Management methods of nitrate content in potato applicable to the soil-climate conditions of Russia

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Abstract. Determination of potato quality should not be limited only to the usually established list of indicators (marketability, starch content, dry matter content, etc.). The safety of crop products should also be analyzed by the presence of undesirable compounds, most often of anthropogenic origin (nitrates, pesticides, radionuclides, heavy metals). Sometimes a quality indicator that does not have an obvious cost is overlooked – the so-called biological or hygienic quality of the product, which significantly affects human health. The biological quality of the product is more important than the yield although it does not have a commercial price. Product quality management requires careful analysis to identify the causes of excessive accumulation of nitrates during the growing season and, on this basis, to develop methods that eliminate them, and then methods to reduce the concentration of NO\textsubscript{3} in already grown tubers. Nitrosamines and nitrosamides formed from nitrates with the participation of nitrites have pronounced carcinogenic, mutagenic and embryotoxic properties. In Russia, according to sanitary and hygienic standards, the MPC of nitrates for potato is 250 mg/kg, and for children and diet food the values are even lower – 80 mg/kg of raw tubers.

1 Introduction

The goals of the work were 1) to analyze the dependence of the NO\textsubscript{3} content in tubers in different soil and climatic zones of the European part of Russia; 2) scientifically substantiate agricultural practices that reduce the accumulation of NO\textsubscript{3} during the growing season; 3) to identify the efficiency of methods to reduce the concentration of nitrates cooking and storage. This is very important for preparing the soil for planting potatoes and obtaining a high yield [1-9].

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2 The Methods

The objectives of the research were: 1) to show the effect of precocity of varieties, vegetation duration, the use of growth-regulating compounds, methods of removing tops on the yield and accumulation of nitrates in tubers; 2) to justify the optimal doses and ratios of nitrogen, phosphorus, and potassium, providing the lowest concentrations of NO₃ in tubers in combination with a high yield; to derive regression equations for the accumulation of nitrates; 3) to establish changes in the NO₃ content in the process of autumn-winter storage and cooking.

The studies were carried out in a series of long and short-term experiments in the Non-Chernozem zone, the Middle Volga region, and the Central Chernozem zone. The soils were sod-podzolic, peat, alluvial, leached chernozems. The conditions of moisture supply were on the dry land, at irrigation and a regulated level of groundwater. By maturity, the varieties were as follows: early-ripening, middle-early, mid-season, middle-late, and late-ripening.

Based on the experiments and analysis of factual information, the following provisions are established.

1. The content of nitrates in the tubers depends on environmental and geographical conditions. If we take the value of this indicator for the Central Non-Chernozem zone as 100%, then in the Northern region with colder climatic conditions and with a shorter vegetation period, it will be 202%, in the North-West - 139%, in the Ural - 149% and in the Volga-Vyatka - 129%. And in the Volga and the Central Chernozem regions with warmer and longer growing periods it will amount to 60%. Thus, to obtain tubers with the best quality and low in nitrates as raw materials for children and diet food, it is most advisable to grow and store potato in the Central Chernozem zone, the Middle Volga region and the Central Non-Chernozem zone.

2. In the processes of nitrate accumulation, the role of fertilizers is great and responsible. They should be applied taking into account the planned quality of the tubers, and these requirements have their characteristics. On the sod-podzolic loamy soil of the Central Non-Chernozem zone with prolonged (for 21 years) use of mineral fertilizers, the doses of which were increased from N50P75K60 in the first two cycles of the crop rotation to N100P150K120 in the third cycle, and in combination with manure at the rate of annual application of 10 t/ha of the arable land, the following was established. The lowest concentration of nitrates in the tubers was at a ratio of N: P: K = 1: 1.5: 1.2. Nitrogen fertilizers had the greatest influence on increasing the concentration of nitrates in the product. Whereas phosphate and, to a lesser extent, potassium fertilizers, on the contrary, reduce nitrate content. This was determined by the direction of carbohydrate metabolism. When using the C¹⁴ radioactive label, we revealed a more active accumulation of carbohydrates in the leaves, an accelerated outflow of assimilates from the aerial part and the conversion of them in tubers into complex compounds at an increased dose of phosphorus and to some extent potassium fertilizer.

The action of mineral fertilizers in a wide range of doses in combination with a number of other methods and under different soil and climatic conditions was as follows. On sod-podzolic sandy loam soil, against the background of manure and at irrigation, the accumulation of nitrates in tubers in a linear relationship was facilitated by the use of nitrogen in complete fertilizer. Phosphorus, in combination with nitrogen, prevented an increase in the nitrate content in tubers with a damping effect. The regression equation for this type of soil is:

\[ Y = 12.6+4.8N+0.8K-1.7 (NP)^{0.5} \quad R = 0.912 \]  \hspace{1cm} (1)
The studies on sod-podzolic loamy soil to determine the effect of peat-dropping compost in combination with increasing doses of mineral fertilizers have shown significant variability in the magnitude of the regression between the amount and type of fertilizer applied and the content of nitrates in the tubers. The regression equation obtained is the following:

\[ Y = 17.1 + 4.5N - 0.6P - 1.2K - 1.0(\text{PK})^{0.5} R = 0.93 \]  

That is, when using peat-dropping compost for potato, nitrogen fertilizer enhanced the accumulation of nitrates in direct relation. For middle-early cultivar ‘Lyubimets’ in sod-podzolic loamy soils of the Non-Chernozem zone the rate of raw peat-dropping compost of not more than 40 t/ha in combination with mineral fertilizers in doses of N30-60P180K180 (ratio N: P; K = 1: 3-6: 3-6) is the most profitable from both economic and environmental-hygienic points of view.

