Chicken droppings influence on sod-podzolic soil fertility change studying experience

V V Okorkov¹, N N Shchukin² and L A Okorkova¹

¹ Upper Volga Federal Agrarian Research Center, 3 Tsentralnaya Street, village Novy, Suzdal district, Vladimir region, 601261, Russia
² Federal Research Center Nemchinovka, 6 Agrochemists Street, village Novoivanovskoe, Odintsovo district, Moscow region, 143026, Russia

E-mail: adm@vnish.elcom.ru, n9159803437@yandex.ru

Abstract. The aim of the research was to study the effect of fresh chicken droppings on the dynamics of the physical-chemical and agrochemical properties of sod-podzolic soil and the yield of grain crops. In the sod-podzolic light loamy soil of the Yaroslavl region in the layer of 0-0.20 m in May, fresh chicken droppings were embedded at the dose of 120 t/ha. By autumn, in the 0-0.40 m layer of pHKCl increased from 4.53-4.99 to 5.38-7.09, the content of mobile phosphorus and exchangeable potassium increased by 2.0-2.4 times, nitrate and ammonium nitrogen - 3-5 times. The content of nitrates in the soil has exceeded the Maximum Allowable Concentration level. The grain yield of the spring wheat studied varieties, triticate and barley varied from 6.7 to 9.5 t/ha, chaffy oats - from 5.7 to 5.9, hulless oats - from 4.4 to 4.6 t/ha. At the beginning of the growing season of crops in the 0-0.40 m layer, the stocks of nitrate nitrogen were close to the stocks of the autumn observation period of 2019, and ammonium nitrogen decreased by 285 kg/ha.

1. Introduction

Recently much attention was paid to improving soil fertility through the use of biological agents including biological preparations [1, 2, 3, 4, 5]. Optimization of the arable land use and field crop rotations was taken into account everywhere, and biological crop rotations were increasingly introduced into production [6, 7, 8].

Currently, due to a sharp decrease in the yield of cattle manure, special attention is given to poultry droppings as the source of organic fertilizers (OF). The use of industrial waste as a OF opens up broad prospects for solving not only problems of agriculture, but also the environment. It is known that the transfer of poultry farming to an industrial basis and the intensification of production at poultry farms made significant changes in the technology of poultry keeping. This has led to the increase in the output volume of litter and its concentration at a limited area in close proximity to poultry farms and improve the sanitary conditions and the obtaining of the litter that corresponds to the "Veterinary-sanitary rules for the preparation and use as organic fertilizer manure, litter, and wastewater at infectious and parasitic diseases of animals and birds". These requirements were also met by the litter obtained in LLC "Poshekhnonskaya Poultry Farm" of the Yaroslavl region.

In a number of studies on gray forest soils of the Upper Volga region [9, 10], studies were conducted on the effectiveness of various degrees of rotted poultry droppings. In this case, a higher
payback with an increase in the yield of a unit of primary nutrient in mineral and organomineral fertilizer systems was revealed in comparison with organic ones. Due to the slower nitrogen transformation of some OF in the early growing seasons of crops, high reserves of nitrate nitrogen were not created in the soil, as in the case of mineral and organomineral fertilizer systems. When using fresh bird droppings on sod-podzolic soils of the Upper Volga region, these issues were not studied.

2. Materials and methods
The research began in 2019 on the soddy-slightly podzolic soil of the Poshekhonsky district of the Yaroslavl region (Table 1).

