Nutrient regime of agrochernozems in oilseeds cultivation in the Kansk forest-steppe

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Abstract. The study was conducted on chernozem-type soils prevailing in the Kansk forest-steppe. The aim of the investigation is to study the temperature and nutrient regime of agrochernozems in spring rapeseed and camelina sativa cultivation. By the period of oilseeds sowing, the temperature did not reach a stable transition through +5 °C of the soil layer at the depths of 0-20 cm. From May to June, the soil temperature sharply increases up to +13-16 °C, and in July it warmed up to 29-30 °C. In August, agrochernozems cooled up to +5-12 °C. It has been found that a 0–20 cm layer of the camelina sativa agrocnosis is on average in 2° C warmer than rapeseed. The quantitative parameters resulting from the processes of ammonification and nitrification in the oilseeds agrocnoses are inversely related. The differences in the quantitative estimation of mineral nitrogen in the rapeseed and camelina sativa agrocnoses are not statistically proven. The initial identical high availability level of labile phosphorus in the oil crops agrocnoses is associated with the predecessor. The decline of this indicator in the rapeseed and camelina agrocnosis to a low level of security in the July period is due to its expenditure on the formation of plant productivity. The availability of exchangeable potassium for agrochernozems in agrocnoses is average, but in absolute terms it is higher in soils of camelina sativa agrocnosis.

1. Introduction
In the world production of oilseeds the rapeseed in the cabbage family (Brassicaceae), cultivated in 30 countries, has a leading position. Camelina sativa, the only plant in the Brassicaceae family is cultivated to produce semi-drying oil. Its seeds contain 29-47% fat oil. In world agriculture, camelina sativa occupies about 150 thousand hectares [1]. These crops have different peculiarities for cultivation conditions. Rapeseed is particularly demanding to the level of nitrogen nutrition. Its high availability of labile soil phosphates is the most important condition that determines the yield of oilseeds and plant resistance to adverse conditions. The productivity of oil crops is determined by a set of natural and agrarian and technological factors. The most important for agrochernozems, the prevailing soils in the Kansk forest steppe, is warm, moisture and nutrients, which must be investigated to determine the feasibility of the agrarian technologies for each of these crops. In this regard, the aim of the paper is to study the thermal and nutrient regimes of agrochernozems in the rapeseed and camelina sativa agrocnoses in the conditions of the Kansk forest-steppe.
2. Research methodology
The study was conducted in stationary field experiments in the Kansk forest-steppe of the Kansk-Rybinsk geomorphological district in land use of “OPK Solyanskojye” LLC in two key plots of land. The preceding crop is a pea-oat mixture. The field of agrocenozayar rapeseed of the Contra KL hybrid (land plot No. 1 - 56° 006”N and 95°052” E) is characterized by a wide-dumped relief with a low grade microrelief in the form of small reductions and increases of various shapes. It is typical for most of the Kansk forest-steppe. In the structure of the soil cover agrochernozems clay-illuvial typical average-powerful and powerful dominate here. Different types of agrochernozems of clayey-illuvial podzolized are found by barely noticeable micro reductions. The agrocnosis of the spring camelina of Uzhursky variety (land plot No. 2 - 56°026” N and 95°243” E) is located on a gentle slope of a wide ridge stretched from west to east. This land plot is distinguished by the greatest complexity of the soil cover and is represented by a combination of clayey-illuvial agrochernozems of typical different types, clay-illuvial podzolized agrochernozems and cryogenic-micellar low-power agrochernozems occupying micro-increases. The thermal regime of soils in oil crops agrocnoses was studied with a “Bayer” thermometer in soil layers from depths of 0-10 and 10-20 cm during the period from May to September on 4 test land plots allocated within each field. The data from the Solyansk agrometeorological station were used for a comparative description of the temperature regime of the adjacent atmosphere. The measuring soil temperature interval is 12–20 days. The selection of soil samples for agrochemical indices was carried out on 10 test land plots from depths of 0–20 and 20–40 cm from May to September. Nitrate nitrogen, exchange ammonium, mobile phosphorus and exchange potassium were determined by conventional methods in samples [2].

