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# The Role of Fertilizers in Improving Soil Fertility, Yield and Quality of Potatoes

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**Abstract**

The article studies the influence of various dosages of organic (manure, poultry litter) and mineral ($N_{60}P_{120}K_{60}$) fertilizers on the yield and quality of potato tubers of the "Nevsky," "Caratop" varieties. Also, the time of introducing organic fertilizers in combination with mineral fertilizers has been studied, as well as their impact on improving soil fertility. After introducing manure in the quantity of 40 t/ha in combination with mineral fertilizers and poultry droppings, 37.1 t/ha of quality tubers were obtained (featuring relatively high content of vitamin C, protein and marketability of tubers).

## Keywords

Organic fertilizers; Mineral fertilizers; Potato varieties; Potato yield; Marketability; Quality of potato tubers

## Introduction

The yield of potatoes depends largely on the correct use of organic and mineral fertilizers [1-4]. Scientific literature has extensive information about the use of fertilizers for potatoes. However, zoning of new varieties necessitates the study of their reaction to the introduction of pomaces in specific soil-climatic conditions [5]. This information is particularly relevant in the conditions of natural emergencies and disasters, which have started to repeat more and more often, the severity of which has increased too [6,7]. According to many researchers [8-11], yield is determined largely by the photosynthetic capacity, which depends both on weather conditions and on the level of mineral nutrition.

In order to improve the yield and quality of potato tubers, proper and widespread use of local organic fertilizers along with mineral fertilizers is very important, as they not only contain essential nutrients needed for plants, but they are also a source of nutrition for the microorganisms inhabiting the soil [12].

Agricultural workers in the Western Kazakhstan face a complex and important task of improving productivity and increasing the yield of potatoes. Owing to the rapid development of oil and gas industry, the population of cities and settlements in the region is rapidly growing. Therefore, the challenge of meeting the population's needs for potatoes is critical. Production of potatoes should be increased not only through expanding the areas for the crop, but also by increasing the yield.

In the system of agrotechnical measures for increasing the yield of potatoes, the most important aspect is the correct choice of dosages of mineral and organic fertilizers and optimum time of their introduction.

We started studying potato fertilizers in 1972, and have continued with some interruptions till present. The research was performed on various soils: meadow alluvial; meadow chestnut, dark chestnut, loamy and sabulous, with various varieties: the Priekul early (very early), the Nevsky (middle early), the Lorkh (middle late), the Caratop and the Udacha (early) varieties.

The main organic fertilizer in the Western Kazakhstan is manure, which is also one of the sources of carbon dioxide required to enhance the air supply and synthesis of organic substances in the leaves of plants.

The time of manure introduction for various crops is determined primarily by the degree of its decomposition and biological properties of the plants.

The absence of manure pits that would eliminate loss of nutrients from the manure inevitably results in using it at different times. Therefore, special recommendations are to be developed as to the time and dosages introduced.

On the contrary, the introduction of intensive technology of cultivating potatoes requires the exclusion of soil compaction after the introduction of manure in the spring, reducing its impurity and achieving earlier planting dates due to changing the time of manure introduction. Therefore, studying of the time of introducing organic fertilizers in the autumn before winter tillage and into frozen tillage into the snow is of great practical interest.

As to the relationship between the nutrition area and the individual agrotechnical factors, using fertilizers in particular, opinions of the researchers do not always coincide, and are sometimes contradictory. Therefore, the studies included two variants of planting patterns. Unfortunately, interaction of plant density with the nutrition mode in a single complex for potatoes has been insufficiently studied this far, and needs further research.

However, sharp reduction in the livestock in recent years resulted in a significant reduction in the supply of traditional organic fertilizers (solid and liquid cattle manure).

However, in the Western Kazakhstan new poultry farms have been built, therefore a problem occurred of recycling and rational use of bird droppings, the share of which in organic fertilizers increased significantly.

Unfortunately, until present, scientific literature has almost no data about potatoes'responsiveness to poultry droppings in the conditions of

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irrigation on chestnut soils. With regard to its chemical composition, one can assume that bird droppings will have different effect on potato plants, as compared to cattle manure, and complete mineral fertilizers.

## Methods

The main purpose of the research was to study the effect of different time of introducing manure in combination with mineral fertilizers and planting density, and using poultry droppings and mineral fertilizers in the cultivation of early ripening varieties on irrigated dark chestnut soils of the West Kazakhstan region on the yield and quality of potatoes (schematic of the experiments are shown in the tables).

The soil cover of the experimental plot with manure was represented by dark-brown medium-loamy soils with powerful loamy deposits, not saline; humus content in the plow horizon varied from 2.6 to 3.4%; thickness of humus horizons was 45-55 cm; bubbling started from 45 to 50 cm.

The soil cover of the experimental plot with bird droppings is also represented by dark chestnut soils of medium thickness. They have loamy granulometric texture and satisfactory agrophysical properties for potatoes cultivation. Content of humus in topsoil (0-30 cm) is 2.8-3.5%, that of nitrate nitrogen – 8-10 mg/kg, that of mobile phosphorus (by Machigin) – 16-25 mg/kg, and that of exchange potassium (in 1% carbon-ammonium extract) – 404-452 mg/kg. The reaction of the soil solution is slightly alkaline (pH water is 7.2-7.3). Bubbling with hydrochloric acid occurs from the depth of 45-48 cm.

Therefore, the experiments with potatoes were performed in the soil and climatic conditions typical for the Western Kazakhstan.

The object of the research during the experiment with manure was the Nevsky medium early variety, and during the experiment with bird droppings – the Nevsky medium early variety and the early Caratop variety. The same fertilization systems were studied on both varieties.

The experiment was started using cattle manure on straw bedding that had been prepared in autumn and winter. The manure was obtained on straw bedding in the quantity of 5 kg of straw per cattle head that was removed daily and stored in a pile on a concrete platform. The characteristics of the manure are as follows: moisture 58-62%, pH – 7.5-8.0, total nitrogen content – 0.50-0.55, phosphorus – 0.22-0.25, potassium – 0.58-0.62 and ash – 12-14%. The manure composition insignificantly differed from year to year.

In the autumn, manure was introduced on September 10-15 before tillage, on November 25-30 – on frozen tillage, on January 5-7 – into shallow snow, and in the spring on April 20-25 – into plowed tillage. The experimental site was divided into plots in the autumn. The required amount of manure was weighed and manually scattered uniformly over the plots.

The dosages of poultry droppings were recorded and calculated accurately in order to ensure they contained the specified amount of nitrogen. The physical weight of bird droppings in the variants of the experiment and years of research ranged between 2.8 t/ha (variants 3, 4) and 9.9 t/ha (variants 13, 14). Chicken manure from the Ural poultry farm was used. Its agrochemical characteristics were the following: weight share of moisture: 35.8-42.6%, total nitrogen – 2.08-2.16%, $P_2O_5$ – 1.92-1.98% and $K_2O$ – 1.54-1.56%.

