RESPONSIVENESS OF SOYBEANS TO THE APPLICATION OF ORGANIC FERTILIZERS BASED ON BIRD DROPPINGS IN THE FOREST-STEPPE OF WESTERN SIBERIA

T.A. SADOKHINA[1,1,2*], E.A. MATENKOVA[2], T.V. GAVRILETS[2], A.F. PETROV[2], V.P. DANILOV[1], I.V. KARKHARDIN[2], K.E. DENISOV[2], A.V. KOKORIN[1], A.N. SADOKHIN[2], A.V. EVTUSHENKO[2]

[1]Siberian Federal Research Center for Agrobiotechnologies, 2B Centralnaya st., Krasnoobsk, Novosibirsk region, 630501, Russia

[2]Novosibirsk State Agrarian University, 160 Dobrolyubova st., Novosibirsk, 630039, Russia

[1](Corresponding Author)

Abstract

This paper presents the results of a study aimed at determining the effectiveness of using bird droppings as an organic fertilizer to preserve soil bioresources and soybean productivity. The study was conducted in 2020-2021 in field experiments in the northern forest-steppe zone of the Ob surroundings in the Novosibirsk region (Russia), on experimental plots with leached, medium-thick, medium-loamy chernozem. In the conditions of the forest-steppe zone of Western Siberia, the effect of the use of preparations based on chicken manure applied under soy was obtained. It has been established that the pre-sowing introduction of preparations into the soil and vegetation treatment activates the vegetative development of plants and contributes to an increase in the yield of green mass and grain. As a result of the application of fertilizers, the safety of plants for harvesting increases by 2-4%.

Keywords: crop structure, organic fertilizer, soil microflora, soy, yield

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Introduction

The poultry sector is one of the fastest-growing agro-industrial sectors in the world due to the growing demand for eggs and meat products (OECD/FAO, 2017). Chicken manure is waste generated in the largest quantities in the process of breeding poultry (Antonov *et al*., 2019). This waste can potentially be important for the application to the soil as an organic fertilizer due to its relatively high nutrient content (Iqbal *et al*., 2022), especially nitrogen, which is associated with an initially high content of protein and amino acids (Gameiro *et al*., 2019). Organic fertilizers based on chicken manure have a diverse composition of basic nutrients and trace elements. This is their advantage over mineral fertilizers (Kyakuwaire *et al*., 2019). In addition, processed bird droppings can improve the physical, chemical, and biological properties of the soil (Geng *et al*., 2019; Sultana *et al*., 2021; Miah *et al*., 2022). Organic fertilizers provide nutrition to the crop of the current season and have a significant impact on subsequent crops included in the crop rotation plan (Antonova and Kalpokas, 2020; Curtis *et al*., 2023). Nevertheless, the use of bird droppings can lead to environmental pollution (Fatoba *et al*., 2021). In this regard, bird droppings processing becomes a promising direction for using bird droppings as fertilizers, which ensures that the quality indicators of fertilizers are brought to the necessary technological, fertilizing, and sanitary/hygienic parameters.

Chicken manure, as an organic fertilizer, is used on different crops, providing them with nutrients. Soy is an important crop that is responsive to fertilization. From an agronomic point of view, it is a nitrogen fixator, as enriches the soil with nitrogen and improves its structure. Under favorable conditions, soybeans can leave up to 50-80 kg/ha of nitrogen in the soil. Soy nitrogen, unlike mineral nitrogen, does not pollute the environment and is easily absorbed by other plants (Falya, Y., et. al., 2021; Kanedi, M., et. al., 2021).

The purpose of the study is to evaluate the possibility of using organic fertilizers and to establish the effect of fertilizers based on chicken manure on the biological activity of the soil, as well as to determine the effectiveness of using bird manure as an organic fertilizer for the conservation of soil bioresources and soybean productivity.

Objectives of the study:

- to identify the effect of organic fertilizers based on chicken manure on the microflora of the soil;

- to evaluate the yield of soybeans against the background of the use of organic fertilizers obtained from chicken manure.

Materials and Methods

The study was carried out in 2020-2021 in the form of field experiments in the northern forest-steppe zone of the Ob surroundings (Novosibirsk region, Russian). The soil of the experimental plot was leached chernozem, medium-thick, medium-loamy, the content of organic carbon in the soil was 3.48%, with a pH of 5.3. The number of absorbed bases was 58-61 mg/eq. per 100 g of soil. The preceding crop was fallow.

