

The yield of spring bird rape (*Brassica campestris* L.) varieties according to the level of mineral nutrition

Viliana Vasileva^{1*}, Ekaterina Lupova² and Dmitry Vinogradov²

¹*Institute of Forage Crops, Pleven 5800, Bulgaria*

²*Ryazan State Agrotechnological University P.A. Kostychev, Ryazan 390044, Russia*

*Corresponding author: viliana.vasileva@gmail.com

Abstract

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The production of spring bird rape (*Brassica campestris* L.) in the Non-Chernozem zone of the Russian Federation is a promising direction for increasing the resource base of oil raw materials in the region. The article presents studies to optimize the mineral regime on gray forest heavy loamy soils of the experimental agrotechnological station of Ryazan State Agrotechnological University Named after P.A. Kostychev (FSBEI HE RSATU) in Ryazan region, in 2016-2019, when growing spring bird rape varieties Kulta and Lipchanka. The duration of the growing season of varieties of spring bird rape in experiments was 73-91 days. The introduction of nitrogen fertilizers lengthened the growing season of the crop, compared with the control, on average, by 4-8 days. A longer growing season was noted in the wet years of research. With an increase in the level of nitrogen mineral nutrition, the flowering and ripening periods were 4–6 days longer compared with the control. Based on the material obtained, it can be argued that the most effective level of mineral nutrition for spring bird rape varieties is N_{180} . While $N_{180}P_{50}K_{50}$ fertilizer was applied, the maximum yield (2.03 t ha⁻¹) was obtained from Kulta variety, $N_{180}P_{100}K_{100}$ and N_{180} was implemented 2.00 and 2.15 t ha⁻¹ yields had from Lipchanka, respectively. The influence of spring bird rape varieties on soil nutrient content changes is not as significant as the effect of fertilizers, primarily nitrogen.

Keywords: spring bird rape; oilseeds; oil content; yield; gray forest soil

Introduction

The structure of sown areas in Russia is often dominated by grain crops, such as wheat, barley and oats. Many agricultural enterprises, including the world ones, reoriented to the production of three to four crops, which makes impossible to maintain a full crop rotation that ultimately leads to a decrease in the efficiency of the crop industry as a whole (Vinogradov et al., 2018; Kosev et al., 2019). An interesting agricultural crop in the Non-Black Earth Zone of Russia is spring bird rape being a good predecessor in crop rotation. It is a promising grass crop, intermediate crop also, which is capable of producing two herbage harvests in the region during the growing season in the same area (Kosolapov &

Trofimov, 2011). The crop grows well on almost all types of soils, except acidified and low fertility ones (Tanner et al., 2015; Shchur & Valckho, 2016).

Spring rape, being a valuable oilseed crop, contains on average 36-46% oil, 20-26% protein and about 10-15% fiber. By-products from the production of oil from the seeds of the crop are important meal and extraction meal, which are used as valuable feed additives for farm animals, largely due to the high content of essential amino acids and protein (Fröhlich & Rice, 2005). As for the quality of oilseeds bird rape competes successfully with many oilseeds of the world (Budin et al., 1995; De Marins et al., 2012; Lupova et al., 2020).

The production of bird rape in the Non-Chernozem zone of the Russian Federation, namely its spring forms,

is a promising direction for increasing the resource base of oil raw materials in the region. Due to the high content of erucic acids and glucosinolates in oilseeds of bird rape, it is currently not widespread. The content of erucic acid in new varieties of ginger is currently no more than 2%, which makes the quality of edible oil very high. But thanks to the emergence of new varieties and hybrids of bird rape having good production characteristics, there is an opportunity for a real solution to problems of producing oilseeds not only throughout the country, but in the region as well (Vinogradov et al., 2018).