The used mineral fertilizers were ammonium nitrate, double superphosphate and potassium chloride. The mineral fertilizers and chicken droppings were introduced before plowing in the autumn.

The experiments were started systematically with the layered layout of the plots. The total area of the experimental plot in the experiment with manure is 84 $m^2$, with bird droppings – 100.8 $m^2$, that of the reference plot – 56 $m^2$, with three repetitions.

The experiments were accompanied by the following observations and research:

1. agrochemical analysis of chicken manure – the weight fraction of moisture (GOST 26713-85), total nitrogen (GOST 26715-85), $P_2O_5$ (GOST 26717-85) and $K_2O$ (GOST 26718-85);
2. soil nutrition regime – nitrate nitrogen ion-metrically (GOST 26951-86), mobile phosphorus and exchange potassium in 1% ammonium carbonate extract according to B. P. Machigin (GOST 26205-91);
3. pH of soil solution – ion-metrically;
4. phenological observations – according to Gossortset (1979);
5. plants density – by measuring 10 consecutive standing plants of potatoes;
6. growth of the vegetative mass – by weighing tops of 10 typical plants in all variants of experiments;
7. assimilatory surface of leaves – using the method of "cut-outs";
8. intensity of photosynthesis – by the changes in the dry weight of the leaves;
9. chemical analysis of the plants – content of nitrogen, phosphorus and potassium was determined in the same weighed quantity after accelerated wet calcination according to Troitsky and Pinvich in the modification by Miboroda [13];
10. the harvest was accounted for by complete harvesting and weighing the tubers on a weigher;
11. the structure of tubers' biological yield – according to the method of the Research Institute of Potato Cropping[14];
12. the quality of potato tubers: starch – by weight; vitamin C – according to Prokoshev; sugar – by Bertrand; protein – using the photo-calorimetric method with the use of the orange G dye; nitrates – using the ion-selective method [15];
13. preservation of potatoes – by fixed samples of 5 kg each.

## Results and Discussion

The results showed that scattering manure on frozen tillage in the autumn and in the winter on snow accelerated snow melting in the field. Earlier snow melting after scattering manure in winter makes it possible to start agricultural works earlier. Introducing manure in the winter decreases soil humidity before planting, on the average for 3 years, by 1.7%, as compared to introducing manure into tillage. However, organic fertilizers increased soil's water-holding capacity, thus increasing the reserves of moisture in it at all times of introducing manure and, consequently, improved water supply for plants during the growing season.

Observations showed that after the introduction of fertilizers, the content of nitrate nitrogen in soil during the growing season was higher than in the variant without manure. After introducing $N_{60}P_{120}K_{60}$ without manure before planting, soil contained 5.77 mg of nitrates/100 g of soil, while after introducing $N_{90}P_{120}K_{60}$, nitrates content increased by 0.28 mg/100 g of soil, and after introducing 40 t/ha of manure before tillage, the nitrate content increased by 2.98 and 3.79 mg, and reached 8.72 and 9.81 mg/100 g of soil.

The combined introduction of solid manure and mineral fertilizers had a positive effect on the accumulation of nitrate nitrogen in all variants. After introducing solid manure in the autumn, nitrate nitrogen content was 1.1-1.3 times lower than after introducing the same dosages in the spring. A general tendency was observed towards increasing the content of nitrate nitrogen from spring till early summer, and a gradual decrease by the beginning of the autumn.

Introduction of solid manure had a positive influence on the content of mobile phosphorus in the soil. In the phase of full growth, phosphorus content increased in various variants by the value between 2.1 and 2.3 mg per 100 g of soil.

Introduction of solid manure increased the exchange potassium content by 6.0-9.8 mg/100 g of soil, depending on the period between introducing and planting.

In the experiment with bird droppings, on the average within the 3 years of the research, in the reference variant before planting potatoes, the nitrate nitrogen in the 0-30 cm layer was 44.8 mg/kg. In the phase of sprouting and flowering, the content of this form of mineral nitrogen increased nearly twice, due to the activation of the nitrification processes under the influence of the temperature and irrigation water. In case of the combined introduction of poultry droppings and mineral fertilizers, the content of nitrate nitrogen in the period of intensive plant growth and yield formation (the flowering stage) in the studied soil layer was 23.1-25.0 mg/kg. It should be noted that with increasing dosage of poultry droppings, the content of nitrate nitrogen increased. The residual amount of nitrate nitrogen before harvesting on fertilized plots was about 60-80 mg/kg. Therefore, the amount of nitrogen available for potato plants ensured high yield of tubers.

The dynamics of available phosphorus in potato crops was not as pronounced as that of nitrate nitrogen. In the reference variant, its content was in the range between 28 and 34 mg/kg of soil. On the fertilized plots, the content of phosphorus compounds extracted with 1% carbon-ammonium extract was about 58-47 mg/kg, and it changed little at the time of taking samples.

Before planting potatoes, the content of exchange potassium in the soil of the reference variant was, on the average for the 3 years, 336-484 mg/kg. Introduction of poultry droppings, and potassium in mineral fertilizers increased the amount to 509-576 mg/kg. With that, there was a clear tendency to increasing the reserve of exchange of potassium with increasing dosages of poultry droppings.

After introducing organic fertilizers, increased soil biological activity was observed. Definition of the total number of microorganisms on meat infusion agar (MIA) showed that the biotas of dark chestnut soils were dominated by bacteria. This regularity was observed in all experimental variants and in all years of the study. The second place belongs to actinomycetes, and the third one to microscopic fungi (Table 1).

In all variants, the number of bacteria increased with the combined introduction of poultry droppings and mineral fertilizers. Separate introduction of poultry droppings and mineral fertilizers influenced the activity of soil bacteria less significantly. The studied systems of fertilizers also increased the number of fungi and actinomycetes. It should be noted that in both the reference and in fertilized plots, the number of bacteria decreased towards the autumn, and, on the contrary, the number of actinomycetes increased.

Phenological observations showed that the dosages of mineral fertilizers and bird droppings and the time of manure introduction influenced the development phases of potato plants. It should be noted that the time of sprouts appearance virtually did not depend on nutrition; the dosages of mineral fertilizers and the time of manure introduction have some influence though on the development phases of potato plants. In all variants, with the introduction of manure, top necrosis started 5-9 days later, as compared to the variant without manure.

