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The quality of spring rape seeds and its dependence on the doses of mineral fertilizers under the conditions of Southern Urals

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Abstract. Spring rape is a high-marginal crop that can be used in different areas of the national economy. Despite this, the area used for sowing this crop in the Russian Federation is still small, and the quality of its seeds does not always meet the standards. The purpose of the research is to identify the most effective doses of mineral fertilizers that allow obtaining the planned harvest of high-quality spring rape seeds in the southern forest-steppe of the Republic of Bashkortostan. The paper presents the results of triennial field researches (2016–2018) on the effect of mineral fertilizers on some indicators of the quality of spring rape seeds of the Iubileynyi variety. The research was carried out in the educational and scientific center of Bashkir State Agrarian University (Ufa, the Russian Federation) on leached black soils of heavy loam granulometric composition. The positive effect of calculated doses of mineral fertilizers on the object of interest was evident. Fertilization increased the spring rape yield capacity and its oil content by 0.34–0.51 t ha^{-1} and 0.1–1.8%, respectively. The yield of oil per hectare also increased. The use of fertilizers increased the content of nitrogen and potassium, averaging over three years 3.32–3.36% and 1.00–1.03%, respectively. The use of fertilizers did not significantly effect the content of phosphorus. The content of phosphorus did not exceed 1.74–1.79%. Crude protein content was 19.4–19.6% for researched period.

Key words: crude protein, mineral fertilizers, oil content, quality, spring rape.

INTRODUCTION

Spring rape is a high-marginal crop. It is used in many different ways in national economy (Zotz et al., 2018; Zemeckis et al., 2019). In recent years the crop areas have been increasing all over the world as well as in the Russian Federation (FAO, 2019; Statistics of The Russian Federation, 2018). China, Canada, countries of the European Union and India are the world leaders in growing rape today. These countries harvest 58 million tons in total, which is equal to 57% of the world's crop. The main exporters of rape seed in the world are Europe, Canada and Australia. The main importers are China, Mexico, Japan, Bangladesh, Pakistan and a number of other countries (FAO, 2019). These countries regulate the market for oil seeds using market and political conditions. There is a guaranteed area for oilseeds cultivation allotted for countries of the EU, which is established every year and is at least 10% of the total area. The EU policy on oilseeds has a certain export quota for rape and a system of per-hectare surcharges (Venus et al., 2017; Forleo et al., 2019). It should be noted that the structure of Russian market for oilseeds differs from that one worldwide. Sunflower occupies the main share of oilseed production, while rape accounts for 3–4% of Russian production.

There are two forms of rape: spring and winter rape. In Canada, for example, spring rape is widespread as conditions for winter rape are unfavorable, while in European countries (Germany, Poland, France, Great Britain, etc.) the climate is more favorable for winter rape cultivation, the yield of which there is almost twice higher than that of spring rape. In Sweden, the same attention is paid to both forms of rape. In the continental climate of Eastern Europe the cultivation of winter rape is a risky business. In Russia, spring rape is mainly grown. Rape production area in Russia was 1,387 thousand hectares and 37 thousand hectares in the Republic of Bashkortostan in 2018. The gross yield in the Russian Federation amounted to 2,216.3 thousand tons with an average yield of 1.4 t ha^{-1} in the country (Statistics of The Russian Federation, 2018).

Both forms of rape are very demanding of nutrients and require high doses of fertilizers. Many farms in the country are unable to apply the necessary amount of fertilizers due to the disparity in prices prevailing in the market, the lack of necessary state subsidies and available loans. Therefore, farms need to develop such a system of fertilization, when the natural potential of plants and soil is used to the maximum extent possible. At the same time, non-production expenses are minimized, and the necessary doses of fertilizers are applied. Thus, our research plays an important role in solving the problem of increasing the efficiency of fertilizers applying.

To develop a rational system of fertilization, it is necessary to take into account numerous parameters, such as the content of nutrients in the soil, the biological needs of plants, the phytosanitary situation of sowings, etc. (Hu et al., 2017; Xiao-Bo et al., 2017). The use of rational doses of fertilizers will allow agricultural producers to obtain maximum yields of high-quality spring rape seeds (Nurlygaianov et al., 2019a). If the amount of fertilizers is insufficient, the seeds of spring rape may not get ripened. Deficit of any nutrient leads to development disorders. For example, a lack of potassium, can lead to the accumulation of ammonia in plant cells. Excessing nitrogen can lead to the accumulation of nitrates in the seeds (Kasiuliene et al., 2016; Szczepanek & Siwik-Ziomek, 2019). Ferilization system requires correct calculation and precise compliance with the technological process (Queiros et al., 2015).