3. Results and discussion
Nitrogen content is the most important indicator of soil fertility. A mineral form of nitrogen (nitrate and ammonium) characterizes the level of nitrogen nutrition of plants; determine the effective soil fertility, functioning and the productivity of ecosystems. A quantitative consumption of the supply levels of agricultural soils with nitrate and ammonium nitrogen in the seeds agrocnoses (rapeseed and camelina sativa) cultivated for oilseeds is shown in figures 1 and 2. The low availability of agrochernozems with nitrate nitrogen and the predominance of the ammonium form in arable and subsurface horizons in the May period is due to fluctuations in weather conditions and low soil temperatures (4-5° C) at the beginning of oilseeds sowing that inhibit nitrification processes. A similar quantitative estimation was accompanied by some differences in rapeseed and camelina sativa agrocnoses in terms of nitrate nitrogen content and the nature of the spatial variability of the indicator. In the soil of camelina sativa agrocnosis, a decrease in the average amount of N-NO3 for 2 mg/kg and an increase in the spatial variation of the indicator by 5% in the 0-20 cm layer of depth.

A similar pattern was noted in the content of the ammonium form of nitrogen. According to the authors of [3], the annual expropriation of finely dispersed soil material from the arable layer of soil by meltwater leads to a significant decrease in nitrogen in this layer; it affects the reserves of this element negatively. An increase in temperature in 10° C in the June period in the studied agrocnoses caused a tendency to increase the nitrate form of nitrogen, but its amount remained in the same class of supply in the agrocnoses of rapeseed and camelina sativa. In the same period, a similar picture was found in both agrocnoses of the ammonium transition form of nitrogen from a low level of security to a very low level (figures 1 and 2). Apparently, this is due to the transformation of the ammonium form into nitrate. A change in the temperature regime of the soil in oilseed crops and the increase in soil surface temperature in the July period to 29-30° C in 2 times intensified the processes of ammonification and nitrification. It led to the significant accumulation of the ammonium form of nitrogen in oilseed agrocnoses, where the availability of this form was changed from a low level noted in the June period to an average level (3rd class of availability). The differences in the quantitative estimates of the ammonium form content of nitrogen during this period between rapeseed and camelina sativa were insignificant and was about 1 mg/kg.
Figure 1. Dynamics of the mineral forms content of nitrogen in agrochernozem in the rapeseed agrocnosis, mg/kg.

The decrease in the nitrate form of nitrogen in agrocnosis was associated with the nitrogen removal by the vegetative mass of rapeseed and camelina sativa. The decrease in the nitrate form of nitrogen in agrocnoses was associated with the nitrogen removal by the vegetative mass of rapeseed and camelina sativa. In general, in the oilseeds agrocnoses during a period of a sharp increase of the ammonium nitrogen, an equally noticeable decrease in nitrate soils is observed; the quantitative parameters resulting from the ammonification and nitrification processes are inversely correlated, which is consistent with published data [4]. Thus, low temperatures cause a weak mobilization activity of agricultural soils. At temperatures below 5° C, mineral nitrogen forms are not accumulated in the soil, but with the increase in temperature from + 13-16° C in the June period to + 29-30° C, the increase becomes significant in July. The differences in the quantitative estimates of mineral nitrogen in the rapeseed and camelina sativa agrocnosis of are not statistically great. The nitrogen removal
with the vegetative mass of rapeseed and camelina sativa leads to the depletion of agrochernozems with nitrates.

Phosphorus is one of the main elements of plant nutrition; therefore, its content in soil is an important indicator of soil fertility. The amount of gross phosphorus in different soils depends on the structure of the parent rock and the severity of biogenic accumulation and it varies from 0.01-0.35%. Phosphorus affects photosynthesis, respiration, core formation and cell division, fat and protein formation, root growth; it accelerates maturation, and increases the resistance of plants to diseases. The level of crop yield directly depends on mobile phosphorus compounds in soil [1, 5-7].