The influence of plant density on the start of top necrosis has been observed only in three variants: after introducing manure in the winter into the snow, against the background of N90P120K60 and after introducing manure in the spring before tillage. In case of planting according to the 70 × 25 cm pattern, and in case of introducing manure in the winter into the show against the mineral background of $N_{90}P_{120}K_{60}$, the start of top necrosis was observed on August 9; in case of introduction in the spring against the background of $N_{60}P_{120}K_{60}$ – on August 10, against the background of $N_{60}P_{120}K_{60}$ – on August 13; and in case of planting according to the 70 × 35 cm pattern, on August 14, 15 and 18, respectively, that is, 5 days later. The total duration of the period between planting and the start of top necrosis in case of introducing $N_{60}P_{120}K_{60}$ was up 101 days, in case of introducing $N_{90}P_{120}K_{60}$ – 103 days, in case of introducing manure before winter tillage – 106 and 108 days, or 5 days longer; in case of introducing manure into frozen tillage – 108 days; in the winter into the snow – 106 days; before introducing into re-plowed tillage – 107 and 110 days, respectively, in case of planting according to the 70 × 25 cm pattern, and in case of planting according to the 70 × 35 pattern, the duration of this period in the last variant was 115 days.

In case of introducing poultry droppings in the amount equivalent to No. 60, the formation of buds was the same as in the reference

| | Sprouts | | | Harvesting | | |
|---|---|---|---|---|---|---|
| Variants | Bacteria | Fungi | Actinomycetes | Bacteria | Fungi | Actinomycetes |
| 1. Reference (without fertilizers) | 6.7 | 0.29 | 3.3 | 4.3 | 0.31 | 4.3 |
| 2. N60P120K60 | 7.6 | 0.30 | 4.2 | 6.5 | 0.31 | 5.4 |
| 3. Bird droppings by No. 60 | 8.6 | 0.30 | 4.2 | 6.9 | 0.31 | 5.3 |
| 4. Background + poultry droppings acc. to No. 60 | 8.6 | 0.32 | 4.7 | 7.4 | 0.34 | 5.5 |
| 5. Droppings acc. to No. 150 | 9.4 | 0.36 | 4.7 | 8.8 | 0.36 | 4.9 |
| 6. Background + droppings, acc. to No. 150 | 10.1 | 0.37 | 4.7 | 8.8 | 0.36 | 4.8 |
| 7. Droppings acc. to No. 210 | 10.2 | 0.39 | 4.8 | 8.1 | 0.36 | 4.7 |
| 8. Background + droppings, acc. to No. 210 | 10.4 | 0.40 | 4.4 | 8.1 | 0.36 | 4.7 |

Only several variants have been mentioned.

**Table 1:** The number of microorganisms in topsoil (0-30 cm) layer of dark chestnut irrigated soil used for potatoes (average over 3 years), mln. in 1 g of soil

variant. In other variants, the phase of budding started 2-7 days later, as compared to the reference (depending on the dosages of droppings).

The greatest duration of the period between planting and the start of top necrosis for the Nevsky variety was noted in case of introducing bird droppings, according to No. 120 against the background of mineral fertilizers. It was 10 days longer, as compared to the reference (without fertilizers), and 14 days longer, as compared to the background ($N_{60}P_{120}K_{60}$). Similar tendency was noted for the Caratop variety as well.

The dosages of introducing poultry droppings, mineral fertilizers and the time of introducing manure greatly influenced plant growth, especially in the budding phase and in subsequent phases of development.

The shortest plants against the background of manure were obtained in case of scattering it into snow. On the average for 3 years, the height of plants in this variant against the background of $N_{60}P_{120}K_{60}$ with dense planting (70 × 25 cm) was 70.7 cm, and against the background of $N_{90}P_{120}K_{60}$ – 72.2 cm, or 1.5 cm taller.

In case of planting according to the 70 × 25 cm pattern, the plants in all variants of the experiment were a little (3.0-7.3 cm) shorter than in case of the 70 × 25 planting pattern.

Defining the height of potato plants in the experiment with bird droppings showed that it was higher in the fertilized plots within the 3 years of the experiment. The excess of the Nevsky variety over the reference was 8.2-13.1 cm in various variants, and that of the Caratop variety – 8.6-12.5 cm.

However, fertilizers had a certain influence not only on plant growth, but also on the number of stems and leaves as well. On the average within 3 years, the number of stems in the reference group for the Nevsky variety was 5.5 per plant, and for the Caratop variety – 5.7. It was noted that with increasing doses of poultry droppings, the number of stems per plant increased from 5.9 (variant 3) to 6.3 (variant 13) for the Nevsky variety, and from 6.0 to 6.4 for the Caratop variety, respectively.

On the average within the 3 years, the Nevsky variety had the least number of leaves per plant (151.6 leaves) in the reference variant, and the maximum (184.9 leaves) in case of introducing droppings according to No. 210 against the mineral background ($N_{60}P_{120}K_{60}$). For the Caratop variety, this indicator was 153.9 and 189 leaves, respectively.

The lowest number of stems in the experiment with the time of introducing manure on the average for 3 years was in case of introducing $N_{60}P_{120}K_{60}$ (5.8 stems) with planting according to the 70 × 25 cm pattern, and the highest number was in case of introducing 40 t of manure per hectare before winter tillage, together with mineral fertilizers in the dosage of $N_{90}P_{120}K_{60}$ (7.2 stems) and the same dosage in case of introduction in the spring into re-plowed tillage and planting according to the 70 × 35 cm pattern (7.4 per stem).

These factors had even greater influence on the number of formed leaves. On the average within the 3 years, in case of introduction of 40 t/ha of manure in the spring against the background of $N_{60}P_{120}K_{60}$, the number of leaves increased by 50.6 leaves, and against the background of $N_{90}P_{120}K_{60}$ – by 41.3 leaves, as compared to the same dosages of mineral fertilizers without manure.

In case of introducing manure into frozen tillage and into the snow in winter, fewer leaves formed. So, on the average within the 3 years, in case of introducing manure into frozen tillage against the background of $N_{60}P_{120}K_{60}$, 166.3 leaves per plant formed, which is higher than in the reference by 13.2 leaves.

In case of introducing manure into snow, the number of leaves increases slightly (by 6.2 and 1.9 leaves), but remains significantly lower than when manure is introduced before tillage in the autumn and in the spring before re-plowing tillage.

When the planting area was widened from 70 × 25 to 70 × 35 cm, the number of leaves increased from 9 to 12 per plant.

In case of introducing manure, strong and well-foliated stems are formed. The pattern of forming the above-ground part of the plants depending on the period of introducing manure and mineral fertilizers becomes particularly well evident in the course of analyzing average data for 3 years. In course of planting according to the 70 × 25 cm pattern, the least weight of tops per plant was formed after introducing $N_{60}P_{120}K_{60}$, which is 135.2 g less than after introducing $N_{90}P_{120}K_{60}$. In case of introducing manure at the dosage of 40 t/ha before tillage, the weight of the top of one plant increased against the first background by 460.4 g, and against the second one – by 362.9 g.

In case of planting according to the 70 × 35 cm pattern, the weight of the top of one plant increased in all variants of introducing fertilizers. However, the greatest weight of top per plant was observed in case of introducing 40 t/ha of manure in the autumn before tillage and in the spring before re-plowing tillage. So, in case of introducing manure into tillage against the background of $N_{60}P_{120}K_{60}$, the weight of tops was by 21 g higher, and against the background of $N_{90}P_{120}K_{60}$ – by 158.8 g higher than in case of dense planting.