Soil and climatic conditions, phytosanitary situation and biological requirements are important for developing recommendations for the rational spring rape cultivation. The purpose of the research is to identify the most effective doses of mineral fertilizers for obtaining high yield of high-quality spring rape seeds in the southern forest-steppe of the Republic of Bashkortostan. The increase in the doses of mineral fertilizers can affect the quality of spring rape seeds. Macronutrients content (N, P, K) is important marker of fertilization efficiency. Oil and crude protein content may depend on fertilizer system.

MATERIALS AND METHODS

Researches were conducted in 2016–2018 in the Training and Research center of the Bashkir State Agrarian University of the Republic of Bashkortostan (Russian Federation, 54.769 °N, 55.866 °E). Field experiment was carried out on leached heavy loam black soils. The arable layer contained 6.8–7.2% of humus, 90 mg of easy hydrolysable nitrogen per 1 kg of soil, 110 mg of mobile phosphorus per 1 kg, 160 mg of exchange potassium per 1 kg. The soil was slightly acidic (pH_{KCl} = 5.2).

Iubileinyi recognized variety was studied according to the scheme: the control variant (without fertilizers); nitrogenous fertilizers were applied in one step for pre-sowing cultivation in a dose of $N_{125}P_{80}K_{50}$; the dose of nitrogen fertilizers was adjusted according to the soil diagnostics results and was applied in one step in a dose of $N_{75–80}P_{80}K_{50}$; split nitrogen fertilizing was used, where 2/3 of the dose was applied for pre-sowing cultivation and 1/3 – for feeding in a dose of $N_{125(2/3\text{ of the dose for pre-sowing cultivation, }1/3\text{ – for fertilization})}P_{80}K_{50}$; split nitrogen fertilizing was used, where the dose was adjusted according to the soil diagnostics results in a dose of $N_{75(2/3\text{ of the dose for pre-sowing cultivation, }1/3\text{ – for feeding})\text{ – }80}P_{80}K_{50}$; nitrogen fertilizers were applied in one step for pre-sowing cultivation, but potassium deficit increased – $N_{125}P_{80}K_{60}$ (Table 1).

Table 1. Experiment scheme

Experiment Variant	N, %		P, %	K, %
	pre-sowing	feeding		
Without fertilizers(control variant)	-	-	-	-
$N_{125}P_{80}K_{50}$	125	-	80	50
$N_{75(80)*}P_{80}K_{50}$	75(85)	-	80	50
$N_{125(2/3\text{ for a pre-sowing cultivation and }1/3\text{ for fertilization})}P_{80}K_{50}$	83.33	41.67	80	50
$N_{75(2/3\text{ for a pre-sowing cultivation and }1/3\text{ for feeding})(80)*}P_{80}K_{50}$	50(56.67)	25(28.33)	80	50
$N_{125}P_{80}K_{60}$	125	-	80	60

Variants was arranged in a classified order, in three replications. The harvest area of the plot is 50 m^2. During the experiments, we followed generally accepted recommendations for research institutions (Dospekhov, 2012).

Farm machinery used during the research corresponded to the scientific system of agriculture recommended for the zone (Puponina, 2010). Phosphorus and potassium fertilizers were applied in autumn for basic soil treatment. Nitrogen fertilizers were applied manually for pre-sowing cultivation and at the stage when spring rape had 4 leaves.

Treatment of spring rape seeds was performed with Kruiser agrichemical in a dose of 15 dm^3 t^{-1}. It was established that to improve drum treatment process, a transit mode of seeds moving inside the working drum is necessary (Khasanov et al., 2019). Fertilizers were introduced in the form of potassium chloride, ammophos, cal urea and ammonium saltpeter. The crop was sown in an ordinary way in the second decade of May with a seed application rate of 2.5 million germinating seeds per hectare. One-phase harvesting conducted when moisture content was lower 25%.