According to climatic resources, it is a moderately warm, insufficiently humidified agro-climatic region (Najafi, M. L., 2020). The average annual precipitation is 350-450 mm, of which 254 mm fall in the warm season (April to September) and 113-130 mm fall from June to August. The hydrothermal coefficient (according to Selyaninov) in the period with an air temperature above 10°C equals 1.0-1.2. The sum of positive temperatures above 10°C averages 1,880°C, with deviations over the years from 1,500 to 2,250°C.

The growing season of 2020 in terms of precipitation can be characterized (by a generalized indicator, the hydrothermal index (HTI) from May to September, equaling 1.29) as close to the climatic norm for the site of the study, but with variable monthly precipitation and lack of moisture in June (HTI=0.4) and in the second decade of July (HTI=0.6). During the growing season of 2021, the amount of precipitation was 202 mm (HTI=0.9). For the period from May to August, the sum of temperatures above 10°C was 2,090° C. In the summer months of plant vegetation, the air temperature was at the level of the average annual value, and only in May, it was higher by 1.7-3.5°C. The precipitation was distributed unevenly.

Experiment design: control variant, chicken manure (without processing), Preparation 1, Preparation 2, nitrogen fertilizers $N_{60.}$ We studied two variants of organic fertilizers based on bird droppings. The fertilizers were obtained by distillation of semi-dry manure in the form of a 10% water solution using a cavitation-vortex heat generator. The manure was treated under different thermal conditions (from 60 to 75ºC), with or without ozone.

In laboratory conditions, the chemical composition of processed chicken manure was determined, and the initial samples of manure served as the control variant. As a result of the study, it was found that the mass fraction of dry matter in the unprocessed chicken manure was 76.7%, and in the processed one it was 3.6%. The proportion of organic matter in terms of dry matter was 77.2% for the initial sample, 81.6% for the processed one, and the pH of the initial samples was 8.6, and 7.0 for the processed ones. The content of total nitrogen, phosphorus, and potassium recounted as dry matter in the initial samples of chicken manure was 4.04, 2.48, and 1.56%. Under the influence of processing, their content in the final product increased slightly (except for phosphorus) and amounted to 5.56, 2.78, and 12.7, respectively. Thus, laboratory studies of the chemical composition of poultry manure revealed an increase in the content of basic nutrients in processed chicken manure, compared with the non-processed one.

The experiments were established in threefold repetition, and the arrangement of the variants was systematic. The sowing and accounting area of plots was 4 * 15 m = 60 m^2. Sowing was carried out in the third decade of May. Fertilizers were applied in two periods: in the spring they were put in the soil for pre-sowing cultivation and during the growing season, they were applied during the formation of soybean grain.

Soybean plants were evaluated by growth and development phases (Yasin, G., et. al., 2020; Noor, S., et. al., 2020). The yield components were analyzed by the method of selecting plants from the accounting plot (Alshehri, K. M., 2020;).

The soil for analysis was selected at ten points of the plot diagonally. The top layer (2 cm) was removed and the soil was collected from a depth of 5-15 cm. Thus, a mixed sample was obtained for microbiological analysis.

The number of the main groups of microorganisms was determined by the generally accepted method of seeding on dense nutrient media. The microorganisms were taken into account in the following media:

- accounting of ammonifiers was carried out on MPA (meat-peptone agar);

- the biochemical activity of microorganisms assimilating mineral forms of nitrogen was determined on SAA (starch and ammonia agar);

- the accounting of aerobic nitrogen fixers was carried out on the Ashby medium using the bio-fouling of lumps (as a percentage);

- the accounting of cellulose-destroying microorganisms was carried out on a Hutchinson medium using the bio-fouling of lumps (as a percentage);

- the biochemical activity of fungi was determined on Czapek's medium.

Microorganisms were seeded by the method of marginal dilutions and incubated at a temperature of 28ºC for 3-7 days. The number of grown colonies, taking into account the soil moisture content, drop volume, and dilution, was recalculated for the number of microorganisms in 1 g of absolutely dry soil.