Currently, the base of spring bird rape varieties has been replenished with new types of domestic selection – Novinka, Iskra, Valo, Lipchanka, Kul'ta. At the same time, there is a need to study and select new, recommended varieties based on characteristics of their productivity, resistance to adverse factors, oil content assessment and responsiveness to the application of mineral fertilizers (Vinogradov et al., 2018). It is known that the potential of new varieties appear only in certain soil and climatic conditions. In this regard, it is necessary to carry out their correct selection, which is possible only with ecological variety testing on various types of regional soil (Zoz et al., 2018). In this case, agro-gray and gray forest soil characteristic of the region are to be tested.

The technology for growing spring bird rape includes the most important element of the use of mineral fertilizers, as well as their effect on crops and soil nutrition. The plant productivity during the growing season is influenced by the configuration of fertilizers in combination with the size of the nutrition area, since the volume of used mineral substances, moisture and solar insolation will depend on this. The purpose of our work was to study the effect of the level of mineral nutrition on the productivity of spring bird rape.

Material and Methods

Experiments were conducted on gray forest heavy loamy soil of the experimental agrotechnological station at FSBEI HE RSATU in Ryazan region, Russia in 2016-2019. Agrochemical soil analysis of the experimental plot is as follows: humus is 3.0-3.2%, the reaction of the soil is medium acidic (pH_{KCl} is 5.3), hydrolytic acidity is low, not exceeding 2.6 mEq/100 g. The amount of absorbed bases is 15 mEq/100 g. The degree of soil saturation with bases is not more than 70%. Containing mobile phosphorus (P_2O_5) is 120-123 mg kg^{-1} , mobile potassium (K_2O) is 149-153 mg kg^{-1} and hydrolyzable nitrogen is 50 mg kg^{-1} .

When choosing options for the level of mineral nutrition, a calculation of norms for applying mineral fertilizers was done for the planned 2.5 t ha^{-1} yields of spring bird rape. Am-

monium nitrate (N 34.4%), ammophos (N 12%; P 52%), nitrophosphate (N:P:K 16:16:16) and potassium chloride (KCl 56%) were used in the experiment. To obtain the planned yield of spring bird rape, subject to preservation and reproduction of soil fertility, it is necessary to introduce mineral fertilizers in the recommended dose of $\text{N}_{180}\text{P}_{100}\text{K}_{100}$.

The technology of growing spring bird rape in the experiment was generally accepted for the Non-Chernozem zone. The predecessor was winter cereals. Sowing was carried out to a depth of 2-2.5 cm, with a sowing rate of 2.5 million pieces of germinating seeds per 1 hectare, in the first ten days of May, in a continuous row method, with seeder CCNT-16 in MTZ-1221 aggregate. For the best contact of seeds with the soil and obtaining friendly seedlings, mandatory seed rolling was carried out by ring-spur rollers 3KKS-6. Pesticide treatments against pests, diseases and weeds were used throughout the growing season. Varieties of spring bird rape Kul'ta and Lipchanka were the objects of the research. Variety Kul'ta is included in the State Register of selection achievements approved for use in the Central and Volga-Vyatka regions of the Russian Federation. Kul'ta is characterized by a yield of up to 2.8 tons per hectare, high oil content and the yield of meal. The average growing season for the Central region is 95-103 days. Erucic acid is contained in not more than 0.6% and often in the form of traces. The variety is declared as suitable for mechanized harvesting, technological, resistant to lodging and shedding. It is suitable for herbage and oilseed cultivation.

Lipchanka, declared as a 000-type variety, gives up to 2.3 tons of oilseeds per hectare. The growing season is 65-72 days. Indicators of resistance to lodging and shedding of oilseeds are above average values. It has a low susceptibility to *Alternaria* blight and is moderate to *Fusarium* blight. It has high quality oil and meal. There is no erucic acid in the oil. The variety is technological and suitable for growing as green feed and seeds.

In the phase of complete ripeness, harvesting was manual and sowing was mechanized with the help of "Taryon-2010". In the yellow ripeness phase, when the seeds in the lower pods of the central branch acquired a brown or yellow color characteristic of the variety, they started to mow the plants.

