Effect of granular fertilizer of disinfected chicken dung application on crop productivity and soil fertility

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Abstract. On dark gray forest and leached chernozem soils of the Tambov region, the effectiveness of using new granular organic fertilizer from poultry excreta was evaluated. After disinfection of the litter by deep drying, the total content of NPK in the fertilizer constitutes 11-12%, the content of trace elements is about 1g/kg. Field experiments conducted in 2019 showed that the yield increase from the introduction of the studied organic fertilizer at a dose of 4-8 t/ha on spring wheat was 25-30%, on spring barley - 20-23%, on sugar beets from the introduction of 8 t/ha - 10-12%, on potatoes - 40-50%, on tomatoes from 6 t/ha - 30-32%. Profitability from the use of this fertilizer on cereals is 130-145%, on technical crops - 140-150%, on vegetables - 230-250%. Optimal fertilizer doses contribute to increasing protein in wheat grains by 1.5%, sugar content in sugar beets by 8-9%, starch content in potatoes by 3-4%, and sugar, dry substances and vitamin C content in tomatoes by 1-2%. The introduction of fertilizer in doses higher than optimal contributes to the increase of basic nutrients and micronutrients content in the soil.

1. Introduction
For various objective and subjective reasons there is a dangerous environmental situation in different regions of Russia and abroad due to the lack of technologies that would allow the effective disposal of biosolids, among which the waste of poultry farms could be considered as the most dangerous one [1]. The main bacteria present in litter are coliform bacterium and salmonella [1, 2].

Deep drying is the process of heat treatment of biomass at a temperature not higher than 300 °C in a low oxygen environment. As a result of this treatment, moisture from biomass and oxygen and less hydrogen are largely removed. As a technology for decontaminating litter, followed by the use of the resulting product as fertilizer, this process is used. The studies we conducted earlier showed that complete disinfection of litter occurs during deep drying, and hydrophobic properties that acquire granules eliminate the risk of secondary infection during their transportation and storage [1, 3].

Dry poultry litter is a fertilizer that can be used not only as the main fertilizer in pre-treatment, but also in spring feeding of winter grains. Phosphorus in this fertilizer is mainly in the form of phosphates and nucleoproteins, potassium in the form of soluble salts, which ensures their digestibility by plants. The amount of available nitrogen reaches 100%, phosphorus - 70%, potassium - 90%. The fertilizer contains a complete set of trace elements, in thiamine and folic acids and their salts are present in a sufficient amount. Fertilizer directly enhances the activity of the main process of plants - photosynthesis.
The purpose of this work is to evaluate the effectiveness of the use of new granular organic fertilizer from poultry excreta, disinfected by deep drying on various crops and to estimate its impact on agrochemical indicators of the soil.

The experimental batch of fertilizer obtained on this equipment was tested in field experiments on the fields of the FSBEI of Higher Education "Michurinsk State Agrarian University." Studies were carried out on crops of spring wheat and spring barley (cereals), sugar beet (technical crops), potatoes and tomatoes (vegetables), which represent a range of the most common crops and help to reveal the positive effect of the use of fertilizers in a one-year experiment under the conditions of central chernozem conservation area.

### 2. Methods and Materials

As raw materials for the production of organic fertilizer, the waste of the Ilovayskaya Poultry Farm, located in the Pervomaisky district of the Tambov region, was used. The total content of NPK in the studied fertilizer is 11.5%, in addition to the basic nutritional elements, it contains 5 trace elements necessary for plants (Table 1). The high content of organic matter ensures their active absorption by plants. The economic efficiency of mineral fertilizers was determined by the prices of the year of research. The average market wholesale price for granular litter amounted to 10 rubles/kg.

The year of research - 2019 (Figure 1) in terms of the amount of precipitation during the growing season is characterized as average (360 mm for the period April-October). Precipitation fell unevenly. There was an early autumn drought (April and June), the first one delayed the growth and development of cereals, the second was accompanied by high (more than 300) temperatures. During this period, the soil dried to a depth of 1 m to humidity below the soluble concentrate, which negatively affected the growth and development of sugar beets.