Table 1. Humus content and physicochemical characteristics of sod-podzolic soil occupied by woody-herbaceous vegetation.

| Soil layer, cm | Humus, % | pHKCl | S mg-equiv/100 g of soil | HA | HEXC | T, % | AlEXC, mg/100 g soil | Particles less than 0.01 mm, % |
|----------------|----------|--------|--------------------------|-----|------|------|---------------------|-----------------------------|
| 0-28           | 1.05     | 4.28   | 9.0                      | 4.34| 0.54 | 67.2 | 4.59                | 22.4                        |
| 28-43          | 0.54     | 4.10   | 15.4                     | 3.32| 0.52 | 82.4 | 3.76                | 33.6                        |
| 43-62          | 0.07     | 4.70   | 21.6                     | 2.27| 0.09 | 90.4 | 0.09                | 36.2                        |
| 62-86          | 0.08     | 4.85   | 21.6                     | 1.75| 0.08 | 92.3 | 0.09                | 36.0                        |
| 86-109         | 0.08     | 6.16   | 23.6                     | 1.22| 0.05 | 95.2 | Not                 | >                             |
| 109-142        | 0.01     | 6.63   | 25.2                     | 0.70| 0.06 | 97.3 | >                   | 33.6                        |
| 142-168        | 0.05     | 7.17   | Not                      | 0.35| 0.06 | Not | >                   | 31.6                        |
| 168-190        | 0.19     | 7.20   | def.                     | 0.52| 0.06 | def. | >                   | 34.7                        |

Note: S – sum of absorbed bases, HA – hydrolytic acidity, HEXC – exchange acidity, T – degree of base saturation.

The upper humus horizon of the soil (about 1.05% humus) is represented by coarse silty light loam (silt content 6.9%), in the A2B horizon (28-43 cm) the content of physical clay increased from 22.4 to 33.6%, silt - up to 19.9%. It observed both the processes of destruction of the mineral part of the soil and the wash-in of silt particles. The movement of silt was carried out with the stabilization of mineral soil particles with acidic organic matter [4].

In the illuvial horizon (43-109 cm), the content of physical clay increased to 35.4-36.2%, and silt - 20.4-23.0%. The transitional horizon (BC, 109-142 cm) and the parent carbonate rock of medium loamy coarse-silty (44.7-45.8%) composition were deeper.

The upper layers of the soil were characterized by a strongly acidic reaction of the medium (pHKCl is 4.28-4.10). Exchangeable acidity in the humus horizon was 0.54 mg-equiv/100 g of soil and is represented mainly by mobile aluminum (4.6 mg/100 g of soil), the inhibitory effect of which on plants can be observed already at the content of 3-5 mg/100 g of soil [5]. In the B-horizon (36-86 cm) of the soil, a medium acid reaction of the medium and a low content of mobile aluminum were observed. In the transitional BC and C horizons, the pHKCl value increased to 6.63 and 7.17-7.20, respectively. The most unfavorable in terms of acidity for plants were the upper layers to the depth of about 40-60 cm.

In 2019, fresh chicken droppings at the dose of 120 t/ha was applied with a spreader for spring plowing (by 20-22 cm). The system of soil cultivation and crop care included: disk ing (12-15 cm), two cultivation (10-12 and 5-7 cm) with harrowing, seed dressing, sowing, pesticide treatment during the growing season (against weeds, diseases and pests). During the experiments, mineral fertilizers were not applied.

Sowing of 3 experiments was carried out on May 25, 2019. The seeding rate of germinating seeds of grain crops is 5.0 million/ha. Repetition is 3 times. The size of the registration plots is 120 m², their placement is systematic. The experiments included varieties of grain crops: spring wheat and triticale, barley, chaffy and hulless oats.
For the period May-September, the amount of precipitation was 408 mm (at the norm of 343 mm) with an average air temperature of 13.3 °C (14.5 °C). The duration of the growing season for spring wheat varieties varied within 106-119 days, barley - 99 and oats - 109 days.

In 2020, the aftereffect (1st year) of chicken droppings was studied. The experiments were laid on May, 29. The scheme, methodology and technology of crops cultivation are similar to the experiments in 2019.

In May-September, 503 mm of precipitation fell out (46% higher than the average annual data), the average air temperature approached the norm and amounted to 14.0 °C. The growing season of varieties of experimental crops in 2020 ranged from 81-94 days (or 18-25 days shorter than in 2019).