On the basis of the "Methods for the state cultivation testing of agricultural crops", censuses and observations were carried out during various phases of the vegetation of spring bird rape varieties (Dospikhov, 1985; Fedin, 1985). Mathematical processing of research results was carried out with the help of computer programs. A biochemical analysis of oil seeds and the soil composition of experimental plots took place in laboratories of FSBEI HE RSATU, Federal State Budgetary Institution "Station of the Agrochemical Service

“Ryazan” and LLC “EMZ-Kubanmaslo” of Tula region. Statistical data processing was carried out using the software product “Statistica 10”.

Results and Discussion

The average values of nutrient depletion per unit of the main crop production were used in the studies, taking into account the by-product, the nutrient content in agro-gray soil by agrochemical indicators, the averaged nutritive efficiency from the soil and fertilizers, and adhering to the calculation method. The missing amount of phosphorus, nitrogen and potassium, which corresponds to the norm of mineral fertilizers in kilograms of active substance per hectare, was calculated by the difference in the depletion of the studied elements by spring bird rape and their amount obtained by plants from the soil.

The brand of mineral fertilizers in the experiment was selected based on the assortment of the market of mineral fertilizers of Ryazan region and the biological characteristics of spring bird rape.

The use of complex fertilizers, which are represented by two or more elements, has been the main focus in the region in recent decades. For oilseeds on gray forest soils, only potassium fertilizers can serve as the main source of potassium. And the central element that determines the quantity and quality of the crop is nitrogen. Based on this, the following fertilizers were selected: nitrophoska (N:P:K-16:16:16), ammophos (N – 12%; P – 52%), ammonium nitrate (N – 34.4%) and potassium chloride (KCl – 56%).

Correction of the norms of mineral fertilizers was carried out for the necessary calculation of a deficit-free balance of nutrients, which leads to stabilization of soil fertility. To adjust the fertilizer application rates, the balance of nutrients was calculated.

When developing a fertilizer system, the correct ratio is established between the individual types and forms of mineral fertilizers, as well as the optimal doses, terms and methods of fertilizer application for individual crops are determined.

High efficiency of mineral fertilizers is ensured only if they are used in a certain scientifically sound system based on certain soil conditions, taking into account zonal climatic conditions, nutrition characteristics of oilseeds, agricultural machinery, fertilizer properties and other factors.

The estimated level of mineral nutrition for bird rape is $N_{180}P_{100}K_{100}$. The level of mineral nutrition $N_{90}P_{50}K_{50}$ and the effect of only nitrogen on the crop were studied in the technology of growing spring bird rape.

The issue of fertility of agro-gray soil is currently one of the key issues in agriculture. The average-weighted amount

of humus in arable soils is not higher than 4.5% and, on average, varies from 1.7-1.9% in sod-podzolic soils to 5% in leached and podzolized chernozems. Soils with humus from 4 to 6% account for about 36%, from 1.5 to 2.0% – 18%. The results of tests show that the state of humus in the soils of the region worsens.

Analyses of the results of an agrochemical survey of arable soils conducted in Ryazan region show that the situation with nitrogen and metabolic potassium depletion in the soil is unsatisfactory. The average-weighted content of metabolic potassium decreased in the soil cover of the region by 2018 to 10 mg 100 g⁻¹, which corresponds to the middle class.

According to the results of studies, a downward trend is observed in the dynamics of the relative area of arable soils with a third class of potassium content for the period 1977-2018. The percentage of the area has decreased to 31 by 2018, which is 5% lower than the original indicator in 1977.