**Figure 2.** Dynamics of the mineral forms content of nitrogen in agrochernozem in camelina sativa agrocenosis, mg/kg.

The high soil enrichment with humus and their heavy particle size distribution determined a very high supply of 0–40 cm layer of depth with labile phosphorus (295–313 mg/kg) with insignificant (Cv = 8-15 %) and average variability in space (Cv = 32-33 %) depending on the nature of the field...
topography. The spatial distribution of phosphorus compounds in soils is primarily associated with the mineralogical structure of rocks, which, in turn, is determined by the history of the relief formation of this territory. In recent years, it has been established that with the content of labile phosphorus in the amount of 130-160 mg/kg rapeseed satisfies its phosphorus needs by 70-80%. A very high initial level of availability of labile phosphorus in the May period of the experimental fields determines the complete satisfaction of the needs of rapeseed and camelina sativa with this element of nutrition without additional phosphorus fertilizers. The dynamics in the month of June showed a decrease in labile phosphorus in the rapeseed agroecosystem in the arable layer to a low availability level, and in the sub-arable one to average availability level. This is due to an increase in temperature up to +13-16°C during this period and the consumption of rapeseed for the formation of the root system of the culture and in general the plant growth and development. The subsequent July period is characterized by a low availability of labile phosphorus for the arable and subsurface horizons of the agrochernozem due to the use of a nutrient for the productivity formation and the removal of the vegetative mass of rapeseed.

In the camelina sativa agroecoses, in the June period, a decrease in the availability of soil with labile phosphates to the increase (4th grade) in availability and in July to a low (2nd class) availability related to the removal of the camelina sativa crop was noted. The estimation of the average statistical parameters of the labile phosphorus in the arable layer while rapeseed growing, showed that its maximum value was 307 mg/kg, and the minimum was 128 mg/kg, hence the average statistical value was 176 mg/kg, estimated by the average level of phosphate in the soil (table 1).

### Table 1. The average parameters of the labile phosphorus content in agrochernozems in growing oilseeds, mg/kg.

| Layer, cm | Statistical indicator | X±Sx | min  | max  | Cv, % |
|-----------|-----------------------|------|------|------|-------|
|           | Rapeseed              |      |      |      |       |
| 0-20      |                       | 175,7±3,9 | 128,3 | 307,1 | 50    |
| 20-40     |                       | 180,2±3,9 | 124,4 | 295,0 | 44    |
| Camelina sativa |               |      |      |      |       |
| 0-20      |                       | 224,9±47,0 | 146,1 | 308,6 | 36    |
| 20-40     |                       | 224,7±47,0 | 149,4 | 312,5 | 37    |

With a high variation of the indicator a similar pattern of the distribution of labile phosphates is also typical for subsoil layer of agrochernozem. The camelina sativa agroecosystem is characteristic for the arable and subsurface layer, the increased soil availability with labile phosphorus with a high variation of this indicator. Thus, the initial high soils availability with labile phosphorus in dynamics decreases to a low level due to the nutrient removal by the oilseed crop. The average statistics for the period May-July showed that in the rapeseed agroecosystem, the soil is characterized by an average level of availability with labile phosphorus, and the soil in the camelina sativa agroecosystem is characterized by its increased level.

