Nutrition regime in agrochernozems under cultivating field crops in arid conditions

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Abstract. The authors found that in arid conditions in the cultivation of soybeans (soya), potato, spring wheat and corn without using fertilizers the content of mineral forms of nitrogen and phosphorus was low and very low. At that time, in fallow fields the ammonium nitrogen content was higher by an average of 6.8-9.2 mg/kg and reached a high level, nitrate nitrogen – by 2.6-5.3 mg/kg and reached an average level of security. The content of mobile phosphorus in all fields was very low and low (56.3-112.5 mg/kg). The content of exchangeable potassium was very high and high, and during periods of severe desiccation it increased by 2.3-1.6 times.

1. Introduction
The global air temperature increase in the continental regions of Eurasia over the past thirty years amounted to more than 0.7°C [1, 2]. In the forest-steppe zone of the Krasnoyarsk Territory an increase in air temperature over the past century amounted to 1.1°C, however, the average annual rainfall in the forest-steppe has decreased and has an extremely uneven distribution throughout the year, more often droughts occur in the middle of the growing season. In this regard, according to the forecast, the shift of natural zones boundaries may occur during next fifty years [3]. Under such conditions, an immediate response to changes in the regime of desiccation and moisture is provided by soil biota and the processes of mineralization and humification associated with it. In turn, with a deficiency in the use of mineral fertilizers [4], the biological activity of agricultural soils, stocks of plant residues and humic substances determine the dynamics of the release of nitrogen mineral forms, a certain fraction of phosphorus mineral forms [5, 6, 7] necessary for plants. The purpose of this study is to study the dynamics of nutrients in agrochernozems while field crops cultivation during dry periods in the Krasnoyarsk forest-steppe.

2. Research methods
The studies were conducted in 2016-2018 in the scientific training manufacturing complex “Borsky” of Krasnoyarsk State Agrarian University. The farm is located on the territory of the Krasnoyarsk forest-steppe with 340-380 mm of average annual precipitation, where frost-free period lasts from 95 to 120 days, the average annual air temperature is positive (+0.6°C), and the sum of active temperatures is 1600 - 1800°C.

The authors selected agrocoenosia as objects of research: Novosibirskaya 15 variety of spring wheat, Zaryanitsa variety of soya, Aramis variety of potato, Katerina SV variety of corn and clean fallow fields located on the complex of typical clay-illuvial, cryogenic-mycelial medium and heavy loamy varieties of agrochernozems. Agrochernozems had a slightly acidic, neutral, and slightly alkaline reaction of the soil solution, increasing with depth (pH7.0 6.5-7.8), low and medium content of mineral forms of...
nitrogen (9.4-23 mg·kg⁻¹), very low and low content of exchange phosphorus (30-125 mg·kg⁻¹), high and very high content of exchange potassium (165-385 mg·kg⁻¹). Humus level ranged from medium to high (5.8-6.9%). Fertilizers were not applied; plant protection products were used.

The preparation of clean fallow consisted of under-winter plowing to a depth of 25-27 cm and four cultivations to a depth of 8-10 cm during the growing season. Before spring wheat sowing, in autumn, flat-cutting processing was carried out to a depth of 5-6 cm; early spring harrowing was carried out in the first decade of May in the year of sowing. When cultivating soybeans, the main processing is flat-cutting, bursting to a depth of 15-17 cm from autumn, early spring harrowing in the year of sowing. Sowing wheat and soybeans were carried out in the second decade of May. The crop residues of soya and wheat were crushed and remained on the field. Potato was grown by seed technology. Two weeks before planting potato, an early spring harrowing was carried out, before planting in the middle of May, the soil was bursting to a depth of 18-20 cm. Planting was carried out in the ridges with row spacing of 90 cm. In early August, desiccation, chopping and scattering of tops were carried out, in the second decade of August potato harvesting started. All potato’s crop residues also remained on the field. Corn was cultivated for fodder purposes, the main processing was dump plowing to a depth of 23-25 cm, cultivation was carried out before sowing with simultaneous harrowing, sowing was carried out in the third decade of May in a wide-row way.

Mixed soil samples were selected in June, July and August. Repeatability is 4-fold, sampling depth is 0-20 cm. In soil samples, the content of nitrate and ammonium nitrogen, mobile phosphorus, and exchangeable potassium according to Chirikov was determined according to generally accepted methods [8]. The results were processed using descriptive statistics and analysis of variance.

The growing seasons in 2016-2018 were extreme in terms of hydrothermal conditions and differed in the alternation of extremely humid conditions in May, when the hydrothermal index was 1.1-2.7 and extremely dry periods in June and July, when the hydrothermal index dropped below 0.5 (Figure 1, Table 1).

![Figure 1. Weather conditions of the growing seasons 2016-2018 [9]](image)

**Table 1.** Long-term average annual hydrothermal conditions of the growing season (according to “Sukhobuzimskaya” weather station, Krasnoyarsk Territory).

| Months | Air temperature, °C | Rainfall, mm | Hydrothermal index |
|--------|----------------------|--------------|-------------------|
| May    | 10.0                 | 32.0         | 1.38              |
| June   | 16.4                 | 44.0         | 1.27              |
| July   | 18.9                 | 69.0         | 1.28              |
August 14.2 62.0 1.34

The mid-vegetation period of 2018 turned out to be especially arid, the deficit of precipitation in the summer months amounted to more than 80%, and hydrothermal index fell to 0.11 by July. An analysis of meteorological data [9] showed that the sum of active temperatures in 2016 was 1838.4, in 2017 – 1969.5, in 2018 – 1897.7°C, with an average long-term value for a given area of 1800°C, the amount of precipitation over these years was lower in an average of 24.5%, compared with long-term average annual data.