Results and Discussion

In chernozems, legumes activate the microflora of the soil, which contributes to an increase in microbial biomass (Khussainov *et al*., 2021; Filippova *et al*., 2022). In such conditions, the importance of nutrient reserves in the soil for crop formation increases (Shitikova and Abiala, 2019; Shchemeleva *et al*., 2021; Makarova *et al*., 2022). Thus, when introducing bird droppings at the beginning of the growing season, the number of ammonifying microorganisms in experimental variants increases most significantly (Table 1). In September, the number of ammonifiers is higher in the nitrogen fertilizers variant, compared with the control one.

At the beginning of the growing season, against the background of Preparation 1 and nitrogen fertilizers, the number of bacteria assimilating mineral nitrogen increases. Preparation 2 reduces the number of microorganisms in this group. By the end of the growing season, the effect of preparations on bacteria that assimilate mineral nitrogen decreases, and the number of bacteria approaches the one in the control variant.

Table 1. Microflora of leached medium loamy chernozem under soybean culture, colony-forming units

(CFU), million in 1g ab of absolutely dry soil, average for 2020-2021.

Variant	Bacteria that assimilate organic nitrogen (MPA)		Bacteria that assimilate mineral nitrogen (SAA)	
	June	September	June	September
Control	83.0	15.5	359.6	33.0
Manure	229.6*	14.7	376.5	32.1
Preparation 1	350.0*	15.8	973.0*	29.5
Preparation 2 with additives	373.1*	13.3	196.5	28.6
Nitrogen fertilizers	373.3*	30.9*	590.0*	45.6
Least Significant Difference (LSD)$_{05}$	*143.6*	8.2	367.08	18.3

*Reliable at 95% level

Calculation of the mineralization coefficient (Table 2) showed that active immobilization processes are observed in all variants (K>1), while these processes are most intense in the control variant in June. The introduction of organic fertilizers in the variant with Preparation 2 and additives reduces the mineralization coefficient by 8.6 times compared to the control variant and by 3.2 times compared to the manure. In September, the values of the mineralization coefficients of the experimental and control samples of the soil were at the same level.

Table 2. Structure and functioning of microbial cenosis when exposed to fertilizers, average values for 2020-2021.

Variant	Mineralization coefficient for SAA/MPA	
	June	September
Control	4.3	2.1
Manure	1.6*	2.2
Preparation 1	2.8	1.9
Preparation 2 with additives	0.5*	2.2
Nitrogen fertilizers	1.6*	1.5
LSD$_{05}$	2.5	2.2

*Reliable at 95% level

In June, the number of microscopic fungi in all variants of the experiment, except for the variant with nitrogen fertilizers, was lower than the control one (Fig. 1). Significant differences were observed in the variant with Preparation 1. The increase of micromycetes against the background of nitrogen fertilizers has been statistically proven. By September, there was no difference in the number of microscopic fungi.