In case of introducing manure in the spring before tillage, the weight of tops of one plant increases, as compared to introducing tillage in the autumn before tillage against the background of $N_{60}P_{120}K_{60}$, by 5.2 g, and against the background of $N_{90}P_{120}K_{60}$ – reduces by 138.3 g.

It should be noted that while the weight of the top of one plant increases in case of less dense planting, it decreases per unit of area. While the greatest weight of top on the average within the 3 years (61.2 t/ha) was obtained in case of introducing manure into tillage and planting according to the 70 × 25 cm pattern, in case of widening the planting area, it was 50.2 t/ha, or approx. 11 t/ha less. The same regularity is observed for other variants of the experiment.

It is established that formation of the assimilation surface of the leaves is also influenced by weather conditions during the vegetation period, dosages of fertilizers and time of manure introduction, and planting density.

On the average within the 3 years, the assimilation surface of one plant in case of introducing only mineral fertilizers at the dosage $N_{60}P_{120}K_{60}$ and planting according to the 70 × 25 cm pattern was 48.35 $dm^2$, the introduction of $N_{90}P_{120}K_{60}$ – 62.29 $dm^2$, or 13.94 $dm^2$ larger, that is, increasing nitrogen content by 30 kg/ha, resulted in an increase in the assimilation surface of the leaf apparatus. In case of introducing 40 t/ha of manure before tillage against the background of $N_{60}P_{120}K_{60}$, the assimilative surface of leaves was 86.45 $dm^2$, or 1.45 times larger, and against the background of $N_{90}P_{120}K_{60}$ – 90.72 $dm^2$, or 1.78 times larger, as compared to the background of mineral fertilizers only. In other variants of manure introduction, the assimilation surface was slightly smaller; however, it was significantly larger as compared to the background of mineral fertilizers.

When the planting pattern was expanded from 70 × 25 cm to 70 × 35 cm, the assimilation surface of leaves per one plant increased in all variants.

The assimilation surface of leaves per one hectare on the average within the 3 years in case of introducing $N_{60}P_{120}K_{60}$ was 27.5 thousand m², while in case of introducing $N_{90}P_{120}K_{60}$ it was 35.5 thousand m², or by 8 thousand m² larger. In case of introducing 40t/ha of manure before tillage against these backgrounds, the assimilation surface of the leaves increased respectively by 21.8 and 16.2 thousand m².

Planting density has a considerable influence on forming the assimilation surface of leaves. While in case of expanding the planting area (70 × 35 cm), the assimilation surface of leaves per plant increases, it decreases per unit of area. So, in case of planting according to the 70 × 35 cm pattern and introducing $N_{60}P_{120}K_{60}$, the assimilation surface of leaves decreased on the average within the 3 years by 4.0 thousand m²/ha, as compared to planting according to the 70 × 25 cm pattern; in case of introducing $N_{90}P_{120}K_{60}$ – by 8.3 thousand m²/ha, and in case of introducing against these backgrounds 40 t/ha of manure before tillage – by 12.2 and 13.2 thousand m²/ha, respectively. Similar regularity is observed for other variants of the experiment.

The time of introducing manure, dosages of mineral fertilizer and planting density influence not only the growth processes, but the intensity of photosynthesis as well. So, in case of introducing mineral fertilizers at the dosage of $N_{60}P_{120}K_{60}$, the intensity of photosynthesis on the average within the 3 years was 6.10 mg/dm²/h, and in case of introducing $N_{90}P_{120}K_{60}$ – 6.54 mg/dm²/h, or more by 0.44 mg/dm²/h.

In case of introducing manure against the background of mineral fertilizers, the intensity of photosynthesis increases in all times of introduction; however, the highest intensity was observed in case of its introduction in the autumn before tillage and in the spring before re-plowing tillage.

The studied systems of fertilizing with poultry droppings also influenced the leaf surface. On the average for 3 years, the area of leaves of one plant of the Nevsky variety was 42.4 dm², and that of the Caratop variety – 43.2 dm². In the variant with introducing poultry droppings according to No. 150, these values were 66.7 and 78.5 dm², respectively. The total leaf area in this variant for the Nevsky variety was 38.1 thousand m²/ha, for the Caratop variety – 44.8 thousand m²/ha (for the reference they were 24.2 and 24.7 thousand m²/ha, respectively).

The obtained data showed that poultry droppings and mineral fertilizers increase not only the size of leaves, but also the intensity of photosynthesis. The maximum value of this indicator for the Nevsky variety was observed in case of introducing poultry droppings according to No. 150 – 8.0 mg/dm²/hour (for the reference it was 5.9 mg/dm²/hour), for the Caratop variety, these indicators amounted to 8.4 and 7.0 mg/dm²/hour, respectively.

The percentage of dry matter in the stems of plants on average for the 3 years was 9.7-10%, in the leaves of potato plants it was 11-12.4%, in tubers – 19-21.6%. It should be noted that with increasing dosages of poultry droppings from No. 60 to No. 210, the relative (percentage) content of dry matter in all organs of plants tended to decrease.

Owing to the better development of fertilized potato plants, their absolute (t/ha) above-ground weight was higher than that in the reference group. So, the total weight of dry leaves and stems on the average over the 3 years of the study was observed in case of introducing manure acc. to No. 150 for the Nevsky variety – 6.12 t/ha, for the Caratop variety – 7.42 t/ha. Without introducing fertilizers, these values were respectively 3.24 and 3.80 t/ha.

The weight of dry matter in the tubers of the Nevsky variety in case of introducing fertilizers increased on average over the 3 years from 5.14 t/ha (unfertilized reference) to 7.49 (introduction of manure according to No. 150). For the Caratop variety, these indicators were respectively 5.86 and 8.40 t/ha, or by 0.72-0.91 t/ha higher than for the Nevsky variety. The introduction of very high dosages of fertilizers (manure acc. to No. 210 and droppings according to No. 210 + $N_{60}P_{120}K_{60}$) resulted in slowing down the accumulation of dry biomass of potatoes in the vegetative organs and in the tubers.

The dosages of the introduced mineral fertilizers and the time of introducing manure also affected the dry matter content in the leaves, stems and tubers. Dry matter content in the leaves ranged between 11.3 and 12.9% in the stems – between 10.4 and 12%, in tubers – between 17.2 and 19.6%.

The lowest content of dry matter in the leaves was noted in case of introducing 40 tons of manure into frozen tillage against the background of $N_{90}P_{120}K_{60}$, and the highest one – against the background of $N_{60}P_{120}K_{60}$ without manure when planted according to the 70 × 35 cm pattern (12.9%), which is higher than in all times of manure introduction. However, when the planting area is expanded, a slight increase by 0.1-0.2% is observed in the content of dry substances in all cases. Similar regularity is observed for the content of dry matter in the stems.

