8.6
	K_2O	4.4
	micro	3.8
	sum	29.3
pH $_{water}$		6.5
Technological parameters	humidity, %	28.0
	dispersibility score	5
	grading	homogeneous, particles 0.5–2 mm

In total for 2017–2018, we carried out 2 short-term field experiments and two production experiments on the use of organic fertilizers. The tested crops were spring wheat and oats, varieties “Kazakhstan early ripening” (Kazahstanskaya rannespelaya) and “Skakun”, respectively. The technology of their cultivation is generally accepted for the forest-steppe zone of the Chelyabinsk region. The years of research were characterized by extremely unstable climatic conditions,

which affected the level of plant productivity by experiments and had an impact on the efficiency of using all types of mineral and organic fertilizers, which turned out to be quite low. The soil in the experimental areas was leached chernozem medium humus, heavy loam granulometric composition. The content of mobile phosphorus is medium, and potassium exchange is high. At the time of sowing the test cultures, the amount of nitrate nitrogen according to the classification of A.E. Kochergin was at an average level.

The experimental design included the following options: Experiment No.1 “Comparative study of the effect of mineral and organomineral fertilizers on productivity and some qualitative indicators of spring wheat” N90P100K40 fertilizer application rate calculated for obtaining grain productivity of 3.0 t/ha. Option 1 – control (no fertilizer was applied); Option 2 – introduced NPK 625 kg/ha; Option 3 – organic fertilizer 720 kg/ha; Option 4 – organic fertilizer 720 × 1.5 kg/ha was added. Experience No. 2 "Comparative study of the effect of mineral and organomineral fertilizers on yield and some quality indicators of oats", fertilizer application rate N70P80K50 Option 1 – control (fertilizers were not applied); Option 2 – NPK 475 kg/ha was introduced; Option 3 – organic fertilizer 560 kg/ha; Option 4 – introduced organic fertilizer 560 × 1.5 kg/ha The plot area in the experiment was 36 м^2, the accounting area was also 36 м^2, the placement of options randomized four times.

Production experiments were carried out at two sites: LLC Belonosovo and LLC Ravis-Krasnoe Pole, Chelyabinsk Region. The yield of spring wheat and oats was determined by the calculation and weighting method according to the results of harvesting the accounting area of the plot. To determine the quality indicators of the products obtained, standard methods prescribed in GOST are used.

3 Results and Discussion

Studies in the Kurgan region showed that in the growing season of 2017, the wheat yield after steam in the version without fertilizers was 1.57 t/ha, with the use of mineral fertilizers in a dose of N20P20 – 1.84 t/ha, N40P40 – 1.94 t/ha, combined the use of nitrogen-phosphorus fertilizers with bird droppings significantly increased productivity to 2.43 t/ha. Increases from the use of mineral fertilizers amounted to 17.2–23.6 %. Against the background of bird droppings, the yield was 2.11 t/ha, with the combined use of organic and mineral fertilizers, the yield was 2.35–2.43 t/ha or 49.7–54.8 % (Table 3).

In the second year of research, the yield of wheat without fertilizers was lower than in 2017 and amounted to 1.50 t/ha, while applying mineral fertilizers, the yield was 1.71–1.85 t/ha. The aftereffect of organic fertilizer also increased crop productivity to 1.63 t/ha. In the variants with the combined use of fertilizers, the wheat yield was higher than the control variant by 0.69–0.73 t/ha (LSD_{05} = 0.07 t/ha).

On average, over two years of research, increases in wheat productivity from the use of mineral fertilizers were 0.24–0.36 t/ha, organic fertilizer – 0.33 t/ha, from their combined use – 0.75–0.77 t/ha.

The use of organic and mineral fertilizers by experience increased the yield of wheat by 15.6–50.0 %. At the same time, the largest reliable increases were obtained in the variants where we used the combination of bird droppings and mineral fertilizers.

The aftereffect of organic fertilizer at a dose of 5 t/ha did not significantly affect the yield of oats (LSD_{05} = 0.10 t/ha). In other experimental variants, the use of mineral fertilizers against the background of bird droppings had a significant increase in the yield of oats.

The highest crop yields are observed in the eighth and ninth variants of the experiment, where the increase was 0.63–0.66 t/ha, respectively.

In general, 4.45 tons of grain units per hectare were obtained for rotation of the crop rotation on the option without fertilizers in the soil-climatic conditions of the Trans-Urals. The use of ammonium nitrate and superphosphate increased crop rotation productivity to 5.36 tons of grain units, or on average by 14.9–21.0 %.

When creating favorable conditions for crops, the largest collection of grain units in crop rotation is also noted on options with the combined use of organic and mineral fertilizers. Crop rotation productivity increased to 6.52 tons of grain units, and the average was 2.17 t/ha of grain units, which is 46.6 % higher than the control variant.