If one takes into account the reduction of the assortment of phosphate fertilizers, as well as data on the content of the element (average-weighted), then it is possible to conclude that it is stable over the past few years. Most likely, the current situation with phosphorus can be explained by the same reasons as for potassium: the aftereffect from phosphorization and the introduction of phosphorus fertilizers into the stock. Given these data, by 2018, the average-weighted amount of the element remained at the level of 9-12 mg 100 g⁻¹. In this case, this level of provision can be described as the average one. It is worth noting that obtaining stable crops with a given number of nutrients will be unlikely. Approximately 11 mg 100 g⁻¹ of soil is the average value of the mobile phosphorus of arable soils in Ryazan region. And with the largest size in non-chernozem soils, this indicator is more than 10 mg 100 g⁻¹. The phosphorus content in some gray forest and sod-podzolic soils reaches up to 14-18 mg 100 g⁻¹. The content of mobile phosphorus usually does not exceed 10 mg 100 g⁻¹ in podzolized and leached soils. Currently, soils with an average phosphorus content amount about 36% and those with an increased content amount about 18%.

The economy of the southern districts of Ryazan region is aimed at the prospect of the use of soil resources, or rather phosphorus. Thus, phosphorus may become a limiting factor in agricultural production in the near future. The range of average-weighted exchange potassium in arable soils of the region is 8-14 mg 100 g⁻¹. Soils with I and II classes of provision amount 28% and those with III class amount 32%. The results of agrochemical analysis of the soil indicate that the acidic arable land in the farm is 23%.

Over the past five years, liming has not been carried out and liming of acidic soils is an important factor that increases soil fertility and, accordingly, increases the yield of agri-

cultural crops. This work must be resumed. Thus, the fertility status of agricultural soils in Ryazan region should be recognized as not optimal for sustainable agricultural production. Therefore, the regulation of mineral nutrition should occupy a special place in the agricultural system.

To obtain the planned yield of spring bird rape, subject to the preservation and reproduction of soil fertility, it is necessary to introduce mineral fertilizers in the recommended norms and established dates. Most mineral fertilizers will be applied to the main fertilizer in spring before sowing the studied crops. Additional fertilization is considered irrational.

Weather conditions of vegetation periods during the years of research were as follows: 2016 was characterized by the average temperature regime over many years of observation and slightly increased humidity (HTI was 1.49). 2017 was characterized by fluctuations from the norm of both temperature and water conditions (HTI was 1.57). 2018 had HTI equal to 0.64 and 2019 with HTI equal to 1.1 was warm, with a predominance of higher than average temperatures, insufficient moisture in the first half of spring bird rape vegetation.

According to the results of experiments, with the growth and development of the studied crop, a decrease in the content of nitrate nitrogen in the soil was noted. At the same time, analyzing the data, one can note an increase in the nitrifying ability of the soil with an increase in the content of nitrates. Due to the more intensive accumulation of vegetative mass by spring bird rape on fertilized variants, an accelerated consumption of nitrate nitrogen was noted in comparison with the control, closer to the phenological stage of the green bird rape pod. The nitrogen content in the soil becomes almost the same and does not change until the end of the growing season.

It is in the period of leaf rosette – budding that the bird rape is actively consuming nitrate nitrogen, and therefore, this element has a decisive role in the formation of the plant yield.

The content of phosphorus and potassium in the 0-20 cm layer also changed under the influence of fertilizers. The content of available phosphorus was higher than the control throughout the growing season of bird rape on fertilized variants. The dynamics of mobile phosphorus was less pronounced than that of nitrate nitrogen. On average, over the course of a year, the cultivation of spring bird rape against the background of natural fertility (control) led to a decrease in the phosphorus content in the soil by 1.5-1.75 mg 100 g⁻¹ of soil. The decrease in potassium content was less significant and amounted to 0.75-0.95 mg 100 g⁻¹ of soil.

