Mineral fertilizers influence on the dynamics of nitrogen, phosphorus and potassium in corn area grown in the forest-steppe zone of Trans-Urals

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Abstract. The research was carried out in order to establish the effect of mineral fertilizers on the nutrient’s dynamics in corn crops. The experiment was carried out from 2016 to 2018 in Zavodoukovsky district of the Tyumen region. The experimental scheme provided for the option without using mineral fertilizers and with the introduction of NPK for the planned yields from 4.0 to 6.0 t/ha of corn grain. In the experiment, a hybrid Obsky 140 was sown; the seeding rate was 70 thousand plants per hectare. It was found that the introduction of mineral fertilizers provides an increase in the content of nitrate nitrogen by 20-25 mg/kg of soil; mobile phosphorus by 9-48 mg/kg. The studies revealed that one kilogram of the active ingredient of nitrogen fertilizers increases the NO₃ content in the soil by 0.17 mg/kg; a kilogram of phosphorus fertilizers in the active ingredient increases P₂O₅ by 0.30 mg/kg; a kilogram of potash fertilizers in the active ingredient increases K₂O in the soil by 0.33 mg/kg. During the growing season of maize, the content of nitrate nitrogen, mobile phosphorus, and potassium in the soil in the control decreases to 5, 58, and 93 mg/kg, respectively. On fertilized options, the decrease in nitrate nitrogen and phosphorus is less – 12-14 and 59-69 mg/kg. Whereas potassium decreases more significantly – 69-92 mg/kg.

1. Introduction
In the Tyumen region, agriculture is intensively developing, especially animal husbandry [1]. As a result, it becomes necessary to use new crops and productive and high-quality varieties to increase crops and fodder production [2].

New technologies in breeding make it possible to develop adapted varieties of agricultural crops, in particular corn, which show good yields even in Siberia [3].

Corn responds well to a high level of nutrition and agricultural technology. This crop shows high yields of grain and green mass only if all the necessary conditions for its cultivation and a high level of nutrients in the soil are met [4,5].

Corn is a promising industrial food and feed crop. It is high-yielding and enough drought resistant. An increase in the area of corn cultivation will allow to obtain a more balanced structure of fruit change, effectively fight against certain types of weeds and diseases [6]. Organic fertilizers are used to improve the conditions of nutritional regime. They not only increase the nutrients supply to plants, but also contribute to the accumulation of organic matter in the soil, growing resistance to erosion, and prevent excessive overconsolidation of ploughing horizon [7]. Fertilization allows more economical use of water, which is necessary for the crop formation. In our region, there are frequent droughts during the
most critical period for maize in the initiation of ear phase [8]. Therefore, it is necessary to pay special attention to the fertilization system. However, when cultivating corn for grain in Siberia, the use of organic fertilizers can negatively affect the period of crop development and lead to lengthening of interphase periods.

Many soils of the forest-steppe zone of Trans-Urals are characterized by an unsatisfactory level of fertility, with low nutrients reserves available for the plant [9]. Despite the fact that the chernozem soils of Trans-Urals have large sown areas and high potential fertility, they have a number of significant disadvantages for maize cultivation [10]. One of them is not satisfactory temperature regime. In May, when it is necessary to sow corn, the soil only warms up to a biological minimum, which will complicate nutritional utilization. Poor phosphorus assimilation at the beginning of corn development with poorly heated soil delays development of root system [11, 12]. This makes it difficult to assimilate other macro and microelements at the initial stages of corn development, which leads to a lengthening of the growing season, and is unacceptable in Siberia. In our region, the best way of the main tillage is dump, which provides not only the highest yield of agricultural crops, but also because of the field unevenness in the spring, the soil warms up better, which favorably affects the early corn sowing [13].

The research aim is to establish the effect of mineral fertilizers on the nutrients dynamics in corn crops in the conditions of the forest-steppe zone of Trans-Urals.

2. Research materials and methods

The experiment was carried out from 2016 to 2018 in Zavodoukovsky district of the Tyumen region. The experiment scheme provided for the application of mineral fertilizers (ammophoska and ammonium nitrate) for various corn grain yields (doses are given on average over the years): 4.0 t/ha – N\textsubscript{83}P\textsubscript{67}K\textsubscript{67}; 5.0 t/ha – N\textsubscript{110}P\textsubscript{93}K\textsubscript{93}; 5.0 t/ha – N\textsubscript{147}P\textsubscript{113}K\textsubscript{113}, an option with natural fertility of leached chernozem was used as a control. The soil of the experimental site is leached medium-thick chernozem, medium-humus, heavy loamy. Agrophysical and agrochemical indicators correspond to the average values of these soils in Western Siberia [14,15]. The content of nitrate nitrogen was 11 mg/kg, mobile phosphorus and potassium 79 and 170 mg/kg of soil. Exchangeable acidity did not exceed pH 6.5 units, humus content – 8.3%.