The highest content of dry matter in the tubers in case of planting according to the 70 × 25 cm pattern was observed in the reference (19.4%), while in case of introducing $N_{90}P_{120}K_{60}$, the content of dry matter slightly reduced (by 0.2%), and in case of introducing 40 t/ha of manure before tillage, it decreases by 0.1%, as compared to the above listed variants.

The most interesting is the analysis of dry mass of leaves. While the highest percentage of dry matter was noted in the variant of $N_{60}P_{120}K_{60}$, the weight of dry matter of both leaves and stems from 1 ha in this variant was the lowest one, and in case of planting according to the 70 × 25 cm pattern it was 2.16 and 1.86 t/ha, respectively, and in case of planting according to the 70 × 35 cm pattern it was 1.80 and 1.46 t/ha, which is less than in case of introducing $N_{90}P_{120}K_{60}$ by 0.54 and 0.20 t/ha, respectively. In case of introducing manure, the dry weight increased in all variants. So, the dry weight of leaves when planting according to the 70 × 25 cm pattern introducing 40 t/ha of manure into the tillage against the background of $N_{60}P_{120}K_{60}$ was 3.61 t/ha, against the background of $N_{90}P_{120}K_{60}$ – 3.72 t/ha, which is higher than against the background of some mineral fertilizers by 1.45 t/ha and 1.02 t/ha, and in case of planting according to the 70 × 23 cm pattern – by 1.03 and 1.29 t/ha, respectively.

The analysis of potato plant organs for nitrogen content showed that during the growing season it had the highest value in the leaves. So, in case of introducing $N_{60}P_{120}K_{60}$ in the budding phase, on the average within the 3 years, the leaves contained 6.26% of the nitrogen from the dry matter; in case of introducing $N_{90}P_{120}K_{60}$ – 5.34%, and in case of introducing 40 t/ha of manure before tillage against these backgrounds – 5.15 and 5.19% of dry matter. In case of introducing manure before re-plowing tillage, the content of nitrogen slightly increases, as compared to its introduction in the autumn. The lowest nitrogen content in the leaves was observed in case of introducing manure to the winter into the snow, and slightly higher in case of introducing manure into frozen tillage.

If the planting area is expanded, the content of nitrogen in leaves against the background of mineral fertilizers and in case of introducing manure in the spring slightly reduced, and in other variants, on the contrary, increased (by 0.15-0.86%).

In the stems, the nitrogen content was more equalized and fluctuated between 3.17 and 3.68% of the dry matter.

The nitrogen content in the tubers in the budding phase ranged between 2.46 and 2.56% of the dry matter.

As the plants grow, the percentage content of nitrogen in the leaves decreases in some variants and increases in others. The content of nitrogen in the stems in the flowering stage decreased in all experimental variants.

The content of nitrogen decreases significantly in the tubers. In the flowering phase, the content of nitrogen in the tubers, in case of planting according to the 70 × 25 cm pattern against the background of $N_{60}P_{120}K_{60,}$ decreases, as compared to the budding phase, by 0.66%, and against the background of $N_{90}P_{120}K_{60}$ – by 0.62%. The lowest content of nitrogen in the tubers in the flowering stage was observed in case of planting according to the 70 × 35 cm pattern against the background of $N_{60}P_{120}K_{60}$ (1.80%), and highest one – in case of introducing manure in the spring against the background of $N_{90}P_{120}K_{60}$ with the same planting density.

The lowest content of nitrogen in all organs of potato plants is observed before harvesting. The highest content of nitrogen in the leaves before harvesting was observed in case of introducing manure against the background of $N_{90}P_{120}K_{60}$, in case of planting according to the 70 × 25 cm pattern – 3.08%, and in case of planting according to the 70 × 35 cm pattern – 3.09%, which is higher than in the reference ($N_{60}P_{120}K_{60}$) by 0.44 and 0.45%, respectively.

The lowest content of nitrogen before harvesting was noted in stems. In case of planting according to the 70 × 25 cm pattern the nitrogen content in stems ranged between 1.42 and 1.99%. In case of planting according to the 70 × 35 cm pattern, the content of nitrogen in the stems is lower, as compared to dense planting.

The lowest nitrogen content (1.55%) was observed in case of planting according to the 70 × 25 cm pattern against the background of mineral fertilizers without manure in the dosage of $N_{60}P_{120}K_{60}$, and the highest one (2.0%) – in case of introducing manure in the spring against the background of $N_{90}P_{120}K_{60}$ in case of planting according to the 70 × 35 cm pattern.

The percentage content of phosphorus in potatoes was more stable, but with the age of the plants it reduced. The leaves always contained more phosphorus than other organs of the potato plants. In the budding phase, the total phosphorus content in the leaves ranged between 0.88 and 1.12% of the dry matter. In the flowering phase, the content of phosphorus in the leaves reduced, as compared to the budding phase in various variants, by 0.04-0.40%. The lowest phosphorus content in the leaves was noted before harvesting; it ranged between 0.48 and 0.55% of the dry matter. Similar regularity is observed for phosphorus content in the stems as well.

The content of phosphorus in the tubers in the budding phase was significantly lower than in stems and in leaves. In the flowering phase, the content of phosphorus in tubers reduces almost twice, as compared to the phases of budding, and ranges between 0.30 and 0.46% of the dry matter. The content of phosphorus in the tubers at the time of harvesting ranged between 0.31 and 0.44% of the dry matter.

As the plants grow, the percentage of the potassium content decreased in the leaves, in the stems and in the tubers. However, in all times of the observation it was lower in the leaves than in the stems in all variants of introducing manure. Thus, in the budding phase, the potassium content in the leaves ranged between 5.06 and 6.20% of the dry matter, and in the stems – between 10.80 and 11.50%; in the flowering phase – between 3.68 and 4.82%, and between 6.90 and 7.70%, respectively; before harvesting – between 2.60 and 3.18%, and between 3.90 and 4.98% of the dry matter.

With the aging of plants, there is a decrease in the potassium content in the tubers. The content of potassium in the tubers in the budding phase fluctuated in many variants from 4.02 to 4.12% of the dry matter, in the flowering phase – from 3.44 to 3.54%, before harvesting – from 3.0 to 3.2% of the dry matter.

The dosages of the introduced mineral fertilizers and the time of introducing manure influence the content of nutrients and their removal by by-products. So, before harvesting the leaves contained between 47.16 and 112.7 kg of nitrogen, the stems contained between 20.44 and 53.15 kg/ha of nitrogen.

The top removes between 67.60 and 165.78 kg/ha of nitrogen, or the difference is 2.45 times. Similar regularity is observed in case of removing nitrogen from 1 hectare by tubers, as well.