Mean annual precipitation in 2016 was twice less compared to normal rate, averaging 37.3 mm during the growing season. 2017 was characterized by heavy precipitation reaching record values of 166 mm, and the air temperature was below the standard. Climate conditions in 2018 were amounting to the long-term average annual values (Hydrometeorological Center of Russia, 2016–2018).

Statistical processing of research results was carried out by the variance and correlation analysis using standard computer software packages such as Microsoft Excel and Statistica 8.0 application. Arithmetic averages, standard errors, standard deviations, variances, confidence intervals, and coefficients of variation were calculated. The reliability of differences for the 95% level of significance was determined by Student's test between the variants of the experiment.

Agrochemical analysis of plants:

– determination of dry matter content and gyroscopic moisture according to All Union State standard 8719-58;

– determination of nitrogen content using the Nessler chemical agent (Jeong, Park & Kim, 2013);

– determination of phosphorus content using vanadomolybdate method (Lew & Jakob, 1963);

– determination of potassium using the flame photometry method (All Union State standard 26726-85, 1987);

– the oil content was determined by extracting it with the use of the Soxhlet apparatus (All Union State standard 10857-64, 1964);

– crude protein content was determined according to All Union State standard 28074-89 (1990).

RESULTS AND DISCUSSION

Oil content is an important indicator of seed quality (Arrua et al., 2017; Nurlygaianov et al., 2019b). The study of the effect of calculated doses of mineral fertilizers on the quality of spring rape products led to the increase in both yield and oil content by 0.34–0.51 t ha^{-1} and 0.1–1.8%, respectively. The use of fertilizers resulted in the increase in oil yield which amounted to 0.902–0.909 t ha^{-1} (Table 2).

Oil content of seeds in all of the studied variants was lower in 2016 compared to 2017 and 2018. This is caused by a decrease in the synthesis of nutrients during the formation of seeds. The decrease in the synthesis was caused by a high air temperature and moisture deficit.

The yield of oil per unit of area is increased by increasing the yield of seeds. Increasing the doses of mineral fertilizers heightened the yield of oil from 1 hectare compared to the control variant by 210 kg due to increased seed yield.

Table 2. Oil content and oil yield of Iubileinyi variety, depending on the calculated doses of mineral fertilizers (average over 2016–2018)

Experiment variant	Yield, t ha^{-1}	Oil content, %	Oil yield, t ha^{-1}
Without fertilizers (control variant)	1.76^{b}	41.7^{b}	0.740
$N_{125}P_{80}K_{50}$	2.14^{a}	43.0^{a}	0.903
$N_{75(80)*}P_{80}K_{50}$	2.10^{a}	42.3^{b}	0.903
$N_{125(2/3\ for\ a\ pre\text{-}sowing\ cultivation\ and\ 1/3\ for\ fertilization)}P_{80}K_{50}$	2.27^{a}	41.8^{b}	0.902
$N_{75(2/3\ for\ a\ pre\text{-}sowing\ cultivation\ and\ 1/3\ for\ feeding)(80)*}P_{80}K_{50}$	2.18^{a}	42.7^{ab}	0.909
$N_{125}P_{80}K_{60}$	2.13^{a}	43.5^{a}	0.909
$LSD_{0.05}$	0.25	0.69	0.01

The same results were obtained by Indian scientists. They studied the effect of macronutrients on the yield and oil content of rape in their research. Increasing the nitrogen dose to 100 kg a. m. per ha increased the yield of spring rape seeds. Further increase in the dose did not lead to an increase in the yield (Liu et al., 2019).

Oil content in the $N_{125}P_{80}K_{60}$ variant of Iubileinyi variety was maximum and amounted to 42.5%. In the variant, where fertilizers were applied in the dose of $N_{125}P_{80}K_{50}$, oil content was 42%, and 41.7% – in the variant with the fertilizers dose of $N_{75(2/3\ for\ pre\text{-}sowing\ cultivation,\ 1/3\ for\ feeding)\ (80)*}P_{80}K_{50}$.

Quality of seeds depend on mineral fertilizers content of macronutrients in the seeds of spring rape can show efficiency of applied fertilizers. Feeding qualities of rape seed are decreases for high rates of fertilizers. Nitrogen is an element that plays a major role in plant metabolism, being a part of complex and simple proteins (Gamzikov et al., 2000).