#### Table 1. Results of chemical and microbiological analysis of granular organic fertilizer from disinfected poultry excreta by deep drying.

| Indicator                        | Unit of Measure | Value | Content of Macroelements | Unit of Measure | Value | Content of Microelements | Unit of Measure | Value |
|----------------------------------|-----------------|-------|--------------------------|----------------|-------|--------------------------|----------------|-------|
| Acidity                          | pH              | 7.54  | Organic matter-C         | % of weight    | 38.6  | Manganese (Mn)           | Mg/kg          | 590   |
| Frequency of pathogenic microorganisms testing | %                 | 0     |                          |                |       | Zinc (Zn)                |                | 290   |
| Determination of microbiota quality | E. coli, staphylococcus, blue coli, salmonellla, thermotolerant bacteria - not found | Nitrogen - N general | 5.75 | Copper (Cu) | 22.7 |
|                                   |                 |       | Phosphorus (P2O5)       | 2.93           | Molybdenum (Mo)          |                | 1.92  |
|                                   |                 |       | Kalium (K2O)            | 2.75           | Cobalt (Co)              |                | 0.31  |

Experiments with wheat of the Mironovskaya sort, barley of the Dvoran sort and sugar beet hybrid Bravissima were carried out on the territory of the Komsomolets farm-breeding plant, located on the watershed of the Lesnoy and Voronezh rivers. Soil - leached medium-powerful medium-humus heavy-sintered chernozem on a cover loam. The precursor to spring cereals is peas, to sugar beets - steam. Experiments are single-factor, short-term, repetition - 4 times, the size of the experimental plot is 50 m2. The placement of options is systematic. Method of applying fertilizers - in the spring for cultivation before sowing [3]. Experience options with spring barley and spring wheat - control (without fertilizers), 2 t/ha, 4 t/ha, 6 t/ha, with sugar beet - control (without fertilizers), 4 t/ha, 8 t/ha, 12 t/ha.

Grain yields were estimated by a direct (continuous) method, sugar beets - by weighing root crops. The natural mass of grain crops was determined by a liter grain tester, filmness of barley - by Omarov’s method, a mass fraction of protein in wheat seed - by the Kjeldahl’s method (GOST 10846-91), amount...
of gluten - according to GOST P 54478-2011, a grain hardness - in accordance with GOST 10987-76, sugar content of sugar beet by a polarizing method - in accordance with GOST 53036-2008) [4].

Precipitation, mm Temperature, °C

![Figure 1](image.png)

**Figure 1.** Weather conditions of the year of observations

Experiments with potatoes of the sort "Synthesis" and tomatoes of the variety "Krasavets" were carried out on the territory of the farm "Roshcha." The soil is gray, deep-glazed, medium-ground, easily sublime on glacial sediments. Predecessor cereals (oats). Experiments are single-factor, short-term, Repetition - 4 times, placement of options - systematic, the size of the experimental plot on potatoes - 25 m², on tomatoes - 10 m². Method of application of fertilizers - in spring for cultivation before sowing. Options of experience on potatoes - control (without fertilizers), 4 t/ha, 8 t/ha, 12 t/ha, on tomatoes - control, 3 t/ha, 6 t/ha, 9 t/ha. Tomato seeds were sown on April 10, diving on April 22 according to a 5 x 5 scheme. In the process of growing seedlings, watering was carried out. Tomato was planted on May 23 according to a 70 x 30 scheme

The potato and tomato yields were taken directly by weighing the whole crop from the plot. In potatoes, starch was determined by polarization. In tomatoes, dry substances were determined by the thermogravimetric method (GOST 28561-90), sugars - by Bertrand, acidity - by titration of 0.1 N. alkali solution with recalculation of results for malic acid, vitamin C - iodometrically (GOST 24556-89), carotene - by Murri (GOST 13496.17-95) [5-7].