Potassium is the most important biophile element; its removal with the field crops harvest is more than phosphorus, and often it is more than nitrogen [8]. It plays a huge role in the water metabolism regulation, in the energy conversion processes, biosynthesis and transport of carbohydrates, in functioning of various enzymatic systems [9]. The plant resistance to a whole complex of unfavorable external factors is determined by the sufficient supply of plants with potassium [10]. The need for oilseeds in potassium to create a unit of seed yield is in 1.5-2 times higher than that of cereals. A lack of potassium reduces the root growth and aerial parts, resistance to cold, resistance to lodging, yield and oil content of seeds. Soil potassium reserves are determined by the mineralogical and granulometric structure of the soil [11]. The content of metabolic potassium in the soil is the main diagnostic indicator by which the potassium supply of plants is considered, although metabolic potassium is not the only form of potassium involved in plant nutrition [12].
During the May period, chernozems of the Kansk forest-steppe were characterized by an average supply of exchange potassium in the rapeseed agrocenosis and an increased level of availability of this nutrient in the camelina sativa agrocenosis according to gradations developed by V.G. Sychev [13]. The dynamics of exchange potassium is determined by weather conditions. The chernozems of the forest-steppe zone of Krasnoyarsk Krai are formed in a moderately dry and continental climate. Due to the uneven precipitation, one can notice an alternation in periods of strong soil desiccation and its abundant wetting. All this contributes to the release and fixation of potassium and, consequently, the seasonal variability of the content of its forms. According to published information, the content of metabolic potassium in soils increases in some years by June and in other years it increases by July. It is associated with a decrease in humidity, an increase in temperature and an increase in the silicate bacteria activity.

The results of studies showed that a change in hydrothermal conditions in June led to an increase in the availability of exchange potassium from an average level to an increased supply of exchange potassium to the subsurface soil layer in rapeseed agrocenosis.

The soil in the camelina sativa agrocenosis was characterized by increased availability of exchange potassium in the arable and subsurface horizons. In the July period of observations, the availability with exchange potassium in oilseeds agrocenoses decreased to an average availability level. Apparently, it is associated with the expenditure of this nutrient on the formation of oilseed crops. The availability with exchange potassium of oilseeds is average (table 2), but it remains increased in the arable layer of camelina sativa agrocenosis.

| Layer, cm  | Characteristic indicator | Statistical indicator | min | max | Cv, % |
|------------|--------------------------|-----------------------|-----|-----|------|
| 0-20       | Rapeseed                 | X±Sx                  | 73,1±1,3 | 69,4 | 74,8 | 4 |
| 20-40      | Camelina sativa          | X±Sx                  | 78,1±6,7 | 64,7 | 85,7 | 15 |
| 0-20       | Camelina sativa          | X±Sx                  | 86,7±5,1 | 78,0 | 95,5 | 10 |
| 20-40      | Camelina sativa          | X±Sx                  | 78,1±6,7 | 64,7 | 85,7 | 15 |

The latter may be due to a smaller removal of this element by the crop yield.

Thus, the agrochernozems of the Kansk forest-steppe are characterized by average effective fertility in terms of some basic elements of mineral nutrition in oil crops agrocenoses.

4. Conclusion

1. The transformation processes of mineral forms of nitrogen in soils of oilseeds agrocenoses are associated with a hydrothermal regime. The most optimal conditions for ammonification and nitrification processes and the accumulation of mineral forms of nitrogen are at temperatures of 16-30 °C in the conditions of the Kansk forest-steppe. The quantitative parameters resulting from the ammonification and nitrification processes in oilseeds agrocenoses are inversely related. The differences in the quantitative estimates of mineral nitrogen in the rapeseed and camelina sativa agrocenoses are not statistically proven.

2. The phosphate regime of agrochernozems is determined by the temperature regime of soils and the biological characteristics of crops grown, also due to the different level of availability of mobile phosphorus. The agrocenosis of camelina sativa is characterized by an increased supply of this nutrient, and for rapeseed it is characterized average. Agrochernozems are characterized by an average availability level with exchange potassium. But in absolute terms, this indicator is higher in the soil of agrocenosis.
3. The temperature regime of arable horizons of agrochernozems during the growing season of oil-bearing cruciferous crops testifies to the role of the temperature of the surface layer of the soil and the nature of agrocenosis in its formation. Agrochernozems of the Kansk forest-steppe are characterized by average effective fertility by the number of basic elements of mineral nutrition in oil crops agrocenoses.

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