The dynamics of the soil agrochemical and physicochemical properties was observed both in the field without the introduction of chicken droppings, and with its plowing at the dose of 120 t/ha, 1 ton of which contained 21 kg of nitrogen, 26 kg of P2O5 and 8.4 kg K2O.

The content of nitrate nitrogen was determined by the potentiometric method, ammonium nitrogen in the soil - by the method of indophenol greenery, mobile phosphorus - according to Kirsanov’s method, exchangeable potassium - according to Maslova’s one, N-NH4 (aq.) – using an ion-selective electrode on NH4+ at a soil:water ratio of 1:1.

3. Results and discussion
It can be seen (Table 2) that in the field without chicken droppings in the 0-30 cm layer, a close to weakly acidic reaction of the medium prevailed, in the 30-40 cm layer - moderately acidic, the supply of phosphorus and potassium - increased. The latter is due to the medium loamy granulometric composition. The initial reserves of nitrate nitrogen in the 0-20 cm layer (62.7 kg/ha) could provide a grain yield of about 2 t/ha. In September, they decreased in this layer by 5.6 times, and in the 0-40 cm layer - by 3.7 (25.3 kg/ha). The stocks of N-NH4 in the 0-40 cm layer in September (71.2 kg/ha) increased 1.5 times compared to June.

In 2020, on the 1st (20.07) and the 2nd (31.08) observation dates, the stocks of nitrate nitrogen in the 0-40 cm layer (in the liquid phase) were similar and, compared to September (September, 10), 2019, decreased from 25.3 to 17.9-20.7 kg/ha, and stocks of ammonium nitrogen - from 71.2 to 53.0 kg/hectare. In the 0-100 cm layer, the N-NH4 reserves amounted to 113 kg/ha. The degree of their transition to the liquid phase during this period in the 0-40 cm layer in 2019 varied from 1.5 to 2.1%, and in 2020 - from 0.6 to 1.3%. One of the reasons for the difference is the higher rainfall in 2020.

Under the action of chicken droppings, the decrease in soil acidity (increase in pHKCl) was observed (Table 3). In September, already in the 30-40 cm layer, the pHKCl value was close to 7.0. During this period, the content of mobile phosphorus (up to 15-31 mg/100 g of soil) and exchangeable potassium (in layers 20-30 and 30-40 cm to 33-45 mg/100 g) increased sharply. Compared to the control variant (Table 2), a sharp increase in the content and reserves of nitrate nitrogen was observed in June and August (3-4 times in layers 0-20 and 20-30 cm).

Abundant precipitation in July 2019 (153 mm) led to the movement of nitrate nitrogen deeper than 40 cm and the formation in September of its maximum reserves in the 30-40 cm layer. In June it was in the 0-20 cm layer, in August - in the 20-30 cm. In the upper soil layers, the N-NO3 content exceeded the maximum allowable quantity (13 mg nitrates/100 g or about 3.0 mg N-NO3/100 g soil).

