The effectiveness of the use of organic fertilizers in the cultivation of spring barley

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Abstract. The article presents the results of a study on the effect of organic fertilizers based on turkey litter on the morphological parameters of spring barley (Hordeum vulgare L.). The field experiment was conducted in the Moscow region on sod-podzolic soils. The results showed that the use of fertilizers significantly improved the growth and development of the crop. The highest efficiency was recorded when applying granular manure at a dose of 15 t/ha: the increase in green mass was 118.5% to the control (5.07 t/ha), dry weight – 100% (1.34 t/ha). The granular form provided more uniform nutrition and better photosynthesis. Increasing the dose to 30 t/ha did not lead to a proportional increase in yield. The introduction of granular turkey manure into the soil at a dose of 15 t /ha can significantly improve the morphological parameters of spring barley, as well as maximize yields (for green fodder and dry weight) compared with the control version of the experiment.

1 Introduction

The effectiveness of modern agriculture directly depends on the systematic use of fertilizers and the continuous improvement of their application technologies [1]. In the context of growing global demand for food and the need to preserve soil fertility, it is of particular importance to find optimal plant nutrition strategies that can ensure a balance between high productivity and environmental sustainability of agrocenoses.

In modern agriculture, striving for sustainability, improving the food quality of crops and increasing yields, organic fertilizers occupy a key place [2, 3]. The interest in them is due not only to the ability to provide plants with nutrients, but also to the positive effect on the agrophysical and biological properties of the soil. Among the wide range of organic fertilizers, granular fertilizers made from animal by-products deserve special attention. They occupy one of the leading places due to their rich composition and ease of use [4, 5].

The use of granular organic fertilizers increases crop yields, while maintaining soil fertility and solving the environmental issue of poultry manure disposal in poultry farms [6]. The problem of accumulation of livestock waste is acute for many regions, and its processing into commercial fertilizers allows to close the production cycle, returning

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nutrients to the soil. The granular form of the fertilizer ensures an even distribution of nutrients over the entire field area, preventing their leaching and reducing losses due to the slow release of active substances [7].

Turkey manure, in turn, has a high content of nitrogen, phosphorus and potassium, as well as a complex of trace elements such as copper, zinc, iron and manganese. The granulation process additionally concentrates these substances, making the fertilizer more efficient and economical, as well as eliminating pathogenic microflora and weed seeds [8]. Granular organic fertilizers based on turkey manure are a highly effective, environmentally friendly and technologically advanced means of increasing the productivity of spring barley. Their use allows not only to increase yields by optimizing plant nutrition, but also contributes to the preservation and reproduction of soil fertility, as well as solves the urgent task of recycling poultry waste within the framework of a circular economy.

Spring barley is a key grain crop that plays an important role in the country's food security and export potential, so it remains in the constant attention of the agricultural sector [9]. The key characteristic that makes spring barley an indispensable object for agronomic research is its exceptional responsiveness to nutritional conditions and high sensitivity to the level of soil fertility. This property makes it possible to consider it as an ideal test crop for evaluating the effectiveness of new types of fertilizers, including organic ones [10]. Long-term studies of the production process of spring barley confirm that the use of fertilizers directly affects the key components of yield: productive bushiness, ear water content, grain weight per ear and the collection of raw protein per hectare. Even with minimal use of mineral fertilizers, barley shows high returns, and fertilization can increase the collection of crude protein by 10%.

From a methodological point of view, the use of spring barley as a test crop is standardized even at the level of European standards. For example, when testing soil improvers and substrates for phytotoxicity, if the presence of graminicidal herbicides is suspected, barley is used as an additional indicator plant along with Peking cabbage. This highlights its recognized role as a sensitive biological indicator capable of detecting the presence of undesirable chemical compounds in soil or fertilizers.

The purpose of this study was to study the effect of organic fertilizers based on turkey litter in different doses on the morphological parameters and yield of spring barley (*Hordeum vulgare L.*) in a field experiment.

2 Materials and methods of research

The field experiment was conducted in the Yegoryevsky district of the Moscow region on an agricultural land plot, and included five options: zero control (without fertilizers, Control), turkey manure of 15 tons/ha (P_{15}), turkey manure of 30 tons/ha (P_{30}), granular fertilizers based on turkey manure of 15 tons/ha (G_{15}) and and 30 tons/ha (G_{30}) the repetition is 4-fold. The area of each plot is 38.1 m^2.