Research results for 2016–2018 showed that the use of fertilizers increased the nitrogen content by 0.68–0.72%, amounting to 3.32–3.36% per completely dry matter (Table 3). In 2016, due to dry and hot weather, the increase was higher compared to other years of research and amounted to 3.51–3.58% for fertilized variants.

Table 3. Nitrogen content in spring rape seeds, % per completely dry matter

Variant	2016	2017	2018	On average over three years	Increase compare to control
Without fertilizers (control)	2.75	2.48	2.63	2.64	-
$N_{125}P_{80}K_{50}$	3.58	3.03	3.46	3.33	0.69
$N_{75(80)*}\ P_{80}K_{50}$	3.52	3.11	3.43	3.32	0.68
$N_{125(2/3\ for\ a\ pre\text{-}sowing\ cultivation\ and\ 1/3\ for\ feeding)}P_{80}K_{50}$	3.51	3.16	3.48	3.36	0.72
$N_{75(2/3\ for\ a\ pre\text{-}sowing\ cultivation\ and\ 1/3\ for\ feeding)(80)*}\ P_{80}K_{50}$	3.54	3.11	3.42	3.33	0.69
$N_{125}\ P_{80}K_{50}$	3.53	3.12	3.41	3.33	0.69
$LSD_{0.05}$	0.26	0.22	0.24	-	-

Phosphorus compounds in a living organism are fundamental. They perform a certain function in the energy volume, formation of adenosine triphosphate, etc. (Postnikov et al., 2001).

The results of the research indicate that the use of calculated doses of mineral fertilizers did not effect on the phosphorus content, and made up 1.74–1.79% (Table 4).

Potassium plays an important role in plant photosynthesis and is involved in many different types of reactions (Predein, 1991).

In the course of research, it was found that the potassium content of spring rape seeds strongly depended on the calculated doses of fertilizers used by us (Table 4). The potassium content increased by 0.13–0.16% to 1–1.03%. The maximum potassium content in spring rape seeds was observed in the N_{125} variant (2/3 for a pre-sowing cultivation and 1/3 for feeding)) $P_{80}K_{50}$ and was 1.07%.

Table 4. Phosphorus content in spring rape seeds, % per completely dry matter

Variant	2016	2017	2018	On average over three years
Without fertilizers (control variant)	1.73	1.65	1.7	1.69
N_{125} $P_{80}K_{50}$	1.80	1.69	1.78	1.76
$N_{75(80)*}P_{80}K_{50}$	1.80	1.68	1.75	1.74
$N_{125(2/3 \text{ for a pre-sowing cultivation and } 1/3 \text{ for feeding})}$ $P_{80}K_{50}$	1.86	1.72	1.80	1.79
$N_{75(2/3 \text{ for a pre-sowing cultivation and } 1/3 \text{ for feeding})(80)*}$ $P_{80}K_{50}$	1.82	1.7	1.78	1.77
N_{125} $P_{80}K_{50}$	1.81	1.71	1.77	1.76
$LSD_{0.05}$	0.05	0.04	0.05	-

Accumulation of potassium in spring rape seeds was largely dependent on the use of fertilizers (Table 5). At the same time, on average, the content of this element increased by 0.15–0.17% in the fertilized variants over four years.

Table 5. Potassium content in spring rape seeds, % per absolutely dry matter

Variant	2016	2017	2018	On average over three years	Increase
Without fertilizers (control variant)	0.87	0.89	0.86	0.87	-
N_{125} $P_{80}K_{50}$	0.95	1.06	1.02	1.01	0.14
$N_{75(80)*}P_{80}K_{50}$	0.94	1.05	1.01	1.00	0.13
$N_{125(2/3 \text{ for a pre-sowing cultivation and } 1/3 \text{ for feeding})}$ $P_{80}K_{50}$	0.98	1.07	1.05	1.03	0.16
$N_{75(2/3 \text{ for a pre-sowing cultivation and } 1/3 \text{ for feeding})(80)*}$ $P_{80}K_{50}$	0.95	1.06	1.02	1.01	0.14
N_{125} $P_{80}K_{50}$	0.96	1.07	1.03	1.02	0.15
$LSD_{0.05}$	0.15	0.16	0.14	-	-

Experiments conducted in Central Europe (Poland) to study the effect of nitrogen, phosphorus and potassium on the accumulation of phosphorus and potassium showed that with average doses of fertilizers, there is an increased accumulation of phosphorus and potassium in shoots and roots during flowering and seed ripening. Very high doses of fertilizers cause the plant to heavily absorb phosphorus and potassium (Szczepanek & Siwik-Ziomek 2019).