3. Findings
The soils of Siberia are characterized by a low level of nitrogen nitrate forms that is associated with a long seasonal freezing of soils and a short growing season. Under such conditions, nitrogen nitrate forms do not have time to accumulate, some of them are immediately absorbed by plants, and the other part is washed out by heavy rainfall of the second half of summer [10]. In these experiments, without the use of fertilizers, the content of nitrate nitrogen in agrochernozem was significant lower than that of ammonia and was characterized by a high degree of variability in time and space (Cv = 43.2 - 67.5%). In June, the nitrate nitrogen content was very low in the fallow field and low in the fields of wheat, potato, soybean and corn. An increase of nitrate nitrogen content to an average level of security was found in the fallow field by August (11.9 mg/kg). The nitrate nitrogen content in the agrochenozem of potato and wheat was low and very low throughout the growing season. When cultivating soybeans and corn, the nitrate nitrogen content in July was average and amounted to 9.3-8.8 mg/kg, and by August decreased to 7.9-3.5 mg/kg, due to its intensive removal of crops. Thus, a significant increase in nitrate nitrogen content in the middle of the growing season occurred only in the fallow field, possibly due to the absence of its removal by crops and higher soil moisture. When cultivating the remaining crops, a lack of moisture led to inhibition of nitrification processes. Studies [11] also established a low and very low nitrogen supply and a significant effect on the activation of nitrate accumulation processes of mouldboard plowing as compared to surface treatments, especially in arid periods.

Table 2. Statistical parameters of nutrient content in agrochernozems (average for the growing season in 2016-2018), mg/kg

| Growing | Nitrate nitrogen | Ammonium nitrogen | Mobile phosphorus | Exchangeable potassium |
|---------|-----------------|-------------------|------------------|-----------------------|
|         | X ± Sx*         | X ± Sx            | X ± Sx           | X ± Sx                |
| Clean fallow | 9.1±4.36 48.2 | 17.9±3.04 17.0 | 105.8±7.80 7.4 | 298±49.1 16.5 |
| Potato | 5.4±2.93 54.0 | 12.9±4.17 32.4 | 89.8±8.38 9.3 | 376±143.0 38.0 |
| Soya | 6.5±2.82 43.2 | 11.1±2.87 26.0 | 67.2±2.37 3.5 | 366±114.8 31.4 |
| Wheat | 3.8±2.39 63.8 | 8.7±3.67 42.1 | 59.7±3.44 5.8 | 410±144.8 35.3 |
| Corn | 9.5±6.41 67.5 | 12.6±2.90 27.0 | 85.2±27.0 32.8 | 286±27.9 9.8 |

* X – avg, Sx – error of avg, Cv, % – variation index

The ammonium nitrogen content in agrochernozem varied from low (7.3 mg/kg) to very high (21.3 mg/kg) and had high variability (up to 42.1%) both in space and in time. An analysis of the data of the dispersion showed that in the fallow field the content of ammonium nitrogen was on average 6.8-9.2 mg/kg higher than the agrochenozem of soybean, wheat, potato, and corn. The strength of influence indicator of the factor “growing” on the ammonium nitrogen content in the soil was 55.6%. Therefore, in arid conditions, fallow fields can accumulate ammonium forms of nitrogen, to a greater extent than nitrate forms.
The content of mobile phosphorus in agrochernozem was very low and low (56.3-112.5 mg/kg), belonged to the first and second class of security, had a low and medium degree of variability in time and space ($C_v = 3.5-32.8\%$).

![Figure 2. Dynamics of nutrients in field crops cultivation, mg/kg.](image)

A significant decrease in available phosphates in the fields with potato, soybean, wheat and corn is caused by their consumption by plants during the growing season. Only in the fallow field occurred the accumulation of mobile phosphorus, apparently due to the remnants of the forecrop (wheat straw). It is known [12] that without the use of fertilizers, the content of mobile phosphorus in chernozems does not exceed 40 mg/kg, and straw and organic fertilizers plowback leads to an increase in the content of mobile phosphorus by 1.3-1.7 times.

The content of exchangeable potassium in agrochernozems was characterized by high and very high availability for these crops (227.7-581.5 mg/kg), the nature of its spatial variability varied from medium to high level ($C_v = 16.5-38.0\%$). In a continental climate with an uneven precipitation and alternating periods of severe desiccation of the soil and its abundant wetting, the content of exchangeable potassium in soils increases along with a decrease in humidity and an increase in temperature in June and July [13]. Our studies confirm a significant increase in exchangeable potassium content in agrochernozems during the drought period. Thus, the dynamics of changes in the content of exchangeable potassium in agrochernozem was significantly affected by the “growing season” factor (the strength of influence indicator = 56.2\%).

### 4. Conclusion

The cultivation of field crops in often repeated arid conditions on the territory of the Krasnoyarsk forest-steppe without using fertilizers significantly reduces the mineral forms of nitrogen and phosphorus in the soil to low and very low level of supply. In fallow fields, despite the drought, the content of nitrate nitrogen and mobile phosphorus increases during the growing season to an average level of 11.9 and
112.5 mg/kg, respectively, the content of ammonium nitrogen to a high level (21.3 mg/kg). The content of exchangeable potassium in agrochernozems of the Krasnoyarsk forest-steppe increases 2.3-1.6 times during dry periods due to its release from soil minerals and reaches 581 mg/kg.

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