By type, the soil is sod-podzolic, by granulometric composition it is medium loamy, forming a rock with sandy loams and sands.

At the beginning of the experiment, the soil in the upper arable layer (0 – 20 cm) had the following agrochemical parameters: pH 6.6, pH KCl 5.2, organic matter 3.5%. Studies of mobile forms of phosphorus (P_2O_5) and (K_2O) (according to the Kirsanov method) 238 mg/kg and 108 mg/kg, respectively. The total nitrogen content (N_{total}) was 0.19%, and the nitrate content (NO^{3-}) was 7.9 mg/kg.

As an experimental crop, spring barley «Nur» (*Hordeum vulgare L.*) is a medium–ripened variety (vegetation period 70 – 93 days), medium-tall with high resistance to lodging. Breeding work of the Nemchinovka Moscow Scientific Research Institute of Agriculture. The variety was included in the State Register of Breeding Achievements in

2002 and is recommended for cultivation in the Moscow region. Sowing qualities of seeds: purity – 98%, germination energy – 98%, germination – 75%, humidity – 13%, weight of 1000 seeds – 43.5g. The seeding rate is 5.5 million per 1 hectare.

The following organic fertilizers were used in the experiment: turkey litter manure (humidity 67.7%), as well as fertilizer in granules obtained from turkey litter manure (water-absorbing component of sawdust, humidity 14-16%).

Organic fertilizer samples were analyzed using the organic fertilizer method, and the results of testing organic fertilizers for key indicators are presented in Table 1.

The temperature regime of the growing season in May 2022 was unfavorable for the cultivation of spring barley, the temperature was only 10.1 °C, which is significantly lower than the annual average of 13.7 °C, which negatively affects development, slowing down the growth and development of seedlings. The temperature in June was close to the average (18.2 °C with an average temperature of 17.3 °C), which partially compensated for the negative effects of the May cold snap. However, a significant decrease in precipitation relative to normal led to a shortage of moisture, especially noticeable in June (-33.8%) and July (-48.2%).

Table 1. Characteristics of organic fertilizers used in field experiments.

Indicator	Turkey manure	Granular fertilizer
pH_{water}	6.0±0.1	6.3±0.1
pH_{KCl}	5.9±0.1	6.1±0.1
Organic matter, %	54.7±5.5	38.7±3.9
P_2O_5, %	4.4	4.2
K_2O, %	3.0	3.6
N_{total}, %	7,4	8.94
NO_3^-, mg/100 g	48.45	66.88

The growing conditions of spring barley generally met the requirements and provided high yield potential. However, the decisive influence factor was humidification.

3 Results and Discussion

As part of the phenological observations, the number of plants per 1 m, plant height, leaf blade area, and bushiness were studied, Table 2.

In the control version of the experiment, the number of plants averaged 79 per 1 m^2 and was minimal compared to other variants, due to the lack of nutritional support in poor sod-podzolic soil. Options with a dose of organic fertilizers of 15 t/ha (G_{15} and P_{15}) demonstrated an almost twofold increase in the number of plants – 169 and 168 pcs/m^2, respectively. This indicates the high efficiency of both forms of fertilizers in a moderate dose.

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The variant with rotted turkey droppings at a dose of 30 t/ha (P_{30}) showed a sharp decrease in the number of plants to 81 pcs/m^2, which practically corresponds to the level of the control variant of the experiment. This may be due to the high contamination of crops with weeds, which actively developed against the background of raw organic fertilizer, inhibiting barley seedlings.

In the variant with granular fertilizer G_{30}, the maximum standing density of 180 pcs/m2 was preserved. Due to the slower release of nitrogen and the absence of weed seeds (unlike raw manure), the application of organic fertilizer in granular form created favorable conditions without the competitive effects of weeds.

Table 2. Morphological parameters of spring barley (tillering phase).

Option	Quantity per 1 m^2, pcs.	Plant height, cm	Bushiness, medium
Control	79	20.8	2.5
G_{15}	169	52.0	3.8
P_{15}	168	51.8	3.1
P_{30}	81	59.9	3.0
G_{30}	180	62.7	3.3
LSD_{05}	26.38	5.41	0.28

The height of plants is an informative integral indicator reflecting the intensity of growth processes and the availability of nutrients. Statistically significant increases in height during fertilization indicate an improvement in the nutritional regime and the creation of optimal conditions for the realization of the genetic potential of the crop. In the control version of the experiment, the minimum height (20.8 cm) was recorded, which is associated with a lack of nutrition. The use of fertilizers has significantly increased the height of plants. It should be noted that even in the P30 variant, where tillering was observed at the control level, the height of the plants (59.9 cm) significantly exceeds the version without fertilizers, due to the high amount of nutrients.