It is necessary to determine the content of crude protein in spring rape seeds, because this indicator is one of the most important in determining the quality of products. Proteins play a major role in metabolism, performing structural and catalytic functions.

Our studies have shown that the content of crude protein in fertilized versions of spring rape seed varied on average over three years from 20.0–20.3% per absolutely dry matter and showed an increase of 3.5–3.9% (Table 6). The content of crude protein of 20.3% was noted in the N_{125} application variant (2/3 for a pre-sowing cultivation and 1/3 for feeding) $P_{80}K_{50}$.

Over the years of research, the maximum increase in the content of raw protein was observed in 2016 due to weather conditions. It was 20.5–20.7% in fertilized variants. The minimum increase was noted in 2017 and was 19.4–19.9%.

Table 6. The content of crude protein in spring rape seeds when using calculated doses of mineral fertilizers, % per absolutely dry matter

Variant	2016	2017	2018	On average over three years	Increase
Without fertilizers (control variant)	17.2	15.9	16.3	16.5	-
N_{125} $P_{80}K_{50}$	20.6	19.5	19.8	20.0	3.5
$N_{75(80)*}$ $P_{80}K_{50}$	20.7	19.4	20.2	20.1	3.6
$N_{125(2/3 \text{ for a pre-sowing cultivation and } 1/3 \text{ for feeding})}$ $P_{80}K_{50}$	20.7	19.9	20.4	20.3	3.9
$N_{75(2/3 \text{ for a pre-sowing cultivation and } 1/3 \text{ for feeding})(80)*}$ $P_{80}K_{50}$	20.6	19.7	20.3	20.2	3.7
N_{125} $P_{80}K_{50}$	20.5	19.8	20.2	20.2	3.7
$LSD_{0.05}$	0.27	0.25	0.24	-	-

The results of our research confirm previously published works about the effect of nitrogen fertilizers on protein content in crop yields (Charbonnier et al., 2019).

The study on the effect of calculated doses of mineral fertilizers on the yield and quality of spring rape seeds proved that climatic conditions had a significant impact on these indicators. Therefore, we need to determine the effect of our calculated doses of mineral fertilizers and weather conditions on variability.

Table 7. Influence of various factors on crop fluctuations and the content of nitrogen, phosphorus, potassium and oil in spring rape seeds, %

Factor	Seed yield	Content of spring rape seeds			
		N	P	K	Oils
Weather conditions	87	50	82	61	51
Calculated doses of mineral fertilizers	11	46	15	32	45
Other	2	4	3	7	4

Fluctuations in the yield of spring rape seeds show that 87% of it was determined by weather conditions, 11% by the calculated doses of mineral fertilizers used, and 2% by other factors (Table 7).

The variability of nitrogen content in the yield of spring rape seeds was almost equally determined by weather conditions and doses of mineral fertilizers. Fluctuations in phosphorus content n seeds by 82% depended on weather conditions, by 15% – on mineral fertilizers, and by 3% – on other factors.

Fluctuations in the potassium content mainly depended on the calculated doses of mineral fertilizers (61%), in 32% – on weather conditions, and in 7% – on other factors. Oil content depended almost equally on weather conditions and calculated doses of mineral fertilizers.

Studies on the impact of various factors on the yield and quality of spring rape seeds, conducted in Canada and the United States, have shown that water supply, balanced nutrition, early planting at low depth, high seeding rate, and a diverse crop rotation are among the best management methods for increasing the yield of spring rape seeds (Assefa et al., 2018).

Under production conditions, the planned level of yield of spring rape seeds is not formed, and its actual value is lower than the planned one. Increasing the dose of mineral fertilizers and changing types and methods of their application lead to the increase in the growing season by 19 days. At the same time, yield varied from 1.3 to 2.2 t ha^{-1}, and the oil content – from 43.0 to 46.0% (Nurlygaianov et al., 2019a).