In June 2020, compared to September 2019, the stocks of nitrate nitrogen in the 0-40 cm soil layer (stocks in the liquid phase) decreased from 161 to 139 kg/ha. Obviously, the active movement of N-NO3, which began in August 2019, continued at a later date. The amount of N-NO3 reserves in the meter soil layer in June 2020 (264 kg/ha) was close to its reserves in the 0-40 cm soil layer in August 2019 (276 kg/ha). By the end of August 2020, there was a decrease in the stocks of nitrate nitrogen both in the 0-40 and 40-100 cm layers. It was mainly due to its absorption by cultivated crops (150 kg/ha N-NO3). This was favored by the decrease in soil acidity (an increase in pHKCl) both in the 0-40 cm layer and in the 40-100 cm layer.
In 2020, the stocks of N-NH₄ soil sharply decreased (in the 0-40 layer from 351 to 66 kg/ha, a decrease of 285 kg/ha), the degree of its transition to the liquid phase decreased. Obviously, this is due to the peculiarities of the mineralogical composition of the clay fraction of these soils, which was dominated by hydromicas and micas. This is indirectly confirmed by the high capacity of cation exchange (23-24 mg-eq/100 g of soil) in layers 40-80 cm (Table 1). It is possible that the crystallization of water in the autumn-winter period led to the increase in the concentration of ammonium ions in the remaining solution and their intensive entry into the absorbed state. The increased concentration of ions in the liquid phase caused coagulation of soil colloids, promoted the intra-aggregate absorption of NH₄⁺ ions of chicken droppings [6]. Data on a sharp decrease in soil N-NH₄ reserves in layers of 0-40 and 40-100 cm and ammonium nitrogen in the liquid phase indicated a weak role of soil N-NH₄, determined in 1 M KCl solution, in the nitrogen nutrition of cultivated crops by the aftereffect of chicken droppings (from 0.5-3.9 to 2.3-22.5%). The high degree of N-NH₄ transition of the soil into the liquid phase (22.5%) in the 0.30-0.40 m layer also indicated a significant movement of N-NH₄ deeper than 40 cm.

Table 2. Dynamics of soil physicochemical and agrochemical properties without the introduction of chicken droppings.

| Layer depth, cm | pH_KCl | P₂O₅ (mg/100 g of soil) | K₂O | N-NH₄ | N-NH₄ (aq.) | w, % | Stocks N-NH₄, kg/ha | Stocks in the liquid phase, kg/ha |
|-----------------|--------|--------------------------|------|--------|-------------|------|---------------------|---------------------------------|
| 0-20            | 4.96   | 14.1                     | 13.7 | 2.09   | 0.96        | 0.0377 | 3.9                 | 28.8                           |
| 20-30           | 4.99   | 13.0                     | 12.0 | 1.35   | 0.73        | 0.0202 | 2.8                 | 11.0                           |
| 30-40           | 4.53   | 12.5                     | 9.8  | 0.74   | 0.49        | 0.0114 | 2.3                 | 7.4                            |
| Σ               |        |                          |      |        |             |        | 48.2                | 94.0                           |

| Layer depth, cm | pH_KCl | P₂O₅ (mg/100 g of soil) | K₂O | N-NH₄ | N-NH₄ (aq.) | w, % | Stocks N-NH₄, kg/ha | Stocks in the liquid phase, kg/ha |
|-----------------|--------|--------------------------|------|--------|-------------|------|---------------------|---------------------------------|
| 0-20            | 5.10   | 12.7                     | 8.24 | 1.32   | 0.96        | 0.0150 | 1.6                 | 28.2                           |
| 20-30           | 5.18   | 12.0                     | 14.2 | 1.10   | 1.14        | 0.0075 | 0.7                 | 17.1                           |
| 30-40           | 4.65   | 11.6                     | 8.9  | 0.66   | 0.84        | 0.0045 | 0.5                 | 12.4                           |
| Σ               |        |                          |      |        |             |        | 58.4                | 65.9                           |

| Layer depth, cm | pH_KCl | P₂O₅ (mg/100 g of soil) | K₂O | N-NH₄ | N-NH₄ (aq.) | w, % | Stocks N-NH₄, kg/ha | Stocks in the liquid phase, kg/ha |
|-----------------|--------|--------------------------|------|--------|-------------|------|---------------------|---------------------------------|
| 0-20            | 5.02   | 11.1                     | 13.9 | 0.37   | 1.31        | 0.0279 | 2.1                 | 39.3                           |
| 20-30           | 5.00   | 14.1                     | 10.6 | 0.48   | 1.46        | 0.0222 | 1.5                 | 21.0                           |
| 30-40           | 5.04   | 14.3                     | 12.7 | 0.39   | 1.06        | 0.0176 | 1.7                 | 10.9                           |
| Σ               |        |                          |      |        |             |        | 71.2                | 25.3                           |