The duration of the growing season of varieties of spring bird rape was 73-91 days. The introduction of nitrogen fertilizers lengthened the growing season of the crop, compared with the control, on average, by 4-8 days. A longer growing sea-

son was noted in wet years of the research. With an increase in the level of nitrogen mineral nutrition, the flowering and ripening periods lengthened by 4–6 days compared with the control. This fact contributes to longer-term bee pollination in agriculture. As a result, it makes it possible to obtain an additional increase in honey during the flowering period of the culture. The studies established a clear pattern of the influence of the level of mineral nutrition on the photosynthetic activity of bird rape crops (Table 1). The index of the leaf surface area of the bird rape for all variants of the experiment was noted at the beginning of flowering – full flowering. Nitrogen nutrition increased the area of the leaf surface. The maximum value on N₁₈₀ variant was obtained 38.3 thousand m² ha⁻¹, which is 35% higher than the control. A similar pattern was observed for such indicators as photosynthetic potential and leaf productivity, where maximum values were achieved on high backgrounds of nitrogen mineral nutrition N₁₈₀P₁₀₀K₁₀₀.

Table 1. Photosynthetic indices of spring bird rape variety Lipchanka at various levels of mineral nutrition, average for 2016-2019

The level of mineral nutrition, kg of active substance/ha	Maximum leaf area, thousand m ² /ha	Photosynthetic potential million m ² /ha * days	Net photosynthesis productivity, g/m ² per day	Productivity of leaves, kg per 1 thousand PhP units
Control	24.9	1.20	2.01	0.86
N ₉₀	30.5	1.40	2.12	0.95
N ₁₈₀	38.3	1.47	2.16	1.13
N ₉₀ P ₅₀ K ₅₀	28.0	1.35	2.08	0.91
N ₁₈₀ P ₁₀₀ K ₁₀₀	35.5	1.46	2.12	0.99
LSD ₀₅	4.1	0.61	0.81	0.09

The net productivity of photosynthesis in the experimental variants did not change significantly, and was observed in the range of 2.01-2.16 g m⁻² per day, where this indicator reached its maximum by the budding phase, and subsequently slightly decreased. The decrease after the beginning of bird rape flowering is explained by an increase in the leaf-stem mass of plants, which leads to a decrease in illumination due to the mutual shading of the crop. It should be noted that photosynthetic indicators decreased significantly by the time of the phenological phase of green pods of bird rape, which can be explained by the partial fall of leaves in the lower part of the stem by this time.

In the studies conducted, the use of mineral fertilizers had a positive effect on the formation of elements of the crop structure, photosynthetic indicators and the yield of spring bird rape (Table 2).

Table 2. The yield structure of spring bird rape according to the level of mineral nutrition, 2016-2019

The level of mineral nutrition, kg of active substance/ha	Variety	Plant population before harvesting, pcs m ⁻²	Number of pods per 1 plant, pcs.	The mass of 1000 seeds, g	Seeds in 1 pod, pcs
Control	Kulta	216.5	23.3	2.3	17.1
	Lipchanka	222.2	24.6	2.0	18.4
N ₉₀	Kulta	226.9	26.3	2.4	18.1
	Lipchanka	231.8	29.4	2.2	19.8
N ₁₈₀	Kulta	227.5	34.7	2.5	19.3
	Lipchanka	232.8	35.8	2.4	20.6
N ₉₀ P ₅₀ K ₅₀	Kulta	222.0	27.2	2.3	18.8
	Lipchanka	225.5	28.0	2.2	20.3
N ₁₈₀ P ₁₀₀ K ₁₀₀	Kulta	223.6	36.8	2.3	19.3
	Lipchanka	228.3	35.5	2.4	20.8

LSD05 AB interactions

by factor A (nutritional level)

by factor B (variety)

4.75

3.06

2.15

1.75

0.95

0.80

The number of pods per plant is an important indicator in the structure of the crop, which is the basis for the formation of seed increase. High indicators of the number of pods per 1 plant were noted on Lipchanka variety with the action of N₁₈₀ and N₁₈₀P₁₀₀K₁₀₀ (35.8 and 35.5 pcs plant⁻¹, respectively). The maximum number of pods per plant was on Kulta variety when N₁₈₀P₁₀₀K₁₀₀ (36.8 pcs). The mass index of 1000 seeds is a relatively stable indicator. It slightly varies depending on the level of mineral nutrition, and often depends on genetic properties of a particular variety or hybrid.