Low availability of nitrogen in sowing time leads to the reduction in yields and oil content (Liu et al., 2019). The study showed that plant height, the number of branches, pods, seeds per pod and weight of 1000 seeds significantly depend on nitrogen and phosphorous fertilizer levels. The use of fertilizers in a dose of $N_{100}P_{50}$ allowed to get the highest yield. But the increase in the dose of nitrogen fertilizers above 100 t ha^{-1} does not allow to get higher yields of rapeseeds (Singh et al., 2019).

During three years of studies, conducted in the conditions of the Republic of Bashkortostan, the average concentration of digestible protein per 1 spring rape feed unit was 147.2–153.8 g., 191.2–197.8g. per 1 spring vetch feed unit and 202.1–209.0g. per 1 feeding mallow feed unit. The use of these crops in mixed sowing together with Sudan grass allowed increasing the concentration of digestible protein to the level of 102.4–190.4 g. When the control concentration was 92.9–98.8 g., the highest concentration of digestible protein was noted with a ratio of 20+80 of $N_{56}P_{67}K_{54}$ mineral nutrition level. High concentration of digestion protein allows improving feeding diet for highly productive dairy cows, beef cattle, and other types of farm animals and poultry (Kuznetsov et al., 2018).

Thus, our results confirm earlier published works on the reduction of seeds oil content with the increase in doses of nitrogen fertilizers (Ahmadi & Bahrani, 2009; Nurlygaianov et al., 2019b). But as it can be seen, the yield of oil from 1 hectare of spring rape crops increases together with the increase in crop yield. In our studies, the use of fertilizers slightly increased the content of nitrogen and potassium in spring rape seeds and amounted to 0.68–0.72% and 0.13–0.16%, respectively. But if we compare our results with the research of Polish scientists, we can distinguish some differences (Szczepanek & Siwik-Ziomek, 2019). According to the results of their research, the introduction of increased doses of fertilizers ($N_{180}P_{70}K_{132}$) leads to the increase in the accumulation of phosphorus and potassium. But our results prove, that the increase in doses of nitrogen fertilizers does not have a significant effect on the accumulation of phosphorus in the seeds of spring rape.

It should be noted that Russia lag manyfold behind the rest of the world in the volume of fertilizer application (Statistics of The Russian Federation, 2018), though our country is in the top 5 for fertilizer production (FAO, 2019), and the results of different countries will have significant differences (Xiao-Bo et al., 2017; Abdulkhaleq et al., 2018; Jankowski & Sokólski, 2018; Kachel-Jakubowska et al., 2018; Meifang et al., 2018).

Our research makes it possible to note once again, that a balanced nutrition plays an important role in obtaining high yields of high-quality rape seeds.

CONCLUSION

According to the results of the study, a positive effect of calculated doses of mineral fertilizers is confirmed. Fertilization has increased the spring rape yield capacity and its oil content. In particular, it is proved that the maximum oil content corresponds to the

use of nitrogen fertilizers $N_{125}P_{80}K_{60}$. The current research reveals the reduction of seeds oil content with the increase of nitrogen fertilizer dosage. However, at the same time, the yield of oil from 1 hectare of spring rape crops increases together with the increase in seed yield. The reduction in oil content may be caused by high air temperature and moisture deficit, associated with a decrease in the synthesis of nutrients during seed formation. It is also found that the use of calculated doses of mineral fertilizers on average over three years leads to an increase in the content of nitrogen, potassium, and raw protein in spring rape culture. In turn, the accumulation of phosphorus in the seeds remains the same. The analysis shows that the yield and phosphorus in spring seeds are more dependent on weather conditions, and less on the calculated doses of used fertilizers. The identical effect of weather changes and fertilization is noted on the content of nitrogen and oil. In turn, fluctuations in the potassium mainly depend on the estimated doses of fertilizers, and in a less degree on weather conditions. Considering the results achieved, various factors should be taken into account when calculating doses of mineral fertilizers to increase the yield and quality of spring rape seeds. Our developments can be applied to study the yield of other crops, being highly relevant and promising due to global climate change.

REFERENCES

Abdulkhaleq, D.A., Hama, S.J., Ahmad, R.M. & Tawfiq, S.I. 2018. Response of some Rapeseed (Brassica napus L.) varieties to Zn fertilizer Under Dryfarming Conditions. *Journal of ZankoiSuLAmani* 1, 143–156.