| Layer depth, cm | pH_KCl | P₂O₅ (mg/100 g of soil) | K₂O | N-NH₄ | N-NH₄ (aq.) | w, % | Stocks N-NH₄, kg/ha | Stocks in the liquid phase, kg/ha |
|-----------------|--------|--------------------------|------|--------|-------------|------|---------------------|---------------------------------|
| 0-20            | 5.15   | 14.8                     | 15.6 | 0.39   | 0.98        | 0.0131 | 1.3                 | 29.4                           |
| 20-30           | 4.78   | 15.3                     | 12.5 | 0.37   | 0.97        | 0.0082 | 0.9                 | 14.6                           |
| 30-40           | 4.61   | 16.0                     | 10.2 | 0.23   | 0.60        | 0.0035 | 0.6                 | 9.0                            |
| Σ               |        |                          |      |        |             |        | 53.0                | 20.7                           |

Note: w – the degree of transition of ammonium nitrogen into the liquid phase.
The role of N-NH₄ in plant nutrition increased sharply in comparison with the control variant, since its amount in the liquid phase in the 0-40 cm layer increased from 0.8-1.6 (Table 2) to 16.4-59.8 kg/ha (Table 3).

**Table 3. Dynamics of the soil physicochemical and agrochemical properties with the introduction of chicken droppings.**

| Layer depth, cm | pHECCl | P₂O₅ | K₂O | N-NO₃ | N-NH₄ | N-NH₄ (aq.) | w, % | Stock s N-NH₄, kg/ha | Stocks in the liquid phase, kg/ha |
|----------------|--------|------|-----|-------|-------|-------------|------|---------------------|----------------------------------|
| 1st term, 1st decade of June 2019 | | | | | | | | | |
| 0-20 | 5.41 | 13.8 | 21.0 | 5.75 | 3.94 | 0.344 | 8.7 | 118.2 | 172.5 |
| 20-30 | 4.95 | 10.1 | 20.1 | 4.36 | 4.69 | 0.394 | 8.4 | 70.4 | 65.4 |
| 30-40 | 4.24 | 7.4 | 14.1 | 0.85 | 0.65 | 0.0153 | 2.3 | 9.8 | 12.7 |
| Σ | | | | | | | | | 198.3 |
| 2nd term, 1st decade of August 2019 | | | | | | | | | |
| 0-20 | 5.05 | 11.6 | 19.1 | 3.80 | 1.26 | 0.111 | 8.8 | 37.8 | 114.3 |
| 20-30 | 6.37 | 14.7 | 36.5 | 6.92 | 7.79 | 1.34 | 17.2 | 116.8 | 104.2 |
| 30-40 | 4.60 | 10.4 | 10.8 | 3.89 | 4.51 | 0.227 | 5.0 | 67.6 | 58.3 |
| Σ | | | | | | | | | 222.3 |
| 3rd term, 1st decade of September 2019 | | | | | | | | | |
| 0-20 | 5.38 | 15.0 | 15.7 | 0.64 | 1.71 | 0.0702 | 4.1 | 51.3 | 19.2 |
| 20-30 | 6.68 | 27.7 | 33.0 | 3.72 | 6.38 | 0.787 | 12.3 | 95.7 | 55.8 |
| 30-40 | 7.09 | 31.0 | 45.4 | 5.75 | 13.6 | 3.06 | 22.5 | 204.6 | 86.2 |
| Σ | | | | | | | | | 351.3 |
| 1st term, June 20, 2020 | | | | | | | | | |
| 0-20 | 6.08 | 21.7 | 19.8 | 2.40 | 1.46 | 0.040 | 2.7 | 43.8 | 72.0 |
| 20-30 | 5.98 | 21.5 | 18.4 | 2.63 | 0.83 | 0.022 | 2.6 | 12.4 | 39.4 |
| 30-40 | 5.66 | 17.6 | 13.8 | 1.86 | 0.66 | 0.011 | 1.7 | 9.90 | 27.9 |
| Σ | | | | | | | | | 66.1 |
| 40-50 | 4.71 | 17.3 | 11.3 | 1.67 | 0.64 | 0.012 | 1.9 | 9.6 | 25.0 |
| 50-60 | 4.73 | 24.4 | 10.6 | 1.48 | 0.88 | 0.011 | 1.3 | 13.2 | 22.2 |
| 60-80 | 4.80 | 22.9 | 9.50 | 1.35 | 0.57 | 0.0085 | 1.7 | 17.1 | 40.4 |
| 80-100 | 5.75 | 23.4 | 11.9 | 1.26 | 0.62 | 0.0097 | 1.6 | 18.6 | 37.8 |
| Σ | | | | | | | | | 124.6 |
| 3rd term, 31.08.2020 | | | | | | | | | |
| 0-20 | 5.93 | 15.8 | 16.7 | 0.63 | 1.36 | 0.0306 | 2.2 | 40.8 | 18.9 |
| 20-30 | 5.86 | 14.6 | 14.4 | 0.98 | 1.05 | 0.0198 | 1.9 | 15.8 | 14.7 |
| 30-40 | 5.35 | 13.5 | 10.3 | 0.66 | 0.79 | 0.0066 | 0.83 | 11.8 | 9.9 |
| Σ | | | | | | | | | 68.4 |
| 40-50 | 4.80 | 13.5 | 9.0 | 0.72 | 0.73 | 0.0050 | 0.68 | 11.0 | 10.8 |
| 50-60 | 4.69 | 14.7 | 9.81 | 0.83 | 0.75 | 0.0054 | 0.73 | 11.2 | 12.4 |
| 60-80 | 4.81 | 15.9 | 9.68 | 0.80 | 0.69 | 0.0039 | 0.57 | 20.7 | 24.0 |
| 80-100 | 5.42 | 17.8 | 13.0 | 0.76 | 0.64 | 0.0027 | 0.43 | 19.2 | 22.8 |
| Σ | | | | | | | | | 130.5 |