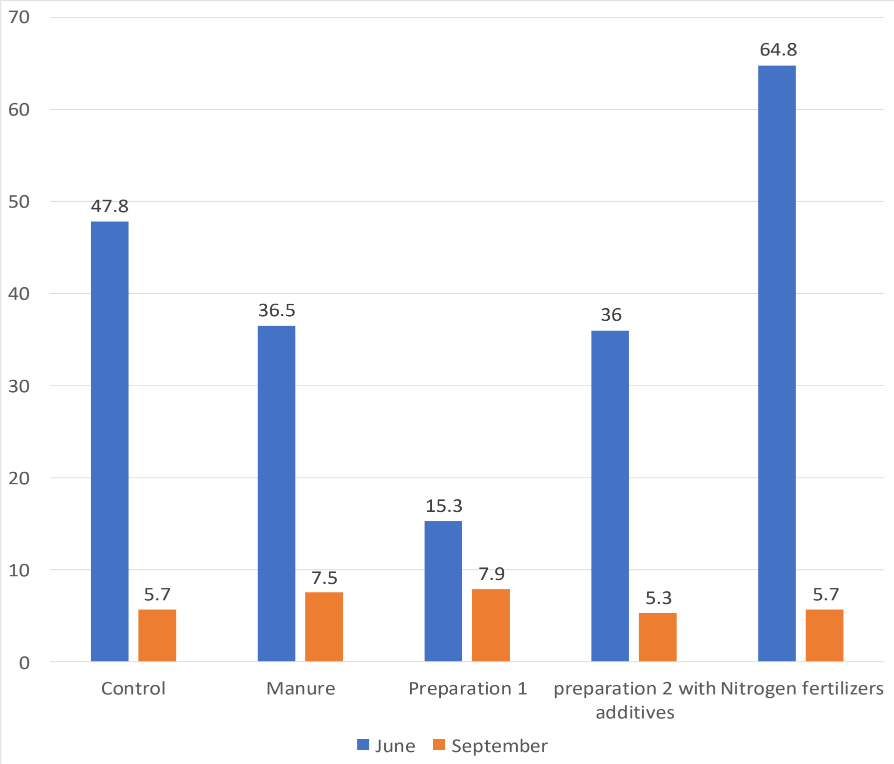

Fig. 1. The number of micromycetes, thousand in 1g of absolutely dry soil (Czapek's medium)10^3.

Note: LSD_{05} *(June)=15.9;* LSD_{05} *(September)=4.8*

Thus, differences in the soil microflora, which carries out the destruction of easily degradable organic residues and further immobilization of nitrogen, were leveled by the end of the growing season.

Nitrogen is largely replenished due to its biological binding from the atmosphere, which is carried out by free microorganisms in the soil and the microorganisms living on the roots of leguminous plants.

The introduction of chicken manure into leached chernozem led to an increase in the number of *Azotobacter* in the manure variant compared to the control one by 14.3%. Against the background of the use of nitrogen fertilizers, microorganisms of this group did not develop in June. In September, the number of nitrogen-fixing microorganisms in all variants increased by 2-4 times compared to the beginning of the growing season (Table 3).

Table 3. *Azotobacter* accounting on Ashby medium, average for 2020-2021.

Variant	*Azotobacter, %*	
	June	September
Control	24.30	97.30
Manure	38.65*	70.65*
Preparation 1	29.30	60.00
Preparation 2 with additives	24.65	57.35*
Nitrogen fertilizers	0	18*
LSD_{05}	*10.5*	*16.2*

*Reliable at 95% level

Consequently, the application of nitrogen fertilizers causes a short-term decrease in *Azotobacter*, then gradually restoring its number. In September, compared with June, the number of nitrogen-fixing bacteria in leached chernozem under the action of chicken manure increased, but the nitrogen intake from biological fixation in experimental variants was less than in the control variant.

In our studies, the effect of preparations based on chicken manure was monitored not only on the soil but also on the growth and development of soybean plants. Based on a field experiment, the positive effect of organic fertilizers on the formation of the main structural elements of the soybean crop was established: the weight and height of plants, the number of branches, beans, seeds, and the weight of seeds from the plant. At the same time, the degree of influence of preparations on the formation of elements of the crop structure depended on the type of preparation.

The positive effect of Preparations 1 and 2 on the height of soybean plants was noted, which differed depending on the phenological phase. In the branching phase, the height in the control was 25.1 cm, in variants with the use of Preparations 1 and 2, it was 2.8-3.2 cm higher (by 11-13%). A similar trend was observed during the flowering phase. In the maturation phase, the height in the control variant was 68.7 cm, and the groups using Preparations 1 and 2 had a growth-stimulating effect, i. e. an increase in plant height by 4.1-5.0%.

The introduction of Preparations 1 and 2 based on chicken manure contributed to a more active accumulation of green mass and dry matter in the soybean flowering phase, which significantly increased by 3.0-3.5 and 0.5-0.8 t/ha, respectively, compared with the control variant (Table 4).

Table 4. Effect of organic and mineral fertilizers on the yield of green mass of soybeans, t/ha (average for 2020-2021).

Variant	green mass, t/ha	dry matter content, %	harvest of dry matter, t/ha
Control	19.5	20.2	4.4
Chicken manure	21.0	19.6	4.13
Preparation No. 1	22.9	22.3	5.2
Preparation No. 2 with additives	23.0	20.2	4.6
Nitrogen fertilizers N_{60}	20.5	20.6	3.8
LSD_{05}	2.1		

The main elements of the structure of the soybean crop are the number of stems per unit area, the number of side branches, the number of productive nodes, the number of beans and seeds per plant, the weight of 1,000 seeds, and the weight of the yield per plant. In our studies, the branching of the stems was weak. There were two branches, and most of them were with beans. However, there were few (1-2) beans, so branching did not make a significant contribution to the overall yield of soybean crops. The stems had 10 nodes, including 8 nodes with beans. For the studied soybean variety, this number of nodes on the stem can be considered optimal, especially since almost 70% of the nodes were fruit-bearing and had beans with mature seeds.