After harvesting, soil samples were taken from each pilot plot in which determined: humus - by Tyurin in Simakov modification (GOST 26213-91), alkaline hydrolyzable nitrogen - by Kornfield (GOST 26107-84), mobile forms of potassium and phosphorus - according to Chirikov (GOST 26204-91), movable forms of manganese and zinc - according to Krupsky and Aleksandrov in acetate-ammonium buffer solution with pH 4.8 (GOST R 50686), cobalt, molybdenum and copper according to Peiva and Truogu by atomic absorption method (GOST R 50687) [3, 4, 6].

3. Results and discussions

The weather conditions prevailing in 2019 were quite difficult for spring crops. A fairly hot and dry spring (April) contributed to the drying of the upper 10-15 cm of soil, which delayed the appearance of seedlings and the development of spring crops. The rains in May slightly improved the situation. But the June heat and lack of precipitation contributed to a decrease in the growing season. As a result, accelerated passage of phenological phases was observed, premature drying of plants - complete ripeness occurred at the end of July.
**Table 2.** Effect of granular organic fertilizer of decontaminated chicken litter application on spring wheat productivity and its economic valuation.

| No. | Experiment variant | Repetitions average | Yield, c/ha | Surplus c/ha | Spike length, cm | amount of grains in the spike, g | mass of grains in the spike, g | Cost of 1 c of crop, rub | Efficiency, % |
|-----|------------------|------------------|-------------|-------------|----------------|------------------------|-------------------------|-----------------|----------------|
| 1   | Control          | 27.0             | -           | -           | 7.2            | 19.5                   | 0.85                    | 414             | 92.8           |
| 2   | 2.0 t/ha         | 29.4             | 2.4         | 8.8         | 7.3            | 20.1                   | 0.88                    | 405             | 108.1          |
| 3   | 4.0 t/ha         | 33.4             | 6.4         | 23.7        | 7.5            | 21.2                   | 0.92                    | 400             | 133.4          |
| 4   | 6.0 t/ha         | 34.6             | 7.6         | 28.1        | 7.7            | 22.4                   | 0.96                    | 398             | 136.6          |
|     | TIR(c) 0.4 (%)   |                 |             |             |                |                        |                         |                 |                |

The delay in development at the beginning of vegetation determined a low crop of spring wheat. The positive impact of the fertilizer application affected the structure of the crop. The largest length of the spike was 7.7 cm and it was achieved by applying 6.0 tons/ha of chicken litter. The largest amount of grains in the spike, the mass of grains in the spike were also obtained in this embodiment of the experiment (Table 2). The protein content, raw gluten and grain nature in the fertilizer-added variants were higher than in the control. They were greater in the test variant with a chicken litter dose of 6.0 t/ha (Table 3). Maximum yield of spring wheat grains was observed in test variants with chicken droppings at doses of 4.0 and 6.0 t/ha. The increase compared to the control was 23.4 and 28.1%, respectively. The greatest economic efficiency was achieved by introducing granular chicken litter at a dose of 6.0 t/ha.

Soil studies showed that when introducing organic fertilizer at a dose of 2 t/ha, the content of nutrients and trace elements remained at the control level, which indicates that almost all nutritional elements of fertilizer were used by plants to form crops. When adding 4 tons/ha, there is an increase in the content of potassium in the soil by 11 mg/100 g of soil, phosphorus - by 4 mg/100 g of soil, and from mobile forms of trace elements - manganese – 2 times, zinc and copper - 1.5 times. In the version with introduction of 6 c/ha compared to the control, there is an increase in phosphorus content 2 times, potassium - 3 times, easily hydrolyzed nitrogen - 1.5 times, humus by 1%, manganese, zinc, copper and molybdenum – 2 times, cobalt – 1.5 times. Based on the obtained data, it can be considered that to obtain stable yields of spring wheat in the conditions of the Tambov region, it is enough to add 4-6 t/ha of the studied fertilizer.