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Our studies showed that a close linear relationship was observed between the degree of the transition of soil ammonium nitrogen into the liquid phase and its content in the soil in the year of action of chicken droppings (Figure 1).

![Graph showing the relationship between the degree of transition of soil ammonium nitrogen into the liquid phase and its content in the year of fresh chicken droppings action (Yaroslavl region).](image)

**Figure 1.** The relationship between the degree of soil ammonium nitrogen transition into the liquid phase with its content in the year of fresh chicken droppings action (Yaroslavl region).

It can be assumed that when the degree of transition of N-N\textsubscript{H4} to the liquid phase is less than 5%, its participation in plant nutrition is weak, with the degree of transition 10% > w > 5%, it is average, and when w > 10%, it is high. On the studied soils, this is achieved when the content of N-N\textsubscript{H4} in the soil, respectively, is less than 2.5 from 2.5 to 5.5, more than 5.5 mg/100 g of soil. With the increase in these parameters, the intensity of N-N\textsubscript{H4} movement along the profile also increases.

On sod-podzolic soils of the Vladimir region of light granulometric composition, using an ion-selective electrode on NH\textsubscript{4}\textsuperscript{+}, the relationship between the degree of transition of soil ammonium nitrogen into the liquid phase was also studied [7]. It ranged from 7.6 to 25.6%. It was revealed that the degree of its transition to the liquid phase increased with the decrease in both the absorption capacity and the content of the fraction less than 0.01 mm in the soil. This may indicate the local movement of ammonium nitrogen from layers with a lower bond strength with the absorbing complex (light particle size distribution) into layers with a heavier particle size distribution.