To determine nutrients content in the soil, the samples were taken every 10 cm to a depth of 40 cm. After that, the soil samples were dried, ground, and nitrate nitrogen was determined in them according to the All Union State standard 26951; mobile phosphorus and potassium according to the All Union State standard 26204.

Agrotechnics provided for the main dumping of the soil after harvesting the predecessor (oats) to a depth of 23-25 cm. In the spring, they harrowed in two tracks – BZSS-1.0. Before corn sowing, the required doses of mineral fertilizers were cut in with the SZP-3.6 seeder, and further cultivation was carried out with KPS-4. We sowed hybrid Obshkiy 140 with a seeding rate of 70 thousand/ha, using a SUPN-8A seeder.

3. Research results

Before sowing maize, the content of nitrate nitrogen in the soil averaged over the years from 10 to 11 mg/kg. In the phase of 5-6 leaves of maize in the control, the content of nitrate nitrogen decreased by 13% relative to the initial values due to its assimilation by plants. In the options with the mineral fertilizers’ introduction for the planned yield of 4.0 t/ha of corn grain, the content of N-NO\textsubscript{3} naturally increased to 27 mg/kg (HCP = 1 mg/kg). A further increase in the level of mineral nutrition naturally increased the content of nitrate nitrogen in the soil. In the option with the introduction of NPK at 5.0 t/ha of corn grain, this indicator increased to 31 mg/kg, in the option with the planned yield of 6.0 t/ha of grain – 35 mg/kg (Fig. 1).
Figure 1. Influence of mineral fertilizers on dynamics of nitrate nitrogen in corn crops, mg/kg

In the phase of 8-9 leaves, the content of nitrate nitrogen in the soil in the control decreased by 15% relative to the previous phase. This was due to the intensive increase in corn biomass. In the option with mineral fertilizers introduction for the planned yield of 4.0 t/ha of corn grain, N-NO₃ consumption is also observed, which was 6 mg/kg. In the options with NPK 5.0 and 6.0, a decrease in nitrate nitrogen in the soil by 5 and 4 mg/kg of soil relative to the previous phase was also noted.

During the flowering period of maize, the content of nitrate nitrogen in the control did not change, the deviation was within the experimental error. This fact is due to the fact that an equilibrium state has been established between the consumption of N-NO₃ and nitrogen of the current nitrification [16].

In the option with mineral fertilizers use for the planned yield of 4.0 t/ha of corn grain, consumption was 22% relative to the previous phase. In the options with the planned yield of 5.0 and 6.0 t/ha of grain, corn absorbed 23 and 25% of nitrate nitrogen relative to the phase of 8-9 corn leaves.

By the time the corn is harvested, the nitrate nitrogen content continues to decrease. In the control, the decrease relative to the flowering phase was 2 mg/kg. In the fertilized options, due to the higher grain yield and a significant content of protein compounds in it, the assimilation of nitrate nitrogen was significantly higher than the control and amounted to 26-43% relative to the flowering phase. Also, the passage of the phenological phases of maize at a high agricultural background is lengthened, and the high supply of N-NO₃ to the soil makes better assimilation possible.

Knowing the exact doses of nitrogen applied to corn with mineral fertilizers; the initial and maximum values of nitrate nitrogen in crops, it is possible to derive the coefficient of increase in the value of N-NO₃ in the soil from the introduction of one kilogram of nitrogen fertilizers in the active substance, which in our calculations is 0.17 mg/kg.

The content of mobile phosphorus in the leached chernozem before sowing corn was 77-79 mg/kg, which corresponded to the average supply of this element. By the 5-6 leaves phase, no changes in phosphorus consumption were observed in the control. This is due to the poor assimilation of this element by corn from insufficiently heated soil during this period. In the option with the planned yield of 4.0 t/ha of corn grain, due to the applied phosphorus fertilizers, an increase in this indicator was noted by 19% relative to the control. The application of mineral fertilizers for the yield of 5.0 and 6.0 t/ha of corn grain increased the content of mobile phosphorus to 106 and 115 mg/kg of soil, respectively (Fig. 2).
Figure 2. Influence of mineral fertilizers on dynamics of mobile phosphorus in corn crops, mg/kg

By the phase of 8-9 leaves of corn on the natural agricultural background, there was an intensive consumption of phosphorus, which amounted to 26% of the total consumption. In this phase, in the option with the planned yield of 4.0 t/ha, the highest consumption of this element was noted, which reached 38% of the assimilation over the entire period of corn development. This is due to the fact that mineral fertilizers provided an optimal balance of nutrients in the soil. A further increase in the level of mineral nutrition ensured consumption of no more than 23% of the total requirement during the growing season.