**Table 3.** Quality indicators of spring wheat grain depending on the doses of poultry excreta application

| Indicators          | Unit of measure | Experiment variant |
|---------------------|-----------------|--------------------|
|                     |                 | Control 2.0 t/ha   | 4.0 t/ha 6.0 t/ha |
| Mass content of protein | %              | 12.0               | 12.5       | 13.0 13.0 |
| Crude gluten        | %               | 23.0               | 23.7       | 24.0 24.1 |
| Vitreousity         | %               | 45                 | 50         | 52 54   |
| Grain unit          | g/l             | 735                | 740        | 750 750 |

A similar situation could be seen in the experiment with spring barley. The positive influence of the introduction of organic fertilizer was already observed at the seedling stage. The highest harvest of spring barley grains was observed in test variants with chicken litter at 4.0 and 6.0 t/ha, and was 30.3 and 31.2 c/ha, respectively (Table 4). The yield increase compared to the control is 19.8 and 23.3%, respectively. The profitability in these experiments is 137 and 140%. Some indicators of the quality of spring barley grain have also improved. So, for example, the filminess and nature of the grain slightly exceeded the parameters under control. They were greatest on the test variant with a dose of chicken litter of 6.0 t/ha.
Soil studies showed that only with the introduction of organic fertilizer at a dose of 2 t/ha the content of nutrients and trace elements in the soil slightly exceeded the indicators in the control version, therefore, most of them were used by plants to form crops. Already in the version with the introduction of 4 t/ha, the content of mobile phosphorus in the soil increased more than twice, potassium - 1.5 times, alkaline hydrolyzable nitrogen - 1.5 times. The content of manganese, zinc and copper has experienced more than 2 times increase. When introducing granular fertilizer at a dose of 6 t/ha, the content of mobile forms of macro and trace elements in the soil increased 3-4 times compared to the control.

Considering these data and the fact that the profitability in the experience variants with the introduction of 4 and 6 t/ha of organic fertilizer did not differ significantly. It can be said that in the conditions of the Tambov region it is enough to add 4 t/ha of the studied fertilizer to obtain stable yields of spring barley.

Table 4. Effect of granular organic fertilizer of disinfected poultry application excreta on productivity of spring barley and its economic valuation

| No. | Experiment variant | Repetition average | Surplus c/ha | Vitreosity, % | Nature, g/l | Cost of 1 c crop, rub | Efficiency, % |
|-----|-------------------|--------------------|--------------|---------------|-------------|---------------------|--------------|
| 1   | Control           | 25.3               | -            | -             | 7.5         | 730                 | 333          |
| 2   | 2.0 t/ha          | 27.3               | 2.0          | 7.9           | 8.0         | 740                 | 324          |
| 3   | 4.0 t/ha          | 30.3               | 5.0          | 19.8          | 8.2         | 745                 | 295          |
| 4   | 6.0 t/ha          | 31.2               | 5.9          | 23.3          | 8.5         | 750                 | 291          |
|     | TIR (c) 0.3 (%)   | 1.4                |              |               |             |                     |              |

The average sugar content of sugar beet roots according to the experience options was 17.6%. When analyzing the effect of fertilizers on the sugar content, the greatest effect is given by the dose of application - 8 t/ha.

Sugar beets, unlike cereals, are characterized by increased consumption of food elements. Soil studies have shown that even with the introduction of granular organic fertilizer at a maximum dose of 12 t/ha, there is a slight increase in the content of nutrients - mobile phosphorus by 40%, potassium - by 20%, alkaline-hydrolyzable nitrogen - by 13%. The content of mobile forms of trace elements in the soil varies differently: manganese increases by 23% compared to control, zinc increases 3 times, copper - 2 times, molybdenum - by 40%. The content of movable cobalt even decreases as the yield of sugar beet increases. With lower doses (4 and 8 t/ha), changes in the content of food elements and trace elements are not reliable. Thus, most of the organic fertilizer feed elements are used by sugar beets to form biomass. The obtained data indicate that with a sufficient amount of moisture in the soil, the increase from the application of organic fertilizer can be higher, so the dose of fertilizers for sugar beets with a sufficient amount of moisture in the soil can be increased.