The maximum height of plants was fixed in the G_{30} variant and amounted to 62.7 cm, which is 66% higher than the control. This indicates that fertilizers in granular form in a high dose provide the most powerful initial growth.

There is a clear pattern: when switching from a dose of 15 t/ha to 30 t/ha, the height of plants increases. When adding rotted manure, the growth was +14% (from 51.8 to 59.9 cm), and granulated manure was +17% (from 52.0 to 62.7 cm).

Productive bushiness is an integral indicator reflecting the effectiveness of the plant's use of growing conditions and the level of mineral nutrition. This characteristic of the crop structure has a high correlation with final productivity and can serve as a reliable diagnostic criterion for evaluating the effectiveness of various agrotechnical techniques, including the use of organic fertilizers. In the control version of the experiment, the bushiness index may be determined by varietal characteristics, but is limited by a poor agricultural background.

The highest bushiness index was recorded in the G15 variant – 3.8, which is 35% higher than the control. This suggests that organic fertilizers in granular form at a dose of 15 t/ha create an optimal balance of nitrogen nutrition, stimulating active branching (tillering).

A high dose of granular fertilizer G_{30} also increased bushiness compared to the control, but was slightly lower than the G_{15} variant. Perhaps the excess nitrogen in the tillering phase at a dose of 30 t/ha shifted the balance in favor of linear growth to the detriment of tillering.

The variants where rotted manure was introduced (P_{15} bushiness 3.1, P_{30} bushiness 3.0) showed an increase in bushiness relative to the control, but it was less pronounced than in the variants with a granular form. This may be due to the uneven decomposition of raw organic matter.

A larger number of leaves and an increased leaf surface area enhance the photosynthetic process, which has a positive effect on the overall productivity of the plant. In the field experiment, the calculation of the area of the leaf blade was carried out using the formula:

$$R=2xy/3$$

where: x is the length of the sheet, y is the width of the sheet.

Spring barley showed significant responsiveness to the application of organic fertilizers (Table 3). At the beginning of observations, the leaf surface area was distributed as follows: the maximum value was noted in the P30 variant (20.90 cm^2). A high dose of rotted manure provided the plants with abundant nutrition from the very beginning, which caused rapid leaf growth.

The high level was noted in variants P_{15} and G_{30}, which amounted to 17.05 cm^2 and 17.03 cm^2, respectively. These variants showed almost identical results, despite the different form of fertilizer.

A moderate dose of granular fertilizer (G_{15}) provided a good, but not maximum, indicator of the leaf blade area at the beginning of the growing season, which may be due to a slower release of nitrogen from the granules compared to the overgrown form.

Table 3. Morphological indicators of spring barley (tillering phase).

Option	Sheet area cm^2 30.06	Sheet area cm^2 19.07	Increase in leaf area over the period	
			cm^2	%
Control	10.53	10.86	0.33	3.1
G_{15}	15.29	20.4	5.11	25.1
P_{15}	17.05	22.97	5.92	25.8
P_{30}	20.90	25.05	4.15	16.6
G_{30}	17.03	26.56	9.53	35.9
LSD_{05}	2.55	2.69		

The minimum value was noted in the control version of the experiment, both at the beginning and at the end of the growing season.

By the end of the observations, the best result was achieved by organic fertilizer in granular form at a dose of 30 t/ha (G_{30}). At the same time, all the variants where different doses of fertilizers were applied in various forms were close in values, demonstrating the overall effectiveness of organic matter.

The leaf area during the period in the variant with granular fertilizers at a dose of 30 t /ha increased by the maximum in the experiment of 35.9% relative to the control. Due to the intensification of photosynthetic activity in variants with organic fertilizers, the process of synthesis of organic substances necessary for plant growth and development improves, which ensures a high yield level.

A comparative analysis of the options revealed two fundamentally different types of actions. Rotted litter is effective in the first month, but loses it by the critical stages of development, especially in high doses. Granular fertilizer, on the contrary, provides a prolonged effect: a dose of 15 t/ha gives a stable result and a dose of 30 t/ha allows you to maximize the potential of the crop, maintaining intensive photosynthesis throughout the entire observation period. The worst effect is provided by the P_{30} variant, where high doses of raw organic matter do not pay off with an increase in biomass.