The height of the attachment of the lower bean should be at least 10 cm from the root neck. The maximum height of the attachment of the lower bean (12 cm) was observed in the variants with the use of preparations 1 and 2. In the experimental variants, two-seeded and three-seeded beans prevailed, while unproductive single-seeded beans in the harvest accounted for 7-18%. There were from 12 to 16 beans on one plant, and their number practically did not depend on the fertilizers applied. The number of beans and the seed set was significantly affected by air and soil drought during the flowering period and the formation of beans (4.4 mm of precipitation fell during the 2nd and 3rd decades of July) in 2021.

The number of seeds per plant was the smallest in the control variant, equaling 18 pcs. The largest one was noted in the variants with preparations 1 and 2 (20 and 22 pcs. per plant, respectively). Although the number of seeds from one plant varied slightly according to the experimental variants, there was a clear tendency to show an increase in the weight of seeds from one plant. The largest weight of seeds from one plant (3.4 to 3.7 g) was obtained on variants with preparations 1 and 2 (Table 5). This indicator was 8% higher than in the control variant.

Table 5. The effect of preparations based on chicken manure on the formation of elements of the structure of the soybean crop, average values for 2020-2021.

Variants	Height before harvest	Number of beans, pcs.	Seeds from a plant, pcs.	Seeds from a plant, g	Branche s	Weight of 1,000 pcs., g
Control	68.7	12	18	3.0	1.5	163
Chicken manure	72.1	13	21	3.2	1.4	155
Preparation 1	71.4	13.5	22	3.7	1.25	166
Preparation 2	71.2	13	20	3.4	1.25	164
Nitrogen fertilizers N_{60}	70.4	12	20	3.2	1.5	163

When studying the correlation with the elements of the crop structure in early-ripening soybean varieties, the greatest correlation between yield and seed weight from the 1st plant was noted (r=0.79). The use of organic fertilizers did not affect the weight of 1,000 seeds, in all variants of the experiment, this indicator equaled 162-166 ± 1.4 g.

Table 6. Yield and quality indicators of soybean seeds, average values for 2020-2021.

Variant	yield c/ha	Indicator			Harvest from c/ha	
		moisture of grain	protein , %	oil content, %	protein	fat
Control	2.1	8.3	38.3	19.9	8.8	4.5
Chicken manure	2.2	7.9	39.2	19.7	9.5	4.7
Preparation 1	2.3	7.8	37.6	20.3	9.7	5.3
Preparation 2	2.4	7.9	38.8	20.0	10.0	5.2
Nitrogen fertilizers N_{60}	2.2	7.7	40.7	19.2	10.2	4.8
LSD_{05}	1.6					

In the conditions of the forest-steppe zone of Western Siberia, the effect of the use of preparations based on chicken manure applied under soy was obtained. It has been established that the pre-sowing introduction of preparations into the soil and vegetation treatment activates the vegetative development of plants and contributes to an increase in the yield of green mass and grain. The greatest effect was obtained with preparation 2 applied under soybean. The increase in soybean grain yield was 0.2...0.3 t/ha or 8-14% compared to the control variant. It was found that the treatment with preparations improved the structural parameters of soybean plants, namely, the number of beans per plant increased by 6-8% and the weight of grains per plant increased by 18-23. The livability of plants by harvesting increased by 2-4%.

Conclusion

The analysis of data on the microbiological composition of soils when applying various forms of organic and mineral fertilizers showed that the use of bird droppings did not have a positive effect on the number of beneficial microflora of the soil under oats. The introduction of Preparation 1 and Preparation 2 improved the microbiological characteristics of the soil, which increased the availability of nutrients for plants, as well as the enzymatic activity of the soil. Thus, one can state that the introduction of organic preparations improves the microflora of the soil, reduces the number of conditionally phytopathogenic fungi, and stimulates cellulolytic activity without having a phytotoxic effect.

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