Table 5. Effect of granular organic fertilizer of disinfected poultry excreta application on sugar beet productivity and economic valuation

| No. | Experiment variant | Repetition average | Surplus c/ha | Sugar content, % | Cost of 1 c crop, rub | Efficiency, % |
|-----|-------------------|--------------------|--------------|------------------|-----------------------|--------------|
| 1   | Control           | 561                | -            | 12               | 74.2                  | 142.6        |
| 2   | Doze 4 t/ha       | 598                | 37           | 6.5              | 73.3                  | 145.5        |
| 3   | Doze 8 t/ha       | 619                | 58           | 10.3             | 71.3                  | 152.4        |
Experiments with potatoes and tomatoes were carried out on gray forest soils confined to the first floodplain terrace of the Lesnoy Voronezh River. These soils have additional humidification due to groundwater located at a depth of 150-200 cm. Tomatoes were watered during critical periods of their development. For a long time, the experimental field at the Grove farm was used to grow vegetables. Compared to experimental fields under field crop rotation, soils are better provided not only with moisture, but also with food elements, since high doses of mineral fertilizers were introduced into the soil.

**Table 6.** Effect of granular organic fertilizer of disinfected poultry excreta application on potato productivity and economic evaluation

| No. | Experiment variant | Repetition average | 1 c crop cost, rub | Efficiency, % |
|-----|--------------------|--------------------|--------------------|---------------|
| 1   | Control            | Yield, c/ha        | Surplus, %         | Surplus       |
|     |                    | 155                | -                  | 19.7          | 774           | 93.7          |
| 2   | Doze 4 t/ha        | 187                | 32                 | 20.6          | 711           | 110.9         |
| 3   | Doze 8 t/ha        | 214                | 59                 | 38.0          | 682           | 119.9         |
| 4   | Doze 12 t/ha       | 232                | 77                 | 49.7          | 685           | 118.9         |

**TIR (c) 8.6 (%) 1.53**

The granular fertilizer applied had a noticeable effect on the growth and development of potato plants already 2 weeks after the emergence of seedlings: the plants were 3-4 cm higher and better faced. At the beginning of flowering, their height reached 60-70 cm, and the control plants did not even rise above 55 cm.

Among the doses of disinfected granular litter studied, an option with an application rate of 8 t/ha of fertilizer should be distinguished. With a high increase in potato yields - 38%. This option is distinguished by the best economic indicators - a decrease in the cost of production and an increase in the profitability of production to 120% (Table 6). Introduction of organic fertilizer increases starch content in potatoes by 2-3%.

The tomato growing area is characterized by a very high content of all basic nutrients elevated and high level of trace elements (Table 9).

But even on well-maintained soils, we see a positive effect of fertilizers on plant growth and development. According to the timing of entering the "beginning of maturation" phase, the options studied differed significantly among themselves. The fastest version turned out to be the 3 one (dose 6 t/ha), the beginning of ripening in which occurred on day 82 after the appearance of seedlings. A little later, the fourth, second and first versions entered the "beginning of maturation" phase (on day 90 and 95 respectively). Comparative estimates of productivity and yield in the test cases showed that the productivity at application of granular fertilizer from disinfected chicken litter at 6 t/ha was highest at 785.7 c/ha. Slightly lower was the yield when granulated bird droppings were added at 3 tons/ha and amounted to 676.4 c/ha. This is 13.6% higher than the control option. With an increase in the application of granular bird droppings to 9 tons/ha, the expected crop increase was not observed, it remained at the level of 719.1 c/ha. This can be traced to all the indicators studied.