These data also indicate the inequality of nitrate and ammonium nitrogen in nutrition during critical periods for plants, when it is necessary to use the amount of nitrogen from the liquid phase in a limited period of time, ensuring high crop yields. To a large extent, this was related to the gray forest soils of the Vladimir high plain, characterized by a medium and heavy loamy composition. At experimental stations, the proportion of the transition of soil ammonium nitrogen into the liquid phase did not exceed 5-6% [6]. With the duration of the use of moderate doses of organic and mineral fertilizers in the gray forest soil of high plain, the decrease in both the stocks of ammonium nitrogen and the degree of its transition to the liquid phase was observed [6].

Table 4 shows data on the influence of stocks of N-N\textsubscript{H4} and N-NO\textsubscript{3} on the grain crops yield by the effect and aftereffect of fresh chicken droppings.
Table 4. Influence of N-NH₄ and N-NO₃ stocks on the grain varieties yield by action (2019) and aftereffect (2020) of fresh chicken droppings.

| Year research | Stocks N-NH₄, kg/ha 0-40 cm | Stocks N-NO₃, kg/ha 0-40 cm | Spring wheat and triticale Variety | Yield, t/ha | Spring barley Variety | Yield, t/ha | Oats Variety | Yield, t/ha |
|---------------|-----------------------------|-----------------------------|------------------------------------|-------------|----------------------|-------------|--------------|-------------|
| 2019, action 120 t/ha chicken droppings | 198 Not def. | 251 Not def. | Darya | 8.09 | Nur | 7.29 | Zlata ** | 5.91 |
| | | | Zlata | 9.46 | Moskovsky | 8.25 | Opolny | 5.74 |
| | | | RIMA | 8.82 | Jaromir | 6.91 | Nemchinovsky | 4.39 |
| | | | Sudarynya | 9.14 | Rodnik Prikamya | 6.74 | Nemchinovsky | 4.39 |
| | | | Normann | 9.37 | LSD₀₅ | 0.56 | Azil ** | 4.58 |
| 2020, after-action | | | | | | | | | |
| 120 t/ha chicken droppings | 124.6 | 139 | 264 | RIMA | 4.68 | Jaromir | 4.72 | Zalp | 5.49 |
| | | | Sudarynya | 4.71 | Nadzey | 4.89 | Nemchinovsky | 4.39 |
| | | | Normann | 5.28 | Zlatoyar | 4.80 | Azil ** | 3.27 |
| | | | Zlata *** | 1.45 | LSD₀₅ | 0.38 | LSD₀₅ | 0.41 |
| | | | LSD₀₅ | 0.32 |

Note: * - spring triticale, ** - hulless varieties, *** - without chicken droppings.

In 2019, according to the action of 120 t/ha of chicken droppings, the yield of spring wheat and spring Normann triticale varieties varied from 8.09 to 9.46 t/ha. Calculations showed that the yield of varieties of 8.82-9.46 t/ha should be achieved by using about 4.5% of photosynthetic active radiation (PAR). The grain yield of barley was in the range of 6.74-8.25 t/ha. The Nur variety used about 3.5% PAR, Moskovsky-86 - 4%, and the Jaromir and Rodnik Prikamya varieties - about 3.2% PAR.

The yield of chalky oat varieties Opolny and Yakov under the conditions of the experiment was 5.74 and 5.91 t/ha, respectively. They used about 2.8% PAR. The grain yield of the more valuable and demanding cultivation technology of hulless grain oats varied from 4.39 to 4.58 t/ha.

According to the aftereffect of 120 t/ha chicken droppings, the yield of spring wheat and spring triticale varieties decreased from 8.09-9.46 to 4.37-5.28 t/ha. On the control variant (without droppings application), the yield of spring wheat variety Zlata was only 1.45 t/ha, while the aftereffect of 120 t/ha chicken droppings was 4.37 t/ha. The yield of this culture did not depend on the reserves of ammonium nitrogen in the soil layer of 0-40 cm, but was determined by the reserves of nitrate nitrogen in it. Obviously, this also applies to other studied cultures. The proportion of the transition of soil ammonium nitrogen into the liquid phase due to the aftereffect of chicken droppings in the 0-40 cm layer decreased from 2.3-22.5 to 0.8-2.7%. Obviously, the differences in the yield of cultivated crops in 2019-2020 are primarily associated with changes in nitrate nitrogen reserves during these years.