The contribution of the growth and generative biometric indicators that form the yield of bird rape is expressed to varying degrees and depends on varietal characteristics of the crop. During all years of the research the relationship between the yield and the number of pods per 1 plant, mass of 1000 seeds and the number of seeds in 1 pod was posi-

tive. The correlation coefficient (r) varied from 0 to 0.9. The exception was Lipchanka variety in 2019.

The responses of biometric indicators of productivity and the yield itself to mineral fertilizers by varietal characteristics were not found. Significant changes in indicators were established only within one variety.

In 2016, according to the population density significant differences of varieties (at p = 0.01) were manifested at high doses of mineral fertilizers (N₁₈₀P₁₀₀K₁₀₀). Fertilizers did not affect the population density of Kulta and Lipchanka varieties. The differences appeared with the additional application of phosphorus and potassium fertilizers at a dose of 100 kg ha⁻¹ of each element against the background of N₁₈₀. In 2016, all NPK dose options did not affect the number of pods and the weight of 1000 seeds of Kulta variety (Figure 1).

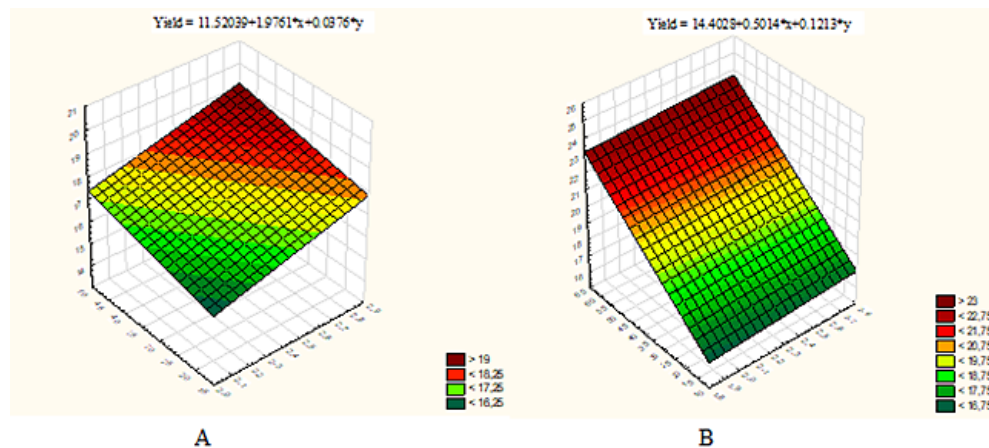


Fig. 1. The dependence of the yield of bird rape Kulta variety on the mass of 1000 seeds (X) and the number of pods (Y) (A – 2016; B – 2017)

Lipchanka variety had significant differences between pairs of variants: control N_{180} and $N_{180}N_{90}P_{50}K_{50}$. The use of all variants of fertilizers contributed to greater formation of the mass of 1000 seeds in Lipchanka variety compared to the control. In 2016, nitrogen, phosphorus and potassium fertilizers used in doses prescribed by the experimental scheme did not provide a reliable increase in the yield of bird rape Kulta variety as compared to control. The use of $N_{90}P_{50}K_{50}$ and $N_{180}P_{100}K_{100}$ did not increase the yield in Lipchanka variety compared to the control. Apparently, given the supply of soil with nutrients, it is sufficient to introduce nitrogen fertilizer at a dose of 180 kg ha⁻¹. Similar patterns with variations in combinations of compared pairs of experimental options were observed in other years.

The experiments showed that the increase in yield mainly depended on the dose of nitrogen introduced. High yields were obtained against high backgrounds of nitrogen mineral nutrition (Table 3). So, on average, with the level of mineral nutrition $N_{180}P_{50}K_{50}$, the maximum yield was observed for Kulta variety (2.03 t ha⁻¹). Lipchanka variety had 2.00 and 2.15 t ha⁻¹ respectively for $N_{180}P_{100}K_{100}$ and N_{180} . However, increasing doses of nitrogen to 150 kg of the active substance was less effective, as the yield increased slightly, or remained at the level of $N_{90}P_{50}K_{50}$.