**Table 7.** Effect of granular organic fertilizer from disinfected poultry excreta application on tomato productivity and economic evaluation

| No. | Experiment variant | Repetition average | Cost of 1 c of harvest, rub | Efficiency, % |
|-----|--------------------|--------------------|----------------------------|---------------|
|     | Yield, c/ha        | Surplus, %         | Average fruit weight, g     |               |
| 1   | Control            |                    |                            |               |
| 2   | Doze 6 t/ha        | 155                | 32                         | 20.6          | 711           | 110.9         |
| 3   | Doze 9 t/ha        | 187                | 59                         | 38.0          | 682           | 119.9         |
| 4   | Doze 12 t/ha       | 214                | 77                         | 49.7          | 685           | 118.9         |

**TIR (c) 9.1 (%) 4.7**
The use of granular fertilizer from disinfected poultry excreta affects the quality of tomato fruits, in particular, the accumulation of sugar and dry substances. So, when adding fertilizer at a rate of 6 tons/ha, the sugar content increased by 0.93% compared to the control version and by 1.3% in terms of the dry substances content. The same trend is observed for the remaining indicators studied. However, in the variant with application of granular fertilizer from bird droppings at a dose of 9 t/ha, the content of vitamin C and carotene slightly exceeded the control variant. The use of various doses of granular fertilizer from disinfected chicken litter has a positive profitability. However, the introduction of fertilizer at a dose of 9 t/ha showed the lowest level of efficiency of 203.8% this is due to the high costs of purchasing fertilizer. The highest level of profitability was achieved in the 6t/ha option and amounted to 254%, which is about 34.3% higher than during the control option.

**Table 8.** Quality of tomato fruits depending on application of different doses of granular fertilizer of disinfected poultry excreta

| No. | Experiments variants | Dry substances, % | Sugar content, % | Acidity, % | Vitamin contents, mg-% | C content, mg-% | Carotene content, mg-% |
|-----|-----------------------|-------------------|-----------------|-----------|------------------------|----------------|-----------------------|
| 1   | Control               | 8.4               | 2.67            | 0.51      | 27.41                  | 2.68           |                       |
| 2   | Doze 3 t/ha;         | 8.9               | 2.88            | 0.44      | 28.15                  | 2.74           |                       |
| 3   | Doze 6 t/ha          | 9.7               | 3.62            | 0.41      | 29.53                  | 3.11           |                       |
| 4   | Doze 9 t/ha          | 9.1               | 3.14            | 0.47      | 28.82                  | 2.98           |                       |

A high initial content of macro and micro elements in the soil will determine that a high content of all nutrients is observed in the soil even at low doses of organic fertilizer introduced. However, it is uneven. Thus, the content of mobile phosphorus, which is in excess, increases by 10 mg/100 g of soil, the content of exchange potassium, the need for which in tomatoes is high, by 3 mg/100 g of soil, the content of easily hydrolyzable nitrogen, which is disadvantageous - by 3.5 mg/100 g of soil. The content of manganese and zinc increases by 25%, the content of which in the soil is characterized as high, and the content of copper, molybdenum and cobalt does not change. With a high initial content of nutrients in the soil, plants use those whose content in the soil is minimal.

**4. Conclusions**

1. The increase in yield among field crops from the use of this fertilizer in the conditions of the Tambov region on leached chernozem on spring wheat was 25-30%, spring barley - 20-23%, sugar beets - 10-12%, among vegetable crops on well-fertilized grey forest soils on potatoes was 40-50%, on tomatoes - 30-32%.

2. Profitability from the use of this fertilizer increases from low-demand crops to more demanding ones and amounts to 118-120% on potatoes, on spring wheat - 130-135%, on spring barley - 135-140%, on sugar beets - 140-150%, on tomatoes - 230-250%.

3. Considering the profitability, the optimal doses of application of the studied fertilizer are on spring wheat - 4-8 t/ha, spring barley - 4t/ha, sugar beets - 8 t/ha, potatoes - 8 t/ha, tomatoes - 6 t/ha.

4. The balanced composition of the main elements of nutrition and trace elements contributes to improving the quality of agricultural products by 0.7-1.5%. The protein and gluten content in wheat grains is 1-1.5% - plateness in barley grain, 9% sugar content, 1-3% - starch in potatoes, by 0.8-1% - sugars, by 1.5% - dry substances, 1-2% - vitamin C content and 0.5% - carotene in tomato fruits.
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