3. The accumulation of nitrates is determined by the length of the growing season. In dynamics, their amount in potato varies from the maximum during the period of tuber formation to the minimum by autumn due to binding by the formed carbohydrates. In sod-podzolic heavy loamy soil in the early cultivar ‘Domodedovo’, the amount of NO\(_3\) before the harvest decreased from 231 to 125 mg/kg or 1.8 times (Fig. 1).

![Fig. 1. Dynamics of the nitrate content in potato tubers, depending on the rates of organic fertilizers: 1) control; 2) N\(_{90}\)P\(_{120}\)K\(_{120}\)—background; 3) background + manure, 30 t/ha; 4) background + manure, 60 t/ha; 5) background + manure 90 t/ha.](image)

In the medium-late cultivar ‘Lorkh’, the decrease was from 265 mg to 82 mg/kg, or 3.2 times. Therefore, the result may be the same in the case of late planting, injury of the top by late blight or early harvesting. Therefore, organizational and agricultural measures should be aimed at making the potato vegetate longer (germination and heating of tubers, optimal early planting dates, preventing the death of tops from late blight or termination of its activity during early mowing).

4. When evaluating cultivars by maturity, it was revealed that the concentration of nitrates varies in decreasing order: the maximum concentration was in early cultivars and the minimal
one was in middle-late and late cultivars. So, if during harvesting the nitrate content in tubers of early cultivars is taken as 100%, then for varieties of later ripening it will be much lower: for middle-early - 73.5%, for mid-season - 71%, for middle-late - 67.2%.

5. Based on field experiments with fertilizers, recommendations on the maximum permissible doses of nitrogen of mineral fertilizers for potato are substantiated, the use of which excludes the accumulation of nitrates in tubers in excess of the permissible concentrations depending on the zone, soil type, and moisture conditions (Table 1).

Table 1. Maximum doses of nitrogen of mineral fertilizers for potato and their corresponding yield levels in various regions of the Russian Federation

| Economic region, zone, soil | Maximum permissible annual dose of nitrogen, kg/ha a.s. | Yield, t/ha |
|----------------------------|-----------------------------------------------------|------------|
| **Potato at dry farming**  |                                                     |            |
| Non-Chernozem zone         | sod-podzolloam: 90-100                              | 25         |
|                           | sod-podzolsandyloam: 120                            | 25         |
| Central-Chernozem region   | 90                                                  | 20         |
| Volga region               | forest-steppe zone: 100                             | 25         |
|                           | steppe zone: 60                                     | 15         |
| North Caucasus region      | mountain zone: 110                                  | 25         |
|                           | steppe zone: 60                                     | 15         |
| Ural region                | forest-meadow zone: sod-podzolloam: 90-100          | 25         |
|                           | sod-podzolicsandyloam: 120                          | 25         |
|                           | forest-steppe zone: 100                             | 25         |
| West Siberian region       | forest-meadow zone: 90                              | 25         |
|                           | forest-steppe zone: 80                              | 25         |
|                           | steppe zone: 70                                     | 15         |
| East Siberian region       | forest-steppe zone: 110                             | 25         |
|                           | steppe zone: 70                                     | 15         |
| Far Eastern region, Kuril Islands, Magadan, Kamchatka | 120 | 25 |
| **Potato at irrigation**   |                                                     |            |
| Central region             | 120                                                 | 35         |
| Central-Chernozem region   | 110                                                 | 35         |
| Volga region               | 110                                                 | 30         |
| North Caucasus region      | 120                                                 | 35         |
| East Siberian region       | 130                                                 | 35         |

6. It was revealed that by cooking methods it is possible to significantly reduce the nitrate content in tubers. So, when peeling the potato, the decrease was 20-28% depending on the variety.

An even greater decrease occurs when cooking peeled potato (peeling + desorption (Fig. 2): in the middle-late cultivar 'Lorkh' it reduced by 47-53%, and in early-ripening potato 'Domodedovsky' – by 54-59%.

During autumn-winter storage (September - April), it was found that in both varieties the content of NO₃ decreased by 25%.

Thus, the potato quality in terms of the nitrate content in tubers can be controlled through the rational selection of doses and ratios of the main nutrients, the use of microelements in the form of complexonates, optimal norms and terms for the application of organic fertilizers, the use of varieties of different ripening periods, optimal planting dates, intensive or
biological protection systems for vegetative tops from late blight. And in already grown products - a decrease in the concentration of nitrates is acceptable due to rational methods of cooking.

**Fig. 2.** Changes in the nitrate content during the cooking of tubers: 1) unpeeled raw; 2) peeled raw; 3) boiled unpeeled; 4) boiled peeled.

### 3 Conclusions
The new scientific results obtained as a result of our studies are in good agreement with the data of various scientific studies that have been obtained by other scientists [10-21].

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