The action of only phosphorus-potassium fertilizers did not contribute to the creation of such a nutritional regime, in which the seed yield of bird rape was increased. At the same time, the application of phosphorus-potassium fertilizers had a significant impact on the content of these nutrients in the gray forest soil of the experimental plot.

The introduction of a dose of $N_{90}P_{50}K_{50}$ in the form of ammonium nitrate (NH_4NO_3), ammophos ($NH_4H_2PO_4 + (NH_4)_2HPO_4$) and nitrophosphate (grade N:P:K-16:16:16)

compensated for the removal of PK and also contributed to accumulation of these elements in gray forest soil, on average over the years, per 0.3-1.1 mg 100 g⁻¹ of soil. At the same time, the introduction of a dose of $N_{180}P_{100}K_{100}$ did not compensate for the loss of phosphorus and potassium in the soil, where the decrease in K_2O and P_2O_5 was 0.25 and 0.55 mg 100 g⁻¹ of soil of the level of natural fertility, respectively. In this regard, in a case of an increase in the dose of nitrogen nutrition, the concentration of phosphorus-potassium elements in the soil decreased at the end of bird rape development. Note that K_2O content varied in the arable soil layer of 20-22 cm more than in the sub-arable layer.

The highest yield in all options was noted in 2018, which can be explained by good heat and moisture provision necessary for growth and development of spring bird rape, as well as a more efficient use of fertilizers by plants. The maximum yield in 2018 was observed on the variant with Kulta variety and the action of N_{180} (2.46 t ha⁻¹).

Note that the application of mineral fertilizers for spring bird rape must be differentiated taking into account the availability of nutrients in the soil. The most energy-efficient technique is fertilizing when sowing. Fertilizing during the main tillage is energetically and economically inefficient and impractical.

Conclusions

Thus, on the basis of the obtained material, it can be stated that the most effective level of mineral nutrition for spring bird rape varieties is N_{180} . When $N_{180}P_{50}K_{50}$, the maximum yield was observed in Kulta variety (2.03 t ha⁻¹) and Lipchanka variety had 2.00 and 2.15 t ha⁻¹ respectively for $N_{180}P_{100}K_{100}$ and N_{180} . The influence of varieties of spring bird

Table 3. Yield of spring bird rape varieties depending on the level of mineral nutrition, t ha⁻¹

Level of mineral nutrition	Variety	Yield, t/ha				
		2016	2017	2018	2019	average
Control (without fertilizer)	Kulta	1.58	1.67	1.80	1.45	1.63
	Lipchanka	1.64	1.78	1.84	1.45	1.68
N_{90}	Kulta	1.75	1.87	2.15	1.56	1.83
	Lipchanka	1.78	2.26	2.12	1.61	1.94
N_{180}	Kulta	1.91	2.20	2.46	1.71	2.07
	Lipchanka	2.06	2.31	2.41	1.82	2.15
$N_{90}P_{50}K_{50}$	Kulta	1.66	1.93	2.13	1.65	1.84
	Lipchanka	1.70	2.00	2.17	1.75	1.91
$N_{180}P_{100}K_{100}$	Kulta	1.85	2.12	2.41	1.73	2.03
	Lipchanka	1.87	2.05	2.23	1.83	2.00
LSD ₀₅ t/ha, AB interactions		0.23	0.24	0.41	0.60	
by factor A (nutritional level)		0.17	0.17	0.29	0.33	
by factor B (variety)		0.11	0.11	0.18	0.21	

rape on the change in the content of nutrients in the soil is not as significant as the effect of fertilizers, primarily nitrogen. The action of only phosphorus-potassium fertilizers does not contribute to creation of such a nutritional regime that will increase seed yield.

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