Table 3. Effect of fertilizers on crop rotation productivity, t/ha (Experimental field of KSAA, 2017-19)

Option	2017		2018		2019		Cereal units			
	t/ha	off	t/ha	off	t/ha	off	total	aver.	off	in %
1 Without fertilizers (control)	1.57	–	1.50	–	1.72	–	4.45	1.48	–	–
2 N20P20	1.84	0.27	1.71	0.21	1.92	0.20	5.09	1.70	0.22	14.9
3 N40P40	1.94	0.37	1.85	0.35	1.96	0.24	5.36	1.79	0.31	21.0
4. Bird droppings, 5 t/ha	2.03	0.46	1.57	0.07	1.76	0.04	5.01	1.67	0.19	12.8
5. Bird droppings, 5 t/ha + N20P20	2.22	0.65	1.67	0.17	2.16	0.44	5.62	1.87	0.39	26.4
6. Bird droppings, 5 t/ha + N40P40	2.46	0.89	1.96	0.46	2.22	0.50	6.20	2.07	0.59	40.0
7. Bird droppings, 10 t/ha	2.11	0.54	1.63	0.13	1.85	0.13	5.22	1.74	0.26	17.6
8. Bird droppings, 10 t/ha + N20P20	2.35	0.78	2.23	0.73	2.35	0.63	6.46	2.15	0.67	45.3
9. Bird droppings, 10 t/ha + N40P40	2.43	0.86	2.19	0.69	2.38	0.66	6.52	2.17	0.69	46.6
LSD_{05} for private differences	–	0.13	–	0.07	–	0.10	–	–	–	–

In experiments conducted on the territory of the Chelyabinsk region, spring wheat and oats were located in the link of a grain-steam crop rotation, while the previous crops for them were: for spring wheat – the first spring wheat in pairs, for oats – second spring wheat in a steam field. Fertilizers were scattered in the spring for tillage prior to sowing.

The ratio of heat and moisture of the vegetation period of 2017, the distribution of precipitation and the potential soil fertility of the experimental plot did not allow to obtain a high yield even on options where mineral and organomineral fertilizers were used. The average yield of spring wheat grain in the control variant was 1.67 t/ha, oats – 1.78 t/ha (Fig. 1.).

The use of mineral and organic fertilizers made it possible to increase the yield of spring wheat from 0.56 to 0.79 t/ha, which corresponds to 34.0–47.0 % relative to the control. The response of oats to the use of fertilizers is close, and the increase was from 0.47 to 0.78 t/ha, which corresponds to 26.0–44.0 % relative to the control.

Verification of the reliability of the results using the method of variance analysis of a one-way experiment confirmed the validity of the differences.

The smallest significant difference for options with wheat was 0.17 t/ha, oats – 0.12 t/ha. Conversely, the differences between the options where fertilizers were used are not significant or are within the limits of experimental error.

This confirms our assumption that the created organic-mineral fertilizers are not inferior to their mineral counterparts in a direct effect on crop productivity.

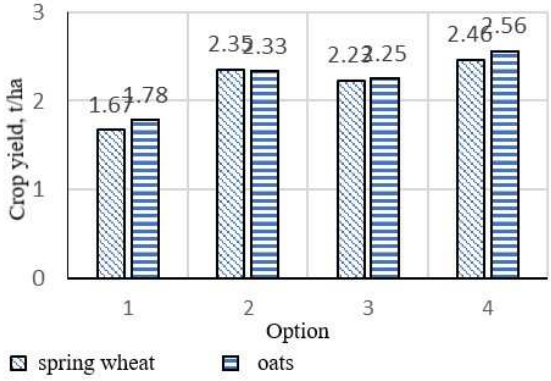

Fig. 1. Grain productivity of spring wheat and oats according to the experimental options, 2017

Production tests of organic fertilizers also showed their high efficiency, including economic one. The profitability of wheat production against the background of mineral fertilizers amounted to 74.5 %, against the background of organic mineral fertilizer – 135.1 %. In the production of oats at Belonosovo LLC, profitability ratios were 23.8 and 74.5 %, respectively

The cost of industrial mineral analogues is significantly higher than the market value of the production of organic fertilizers, even taking into account the trade allowance.

Based on this, it can be considered that fertilizers obtained on the basis of bird droppings can provide competition for mineral fertilizers (Table 4).

Table 4. Results of comparative production tests of organic fertilizers, 2018

Indicators		Venue, culture	
		LLC Belonosovo, oats	LLC Ravis – Krasnoe Pole, spring wheat
Contributed, t/ha	azofoska	0.5	0.6
	organic fertilizer	0.8	1.0
Productivity by options, t/ha	control	1.8 ±0.30	2.1±0.25
	mineral tuks	2.6±0.23	2.8±0.22
	organic fertilizer	2.8±0.28	2.9±0.17
Profitability of production against the background, %	mineral tuks	23.8	74.5
	organic fertilizer	74.5	135.1

4 Conclusion

Studies conducted to study the effect of the use of combinations of bird droppings and mineral fertilizers, organomineral fertilizers on crop yields and crop rotation productivity have shown that this technique can significantly increase arable land productivity. Based on the results obtained, the following conclusions can be drawn:

- on average over three years of research, increases from the use of mineral fertilizers amounted to 0.22–0.31 t/ha point of credit, from bird droppings – 0.19–0.26 t/ha point of credit, from the sharing of fertilizers – 0.67–0.69 t/ha point of credit;
- use of organic mineral fertilizers obtained on the basis of bird droppings with enrichment with minerals highly effective reception, grain productivity of spring wheat and oats even in adverse weather conditions exceeded the control options by 44.0–47.0 %;
- comparative analysis of options with mineral fertilizers and organomineral fertilizers showed that the latter are not inferior in direct effect to increasing the productivity of grain crops, and in some cases they surpass the mineral counterpart;
- comparative production tests have confirmed the significant economic efficiency of the use of complex organomineral fertilizers relative to its industrial mineral counterpart (according to the content of the active substance).

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