Ahmadi, M. & Bahrani, M.J. 2009. Yield and Yield Components of Rapeseed as Influenced by Water Stress at Different Growth Stages and Nitrogen Levels. *American-Eurasian Journal of Agricultural and Environmental Sciences* **5**(6), 755–761.

All Union State standard 26726-85. Reagents. Flame-photometric method for the determination of sodium, potassium, calcium and strontium as impurities. Implementation date – 01-01-1987.

All Union State standard 10857-64. Oil seeds. Methods of determination of oil content. Implementation date – 22-04-1964.

All Union State standard 28074-89. Vegetable feeds. Method for determination of crude protein solubility. Implementation date – 01-01-1990.

Arrua, M.M., Duarte, J.B., Tomm, G.O., Augustinho, B., Mezzalira, E., Piva, A.L., Anderson, S. & Tsutsumi, C.Y. 2017. Agronomic characteristics and oil content of different genotypes of canola (Brassica napus L. var. oleifera). *African Journal of Agricultural Research* **12**, 2002–2007.

Assefa, Y., Prasad, V.V., Foster, C., Wright, Y., Young, S., Bradley, P., Stamm, M. & Ciampitti, I.A. 2018. Major Management Factors Determining Spring and Winter Canola Yield in North America. *Crop Science Society of America* **58**, 1–16.

Charbonnier, E., Fugeray-Scarbel, A. & Lemarie, S. 2019. Colza: quellevalorisation pour des variétés plus efficientesen azote dans le contextefrançais? *Oilseeds & fats Crop and Lipids* **26**, 1–8 (in French).

Dospekhov, B.A. 2012. *Method of field experience (with the basics of statistical processing of research results)*. Moscow, Book on demand, 352 pp.

FAO. 2019. *The State of World Fisheries and Aquaculture 2019 (SOFIA): Contributing to food security and nutrition for all, Food and Agriculture Organization*, Rome, pp. 200.

Forleo, M.B., Palmieri, N., Suardi, A., Coaloa, D. & Pari, L. 2019. The eco-efficiency of rapeseed and sunflower cultivation in Italy. Joining environmental and economic assessment. *Journal of Cleaner Production* **172**, 3138–3153.

Gamzikov, G.P., Vlasenko, N.G. & Chichkan, T.N. 2000. Features of nitrogen nutrition of field cabbage crops in the forest-steppe of Western Siberia. *Russian Academy of Agricultural sciences* **6**, 15–18.

Hu, Q., Hua, W., Yin, Y., Zhang, X., Liu, L., Shi, J., Zhao, Y., Qin, L. & Chen, C. 2017.Hanzhong Wang Rapeseed research and production in China. *The Crop Journal* **5**, 127–135.

Hydrometeorological Center of Russia. 2018. Available at: https://meteoinfo.ru/

Jankowski, K.J. & Sokólski, M. 2018. The effect of micro-granular starter fertilizer on the biomass quality of winter oilseed rape. *Journal of Elementology* **23**, 1243–1255.

Jeong, H., Park, J. & Kim, H. 2013. Determination of NH 4+ in Environmental Water with Interfering Substances Using the Modified Nessler Method. *Journal of Chemistry*, **9**.

Kachel-Jakubowska, M., Sujak, A. & Krajewska, M. 2018. Effect of Fertilizer and Storage Period on Oxidative Stability and Color of Rapeseed Oils. *Polish Journal of Environmental Studies* **27**(2), 1–10.

Kasiuliene, A., Paulauska, V. & Kumpiene, J. 2016. Influence of nitrogen fertilizer on Cd and Zn accumulation in rapeseed (Brassica napus L.) biomass. *Agronomy Research* **14**(2), 418–427.

Khasanov, E., Gabitov, I., Mudarisov, S., Khamaletdinov, R., Rakhimov, Z., Akhmetyanov, I., Farkhutdinov, I., Masalimov, I. & Musin, R. 2019. Justification of parameters of seed treater with an eccentrically fixed drum influencing the motion character and seed treatment modes. *Bulgarian Journal of Agricultural Science* **25**(S2), 119–128.