The content of phosphorus and its removal with the harvest was considerably less significant than that of nitrogen and potassium. Removal of phosphorus by tubers ranged between 19.20 and 29.73 kg/ha.

Out of the nutrition elements, potatoes remove mostly potassium. Removal of potassium by tops ranged between 103.74 and 281.44 kg/ha. The same regularity was observed for the removal of potassium by the tubers. However, in some variants, potassium removal by the tubers is higher than that by the leaves, on the contrary. So, in case of introducing $N_{60}P_{120}K_{60}$ and planting according to the 70 × 25 cm pattern, potassium removal by the tubers per hectare was 169.92 kg, and by the tops −128.7 kg, or by 41.22 kg/ha less, and in case of introducing $N_{90}P_{120}K_{60}$ – by 9.39 kg/ha less.

In case of introducing manure in the autumn into tillage, potassium removal by tops was, on the contrary, greater than that by the tubers. So, in case of introducing 40 t/ha of manure against the background of $N_{90}P_{120}K_{60}$, removal of potassium by plant tops amounted to 274.87 kg/ha, and against the background of $N_{60}P_{120}K_{60}$ – 281.44 kg/ha, which is respectively more than that by the tubers by 75.23 and 61.96 kg/ha.

On the average for 3 years, for obtaining 1 ton of tubers with the corresponding number of tops, in case of introducing mineral fertilizers only (without manure) in the dosage of $N_{60}P_{120}K_{60}$ and in case of planting according to the 70 × 25 cm pattern, the potato plants adsorbed 5.96 kg of nitrogen, 1.47 kg of phosphorus and 10.74 kg of potassium; in case of introducing $N_{90}P_{120}K_{60}$, the potato plants adsorbed 6.96, 1.53 and 11.83 kg, respectively.

Depending on the time of manure introduction and planting density, for the production of 1 ton of tubers, the potatoes absorbed between 5.68 and 8.11 kg of nitrogen, between 1.34 and 1.78 kg of phosphorus, and between 10.28 and 14.20 kg of potassium.

Introduction of poultry droppings either without mineral fertilizers or in combination with them was also reflected in the chemical composition of the plants. Under the influence of fertilizers in all organs of potato plants (leaves, stems, tubers) the content of nitrogen, phosphorus and potassium increases. Adsorption of nutrients by fertilized plants in advance was observed during the budding phase and the phase of mass flowering, and continued until top necrosis. At all times, the highest content of nitrogen and phosphorus was observed in the leaves of the Caratop variety in the flowering phase (3.96-5.21% and 0.43-0.51%, respectively). During this phase, the leaves contained 3.16-3.72%; the stems contained 7.10-7.22% of potassium of the absolutely dry weight. Before harvesting, the tubers accumulated nitrogen in the amount of 0.68-0.86%, phosphorus – in the amount of 0.35-0.40%, potassium – in the amount of 0.63-0.86% of dry weight. In the Nevsky variety, the content of nutrients in all plant organs was slightly lower, which we attribute to the biological differences of the studied varieties.

Introduction of poultry droppings and mineral fertilizers for the potato resulted in an increased removal of nitrogen, phosphorus and potassium with both main and by-products.

The studied system of fertilizing also influenced significantly the consumption of nutrients for obtaining one ton of potatoes with appropriate amount of side products. The comparison of these two varieties shows that 1 ton of tubers of the Caratop variety consumes more phosphorus and potassium than the Nevsky variety.

The research has shown that the time of introducing solid manure has a significant effect on the yield and the quality of potato tubers. The lowest yield of potatoes in all years of research was obtained in case of introducing $N_{60}P_{120}K_{60}$ without manure, while the highest yield

| Planting pattern | Time of manure introduction | Yield, t/ha | Marketability, % | Content | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Dry substances, % | Starch, % | Vitamin C, mg % | Protein, % | Total sugar, % | Nit rates, mg/kg |
| 70 × 25 cm | $N_{60}P_{120}K_{60}$ (reference) | 27.8 | 87.2 | 19.4 | 14.7 | 18.9 | 1.31 | 0.68 | 48.3 |
| | $N_{90}P_{120}K_{60}$ | 29.0 | 85.2 | 19.2 | 14.4 | 18.7 | 1.25 | 0.70 | 54.6 |
| | 40 t of manure into tillage + $N_{60}P_{120}K_{60}$ | 33.4 | 89.1 | 19.2 | 14.2 | 20.3 | 1.41 | 0.64 | 57.6 |
| | 40 t of manure into tillage + $N_{90}P_{120}K_{60}$ | 37.1 | 88.0 | 19.1 | 13.9 | 20.1 | 1.34 | 0.66 | 61.6 |
| | 40 t of manure into frozen tillage + $N_{60}P_{120}K_{60}$ | 31.0 | 85.7 | 18.8 | 13.8 | 19.6 | 1.30 | 0.66 | 59.0 |
| | 40 t of manure into frozen tillage + $N_{90}P_{120}K_{60}$ | 33.8 | 85.4 | 18.6 | 13.6 | 19.4 | 1.26 | 068 | 64.0 |
| | 40 t of manure into snow in the winter + $N_{60}P_{120}K_{60}$ | 29.3 | 85.3 | 18.4 | 13.8 | 19.4 | 1.29 | 0.67 | 63.6 |
| | 40 t of manure into snow in the winter + $N_{90}P_{120}K_{60}$ | 32.9 | 84.8 | 18.2 | 13.6 | 19.2 | 1.26 | 0.68 | 66.6 |
| | 40 t of manure into re-plowing + $N_{60}P_{120}K_{60}$ | 31.6 | 82.9 | 17.5 | 13.4 | 19.9 | 1.24 | 0.67 | 73.0 |
| | 40 t of manure into re-plowing + $N_{90}P_{120}K_{60}$ | 33.4 | 80.3 | 17.2 | 13.3 | 19.7 | 1.20 | 0.69 | 78.3 |
| 70 × 35 cm | $N_{60}P_{120}K_{60}$ | 25.6 | 89.6 | 19.5 | 15.2 | 19.3 | 1.35 | 0.65 | 42.3 |
| | $N_{90}P_{120}K_{60}$ | 26.8 | 87.5 | 19.3 | 14.8 | 19.0 | 1.30 | 0.66 | 52.3 |
| | 40 t of manure into tillage + $N_{60}P_{120}K_{60}$ | 32.0 | 92.0 | 19.6 | 14.5 | 20.6 | 1.46 | 0.65 | 47.3 |
| | 40 t of manure into tillage + $N_{90}P_{120}K_{60}$ | 34.0 | 91.9 | 19.6 | 14.3 | 20.4 | 1.42 | 0.66 | 53.0 |
| | 40 t of manure into frozen tillage + $N_{60}P_{120}K_{60}$ | 29.2 | 87.8 | 18.8 | 14.1 | 19.7 | 1.34 | 0.65 | 55.6 |
| | 40 t of manure into frozen tillage + $N_{90}P_{120}K_{60}$ | 31.6 | 87.0 | 18.6 | 14.0 | 19.5 | 1.32 | 0.66 | 58.3 |
| | 40 t of manure into snow in the winter + $N_{60}P_{120}K_{60}$ | 28.8 | 87.0 | 18.8 | 14.0 | 19.6 | 1.34 | 0.65 | 61.3 |
| | 40 t of manure into snow in the winter + $N_{90}P_{120}K_{60}$ | 30.0 | 86.4 | 18.6 | 13.9 | 19.4 | 1.31 | 0.66 | 63.0 |
| | 40 t of manure into re-plowing + $N_{60}P_{120}K_{60}$ | 31.1 | 86.8 | 18.5 | 13.6 | 20.1 | 1.28 | 0.68 | 68.6 |
| | 40 t of manure into re-plowing + $N_{60}P_{120}K_{60}$ | 32.0 | 85.6 | 18.2 | 13.4 | 19.8 | 1.25 | 0.69 | 72.6 |