In the period from 8-9 leaves to flowering, mobile phosphorus changes in the soil were not observed in the control, deviations were within the range of HPC05 = 3 mg/kg. In the fertilized options, the absorption of P$_2$O$_5$ was intense, the consumption of mobile phosphorus ranged from 10 to 20% relative to the booting phase. The consumption of phosphorus only in fertilized options during this period is explained by the fact that in these cases there was a favorable balance of nutrients, while in the control it was disturbed due to a deficiency of nitrate nitrogen.

By the time of harvesting, control maize assimilated 16% of mobile phosphorus relative to the flowering phase. In the fertilized options, due to the higher productivity, the assimilation of phosphorus increased. In the option with NPK at 4.0 t/ha, this indicator increased to 17%, increasing in the options with the planned yield of 5.0 and 6.0 t/ha of corn grain to 24 and 26%, respectively.

After calculating the increase in the content of mobile phosphorus in the soil, depending on phosphorus fertilizers doses, we were able to establish that the introduction of one kilogram of the active substance phosphorus provides an increase in the content of mobile phosphorus in the soil by 0.30 mg/kg.

Potassium is one of the important nutrients that ensures the resistance of crops to short-term frosts, which are not uncommon in our conditions [17].

Before corn sowing, the content of mobile potassium on leached chernozem ranged from 167 to 170 mg/kg, which characterizes the soil as highly secured (Fig. 3).
By the phase of 8-9 leaves, control corn assimilated 15% of mobile potassium, which amounted to 34% of the total consumption. Mineral fertilizers contributed to the stabilization of the K₂O content in the soil. As a result, the values of the content of mobile potassium in the studied layer did not change, the deviations were within the experimental error (HCP05 = 25 mg/kg).

From the phase of 8-9 leaves to harvesting, the content of mobile potassium in the control decreased to 93 mg/kg of soil – the deviation from the initial value was 45%. The same pattern was observed in the option with the planned yield of 4.0 t/ha of corn grain. A further increase in the level of mineral nutrition ensured a better potassium intake in corn due to an intensive increase in biomass in the second half of the growing season, where the values of mobile potassium decreased to 69 mg/kg soil – the deviation from the initial values was 59%.

Our calculations showed that one kilogram of the active substance of potash fertilizers provides an increase in the content of mobile potassium in the soil by 0.33 mg/kg.

4. Conclusion
1. The content of nitrate nitrogen in leached chernozem is 10-11 mg/kg. In the phase of 5-6 leaves, the control corn assimilates no more than 13% of nitrate nitrogen. The introduction of mineral fertilizers for the planned yield of up to 6.0 t/ha of corn grain provides an increase in the content of nitrate nitrogen in the soil to 27-35 mg/kg. During the growth, corn consumes a significant amount of nitrogen, as a result of which, for harvesting, the content of nitrate nitrogen in the control decreases to 5 mg/kg, in the fertilized options – up to 12-14 mg/kg. The introduction of one kilogram of the active ingredient of nitrogen fertilizers increases the content of N-NO₃ in the soil by 0.17 mg/kg.

2. The content of mobile phosphorus before corn sowing was 77-79 mg/kg, the application of mineral fertilizers increased the content of P₂O₅ to 98-115 mg/kg. Until the phase of 5-6 leaves, corn in the control does not assimilate phosphorus, after which active consumption begins. By the corn harvesting, the content of mobile phosphorus in the control is reduced to 58 mg/kg, in the fertilized options – to 59-69 mg/kg of soil. One kilogram of phosphorus fertilizers in the active ingredient increases the content of P₂O₅ in the soil by 0.30 mg/kg.

3. The content of mobile potassium on leached chernozem varies from 167 to 170 mg/kg of soil. By the phase of 8-9 leaves, the control corn assimilates 15% of potassium. The introduction of potash fertilizers stabilizes the potash regime of the chernozem leached before this phase. By the harvesting, the content of mobile potassium decreases to 93 mg/kg in the control and to 92-69 mg/kg in the fertilized
options, and the higher the planned yield, the higher the assimilation of this element. One kilogram of potash fertilizers in the active ingredient increases the content of K\textsubscript{2}O in the soil by 0.33 mg/kg.

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