Kuznetsov, I.Y., Akhiyarov, B.G., Asylbaev, I.G., Davletov, F.A., Sergeev, V.S., Abdulvaleyev, R.R., Valitov, A.V., Mukhametshin, A.M., Ayupov, D.S. & Yagafarov, R.G. 2018. The Effect of Sudan grass on the mixed sowing chemical composition of annual forage Crops. *Journal of Engineering and Applied Sciences* **13**(S8), 6558–6564.

Lew, R. B. & Jakob, F. 1963. Interference of silicon in the determination of phosphorus by the vanadomolybdate method. *Talanta* **10**(3), 322–324.

Liu, Q., Ren, T., Zhang, Y., Li, X., Cong, R., White, P.J. & Lu, J. 2019. Yield loss of oilseed rape (Brassica napus L.) under nitrogen deficiency is associated with under-regulation of plant population density. *European Journal of Agronomy* **103**, 80–89.

Meifang, S., Yitao, H., Shuai, H., Junfeng, H., Fowen, C., Jialong, Z. & Jifu, L. 2018. Effects of long term potassium fertilizer application on crop yield and potassium distribution in soil aggregates in paddy-upland rotation system. *Journal of Southern Agriculture* **49**, 1082–1088.

Nurlygaianov, R., Ismagilov, R., Islamgulov, D., Ahiyarov, B., Abdulvaleev, R., Ismagilov, K. & Ginijtova, F. 2019a. Agro-Technical Basis for Spring Rape Seed Productivity Depending on Different Climatic Zones of the Russian Federation. *International Journal of Advanced Science and Technology* **27**(1), 222–230.

Nurlygaianov, R.B., Ismagilov, R.R., Akhiiarov, B.G., Ismagilov, K.R. & Alimgafarov, R.R. 2019b. Peculiarities of mineral nutrition of spring rape. *International agricultural journal* **1**(367), 29–31.

Postnikov, D.A., Noiman, G. & Romkheld, F. 2001. Accumulation of phosphorus by white mustard and rapeseed when applying various forms of phosphates to the soil. *Izvestiia (news) of Timiriazev Academy of Agriculture* **1**,113–124.

Predein, Iu.A. 1991. The content of mineral elements in the dry matter of spring cabbage. In: *Effective use of organic and mineral fertilizers in the Cis-Ural region*. Perm, pp. 84.

Puponina, A.S. 2010. *Land husbandry*. Moscow, Kolos, 550 pp.

Queiros, J., Malça, J. & Freire, F. 2015. Environmental life-cycle assessment of rapeseed produced in Central Europe: addressing alternative fertilization and management practices. *Journal of Cleaner Production* **99**, 266–274.

Singh, R., Lal, M., Singh, G. & Kumar, T. 2019. Effect of nitrogen and phosphorus on growth parameter and yield of canola (Brassica napus L.). *Journal of Pharmacognosy and Phytochemistry* **8**, 380–384.

Statistics of the Russian Federation. 2018. Publication catalog: Federal State Statistics service. Available at: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/publications/catalog/doc_1265196018516.

Szczepanek, M. & Siwik-Ziomek, A. 2019. P and K accumulation by rapeseed as affected by biostimulant under different NPK and S fertilization doses. *Agronomy* **9**(9), 477.

Venus, T.J., Drabik, D. & Wesseler, J. 2017. *The Interaction among the Regulation of New Plant Breeding Techniques, GMO Labeling, and Coexistence and Segregation Costs. The Case of Rapeseed in the EU 2017*. LICOS Discussion Paper Series. No. 389/2017.

Xiao-Bo, G., Yuan-Nong, L. & Ya-Dan, D. 2017. Optimized nitrogen fertilizer application improves yield, water and nitrogen use efficiencies of winter rapeseed cultivated under continuous ridges with film mulching. *Industrial Crops and Products* **109**, 233–240.

Zemeckis, R., Dautartė, A., Kretavičius, J. & Droždz, J. 2019. Effects of winter and spring rape seed treatment with neonicotinoids on honey bees. *Zemdirbyste-Agriculture* **106**, 173–182.

Zotz, A., Bernhard, U. & Bonin, J. 2018. KORVETATM – a new herbicide for the control of a wide range of broadleaf weeds in winter oilseed rape applied in spring. *Julius-Kühn-Archiv* **458**, 359–362.