In 2019, the stocks of nitrate nitrogen in the 0-40 cm soil layer amounted to 251 kg/ha, which provided an average yield of 4 spring crops (Zlata, RIMA, Sudarynya and Normann) of 9.20 t/ha. In 2020, their average yield decreased to 4.89 t/ha, and N-NO₃ stocks to 139 kg/ha. It turned out that in 2020 the yield of 4 spring crops decreased by 1.89 times, and stocks of N-NO₃ by 1.81 times. This
tested the decisive role of the stocks of mainly nitrate nitrogen in the 0-40 cm layer on their yield. The high supply of it to the soil layer 0-40 cm in the early stages of the growing season to its middle contributed to the absorption of the main amount of N-NO₃ of their total removal. Well-developed plants absorbed the rest of the nitrogen from the deeper layers of the soil, when their increased acidity did not negatively affect the functioning of the root system.

For spring barley for the same years, the yield ratio was 1.55 (7.58 : 4.90 = 1.55), and 1.81 for the reserves of nitrate nitrogen in the soil layer 0-40 cm. Apparently, due to intensive trimming, the maximum nitrogen absorption by this crop in 2019 shifted to later dates. So, the ratio of nitrate nitrogen reserves in the 0-40 cm layer, equal to 1.57, was established for their reserves in 2019 in mid-August, which were estimated by the average reserves in the 2nd and 3rd periods, and in the 1st term of 2020 (218 : 139 = 1.57) (Table 3).

For hulless oats, the yield ratio (2019 to 2020) was 1.12. Among grain crops, oats are characterized by increased aluminum resistance. For this culture, the ratio of nitrogen reserves in the liquid phase of the soil in its entire meter layer is important. It was 1.14 in it for the 1st decade of August 2019 ((276.3 + 26.8) : (264 + 1.7) = 1.14).

More demanding nutritional conditions, hulless oat varieties require a high nitrogen supply in the upper part of the soil profile. The maximum nitrogen absorption in them in 2019 shifted to a later date (like in barley). The ratio in crop yields over these years was 1.42 (4.48 : 3.16), and in the stocks of nitrate nitrogen - 1.57 (218 : 139).

4. Conclusions
Calculations showed that the approximate size of the accumulation of available forms of nitrogen during the transformation of poultry droppings and their use for 2 years should be determined from the following components: 1) the increase in the reserves of ammonium and nitrate nitrogen per year of action in the soil layer 0-40 cm 627 kg/ha (351 + 276); 2) nitrogen removal by the harvest of spring wheat and triticale: 276 kg/ha (9.20 × 30), where 9.20 is the average yield in t/ha, 30 is the nitrogen removal of 1 ton of grain, taking into account by-products in kg; 3) accounting for reserves of ammonium and nitrate nitrogen in a meter layer of soil without the introduction of chicken droppings - 150 kg/ha.

As the result, the total amount of accumulation of mineral nitrogen from the use of 120 t/ha chicken droppings for the year of its operation was: 753 kg/ha (627 + 276 - 150).

In the year of operation of the chicken droppings, from 1 ton of it, about 6.3 kg of mineral nitrogen was obtained, which corresponds to 30% of the transformation of chicken droppings nitrogen (6.3 : 21 × 100).

In the 2nd year of action (1st year of aftereffect) of the chicken droppings, no additional growth of mineral nitrogen in the soil was found, about 150 kg/ha of nitrate nitrogen was used by plants and at least 280 kg/ha of ammonium nitrogen was absorbed by the absorbing soil complex.

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