**Table 2:** Influence of the time of manure introduction in combination with mineral fertilizers and plant density on the yield and quality of potatoes of the Nevsky variety (the average over 3 years)

was obtained in case of introducing 40 t/ha of manure into the tillage against the background of $N_{90}P_{120}K_{60}$ (Table 2).

In case of introducing manure in the spring into re-plowed tillage in case of planting according to the 70 × 25 cm pattern, the yield on the average within the 3 years was lower than in case of introducing manure into tillage against the background of $N_{60}P_{120}K_{60}$ by 1.8 t/ha, and against the background of $N_{90}P_{120}K_{60}$ – by 3.7 t/ha, and in case of planting according to the 70 × 35 cm pattern – by 0.9 and 2.0 t/ha, respectively.

In case of expanding the planting area, the yield is reduced in all variants of the experiment. So, in case of introducing $N_{60}P_{120}K_{60}$ and $N_{90}P_{120}K_{60}$ and expanding the planting area from 70 × 25 cm to 70 × 35 cm, the yield decreased on the average within the 3 years by 2.2 t/ha, while in case of introducing 40 t/ha of manure into tillage – against the same backgrounds – by 1.4 and 3.1 t/ha, respectively. For other variants, similar regularity is observed.

Manure introduction into tillage resulted in the growth of tubers marketability. In case of thinned planting, marketability of tubers increases. So, on the average within the 3 years, marketability of the tubers in case of introducing $N_{60}P_{120}K_{60}$ and planting according to the 70 × 35 cm pattern was higher than in case of dense planting (70 × 25 cm) by 2.4%, and in case of introducing $N_{90}P_{120}K_{60}$ – by 3%, in case of introducing in the winter into the tillage against the mentioned backgrounds – by 2.9 and 3.9%, respectively. Similar regularity is observed for other variants of the experiment.

Mineral fertilizers, the time of introducing manure and the planting density significantly influence the content of dry substances in the tubers. The lowest content of dry matter was obtained in the reference group ($N_{60}P_{120}K_{60}$). On the average within the 3 years, collection of dry substance in this variant in case of dense planting was 5.39 t/ha, which is less than in case of introducing manure into tillage by 1.07 t/ha, and against the background of $N_{90}P_{120}K_{60}$ – by 1.51 t/ha, while in case of planting according to the 70 × 35 cm pattern – 5.01 t/ha and less, respectively, against the background of $N_{60}P_{120}K_{60}$ – 1.27 t/ha, against the background of $N_{90}P_{120}K_{60}$ –1.5 t/ha. The same tendency is observed for the collection of starch.

The general regularity is a slight decrease in the content of vitamin C in the tubers with increasing dosages of nitrogen in the mineral fertilizer from 60 to 90 kg/ha. The highest content of vitamin C in tubers was detected in case of introducing manure in the autumn into the tillage, and the lowest – in case of introducing $N_{90}P_{120}K_{60}$ without manure.

The most intensive accumulation of protein in the tubers was observed in case of joint introduction of 40 t/ha of manure in the autumn against the background of $N_{60}P_{120}K_{60}$. In case of increasing dosages of nitrogen in the mineral fertilizer from 60 to 90 kg/ha, a decrease in the protein content in the tubers by 0.02-0.07% is observed.

On the average over 3 years of the research, the yield of the Nevsky variety in the reference variant in the experiment with poultry droppings was 25.2 t/ha (Table 3).

Among the studied systems of fertilizers, the maximum yield of tubers in terms of our research (37.1 t/ha) was provided by introducing poultry droppings into plowing acc. to No. 150 (Variant 9). Almost the same results were obtained in case of introducing poultry droppings acc. to No. 120. Adding mineral fertilizers to these dosages of organic

| No. | Variants of the experiment | Yield, t/ha | Marketability, % | Content | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Dry substance, % | Starch, % | Vitamin C, mg/ % | Protein, % | Total sugar, % | Nitrates, mg/kg |
| 1 | Reference without fertilizers | 25.2 | 86.2 | 20.4 | 14.4 | 18.5 | 1.36 | 0.68 | 48.6 |
| 2 | $N_{60}P_{120}K_{60}$ | 29.8 | 88.2 | 21.6 | 15.2 | 19.4 | 1.48 | 0.62 | 49.2 |
| 3 | Bird droppings acc. to No. 60 | 31.8 | 87.1 | 20.2 | 14.1 | 19.1 | 1.48 | 0.67 | 50.4 |
| 4 | Background + droppings, acc. to No. 60 | 33.1 | 88.8 | 21.4 | 14.8 | 19.3 | 1.48 | 0.63 | 49.6 |
| 5 | Bird droppings acc. to No. 90 | 34.3 | 87.8 | 20.1 | 14.0 | 18.9 | 1.46 | 0.64 | 64.2 |
| 6 | Background + droppings, acc. to No. 90 | 35.5 | 88.6 | 21.3 | 14.6 | 19.2 | 1.48 | 0.63 | 60.1 |
| 7 | Bird droppings acc. to No. 120 | 36.6 | 85.4 | 20.0 | 13.9 | 18.5 | 1.42 | 0.68 | 68.5 |
| 8 | Background + droppings, acc. to No. 120 | 35.7 | 86.0 | 21.0 | 14.4 | 19.0 | 1.46 | 0.65 | 62.4 |
| 9 | Bird droppings acc. to No. 150 | 37.1 | 87.4 | 19.6 | 13.8 | 18.4 | 1.42 | 0.69 | 78.2 |
| 10 | Background + droppings, acc. to No. 150 | 35.0 | 84.2 | 20.8 | 14.2 | 18.8 | 1.44 | 0.68 | 68.1 |
| 11 | Bird droppings acc. to No. 180 | 34.4 | 83.3 | 19.2 | 13.6 | 18.2 | 1.41 | 0.70 | 94.6 |
| 12 | Background + droppings, acc. to No. 180 | 32.7 | 84.0 | 20.2 | 14.1 | 18.7 | 1.43 | 0.69 | 70.8 |
| 13 | Bird droppings acc. to No. 210 | 32.1 | 83.4 | 19.0 | 13.4 | 18.1 | 1.39 | 0.70 | 98.8 |
| 14 | Background + droppings, acc. to No. 210 | 31.1 | 83.7 | 20.0 | 13.8 | 18.6 | 1.41 | 0.68 | 72.5 |
| | LSD05 | 0.92 | | | | | | | |