The use of organic fertilizers significantly increased the productivity of spring barley both in terms of dry matter and green mass (Table 4).

The G15 variant demonstrates the highest efficiency. The high dry mass yield (1.34 t/ha) at the maximum green mass indicates that the plants have not just accumulated water, but have formed a dense, well-developed biomass with a high content of organic substances. This result correlates with the data in Table 2, where G15 showed maximum bushiness (3.8), and Table 3, where the variant demonstrated a consistently high increase in leaf surface (25.1%). It was the bushiness that provided a large number of productive stems, which was directly converted into a crop.

Table 4. Yield of green and dry weight of spring barley.

Option	Green mass		Dry mass	
	t/ha	increase in control, %	t/ha	increase in control, %
Control	2.32	-	0.67	-
G_{15}	5.07	118.5	1.34	100.0
P_{15}	3.64	56.9	1.25	86.6
P_{30}	2.58	11.2	0.71	6.0
G_{30}	3.80	63.8	0.85	26.9
LSD_{05} t/ga	0.74		0.17	

* On average, for two mowing

The introduction of rotted turkey manure in a dose of P_{15} gives a high yield of dry matter (1.25 t / ha) with a relatively low green mass (3.64 t/ha). The ratio of green to dry weight here is about 2.9:1, which indicates a higher density of tissues and a better accumulation of dry matter. In terms of dry weight, P_{15} approaches the G_{15} variant (1.25 versus 1.34 t/ha), although it is significantly inferior in terms of green mass. This means that rotted manure at a dose of 15 t/ha contributed to the formation of high-quality biomass, but the total volume of the accumulated mass (green) turned out to be lower than when applying organic fertilizer in granular form, probably due to less uniform nutrition during the season.

Variant P30 demonstrates the negative effects of a high dose of rotted manure. Despite a strong start in leaf area (Table 3, maximum 20.90 cm^2 by 30.06) and a high plant height (Table 2, 59.9 cm), the final yield was extremely low. The reasons were laid down earlier: a sharp decrease in the number of plants due to contamination (Table 2, only 81 pcs/m^2) and a low relative increase in leaf surface (16.6%, Table 3). The surviving plants were tall, but there were few of them, and they could not form a full-fledged crop due to competition with weeds and, probably, uneven moisture. The high dose of raw organic matter had a negative impact on plant growth and development.

The application of granular fertilizer at a dose of 30 t/ha did not lead to an increase in yield, but, on the contrary, reduced it compared to the G_{15} variant. The green mass harvest decreased from 5.07 to 3.80 t/ha, dry – from 1.34 to 0.85 t/ha. Therefore, it can be concluded that the dose of 30 t/ha of organic fertilizer in granular form was excessive, despite the fact that this variant had the maximum leaf growth in the second period (35.9% in Table. 3) and high density of standing (180 pcs/m^2 in Table 2). Probably, the excess nitrogen caused the "greasing" of plants – excessive growth of vegetative mass to the detriment of the formation of productive stems and the accumulation of dry matter. The plants were tall (62.7 cm), with large leaves, but the yield was lower than at a dose of 15 t/ha.

4 Conclusion

Thus, the use of granular turkey manure is a promising method for increasing the productivity of spring barley by improving key physiological and biochemical processes in the crop. This opens up opportunities for the effective use of organic fertilizers, reducing the dependence of agriculture on traditional mineral fertilizers.

The application of granular fertilizer at a dose of 15 t/ha provided the greatest agronomic efficiency (G_{15}). This option gave the maximum increase in both green (118.5%) and dry weight (100.0%). Increasing the dose of granular fertilizer to 30 t/ha proved to be impractical, as it led to a decrease in yield. Rotted manure at a dose of 15 t/ha

showed a good result in the accumulation of dry matter, comparable to the G_{15} variant, but significantly inferior to the total biomass collection. The introduction of rotted manure at a dose of 30 t /ha can be considered ineffective due to the lack of a statistically significant increase in control.

To ensure the yield of green mass of spring barley at the level of 5.07 t/ha and 1.34 t/ha for dry weight, it is recommended to apply granular fertilizer based on turkey litter at a dose of 15 t/ha before sowing in the spring.

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