**Table 3:** The influence of poultry droppings on the yield and quality of potatoes of the Nevsky variety (the average over 3 years)

| No. | Variants of the experiment | Yield, t/ha | Marketability, % | Content | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Dry substance, % | Starch, % | Vitamin C, mg/ % | Protein, % | Total sugar, % | Nitrates, mg/kg |
| 1 | Reference without fertilizers | 26.9 | 88.1 | 21.8 | 14.1 | 19.4 | 1.42 | 0.68 | 46.2 |
| 2 | $N_{60}P_{120}K_{60}$ | 30.8 | 96.7 | 22.7 | 16.2 | 20.2 | 1.58 | 0.50 | 47.4 |
| 3 | Bird droppings acc. to No. 60 | 32.4 | 90.8 | 22.1 | 15.4 | 19.2 | 1.49 | 0.65 | 48.1 |
| 4 | Background + drop-pings, acc. to No. 60 | 34.5 | 96.0 | 22.9 | 15.8 | 19.8 | 1.56 | 0.62 | 47.7 |
| 5 | Bird droppings acc. to No. 90 | 35.9 | 92.6 | 21.6 | 15.3 | 19.1 | 1.48 | 0.63 | 62.1 |
| 6 | Background + drop-pings, acc. to No. 90 | 36.7 | 95.6 | 20.5 | 15.6 | 19.5 | 1.55 | 0.61 | 58.5 |
| 7 | Bird droppings acc. to No. 120 | 37.9 | 91.9 | 21.4 | 14.3 | 19.0 | 1.46 | 0.67 | 64.2 |
| 8 | Background + drop-pings, acc. to No. 120 | 37.7 | 94.7 | 22.3 | 15.1 | 19.3 | 1.52 | 0.64 | 60.4 |
| 9 | Bird droppings acc. to No. 150 | 39.3 | 90.6 | 21.1 | 13.9 | 18.8 | 1.45 | 0.67 | 66.6 |
| 10 | Background + drop-pings, acc. to No. 150 | 35.7 | 93.7 | 22.3 | 14.8 | 19.2 | 1.51 | 0.62 | 59.3 |
| 11 | Bird droppings acc. to No. 180 | 34.7 | 88.4 | 21.0 | 13.6 | 18.7 | 1.43 | 0.69 | 80.6 |
| 12 | Background + drop-pings, acc. to No. 180 | 33.8 | 93.5 | 22.0 | 14.2 | 19.1 | 1.49 | 0.62 | 76.5 |
| 13 | Bird droppings acc. to No. 210 | 32.9 | 86.5 | 20.5 | 13.3 | 18.6 | 1.42 | 0.69 | 88.6 |
| 14 | Background + drop-pings, acc. to No. 210 | 31.9 | 92.3 | 21.6 | 14.0 | 18.9 | 1.48 | 0.61 | 72.5 |
| LSD05 | | 1.44 | | | | | | | |

**Table 4:** The influence of poultry droppings on the yield and quality of potatoes of the Caratop variety (the average over 3 years)

fertilizers (variants 8 and 10) did not provide positive results. Using high dosages of fertilizers (variants 11-14) resulted in the reduction of the yield of the Nevsky potato variety.

In the experiment with the Caratop variety (Table 4), on the average over 3 years, similar regularities have been detected. However, in comparable variants of the experiment, the yield of tubers of this variety was higher. Without fertilization, the yield of potatoes of the Caratop variety was 26.9 t/ha. With the use of an optimal fertilizing system (variant 9), the yield of tubers was 39.3 t/ha, or by 12.4 t/ha higher than that in the reference.

Determination of the structure of the biological yield showed that using an optimal system of fertilizing resulted in decreasing the share of small tubers in total harvest (weighing less than 25 g) and in a marked increase in the number of medium-sized tubers (51-80 and 26-50 g). It has also been noted that against the background of mineral fertilizers the yield of large tubers (80-100 g and above) was higher than without mineral fertilizers.

Fertilizing potato plants with bird droppings did not result in the reduction of such quality indicators as content of starch, vitamin C, protein and total sugar.

Determining the quality of the crop should not be limited to the usual analysis of the existing list of indicators (marketability, starch content, dry matter, etc.). At present, the quality of potatoes, vegetables and fodder should include safety assessments of crop production, nutritional value (starch, sugar, vitamins, proteins, fiber); like other crop products, tubers may contain several undesirable compounds, mostly of anthropogenic origin.

A considerable danger for the health of people and animals are nitrates, which are transformed into nitrite in the intestinal tract of warm-blooded animals and humans. It is nitrites and secondary amines and nitrosamines that cause diseases in humans and animals due to the formation of methemoglobin in blood, which is especially dangerous for children.

A slight increase in nitrates content was observed in the Nevsky variety in case of introducing poultry droppings according to No. 180 (94.6 mg/kg) and No. 210 (98.8 mg/kg), for the Caratop variety – 0.6-8.6 mg/kg, respectively; in other variants, these indicators were below the MPC.

Accumulation of nitrates in the tubers is to some extent influenced by several factors: the time of introducing manure, the dosages of mineral fertilizers, planting density and prevailing weather conditions during the growing season.

In the experiments with the time of introducing manure, the greatest amount of nitrates in the tubers was observed in case of introducing manure into re-plowed tillage. On the average over 3 years, the nitrate content in tubers in this variant in case of planting according to the 70 × 25 cm pattern was 1.6 times higher than in the reference variant, and in case of planting according to the 70 × 35 cm pattern – 1.5 times higher. However, nitrates content in tubers in all years of the study in all variants did not exceed the MPC (80 mg/kg).

## Conclusion

The introduction of mineral and organic fertilizers influences the growth processes, the formation of the above-ground mass, the number of stems and leaves, the assimilation surface of the leaves and the intensity of photosynthesis. The dosages of fertilizers and combination of nutrients in them influence the yield, marketability of tubers, content of dry matter, starch, vitamin C, total sugars and nitrates. The highest yield (37.1 t/ha) of good quality tubers was obtained in case of introducing 40 t/ha of manure into tillage in combination with mineral fertilizers at the dosage of $N_{90}P_{120}K_{60}$ and poultry droppings acc. to No. 150. The yield of early varieties against fertilized backgrounds is higher than the Nevsky medium early variety. The content of nitrates in the variants with fertilizers did not exceed the MPC (250 mg/ha).

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