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AGRICULTURAL SCIENCES

THE EFFECT OF SOWING METHOD AND N APPLICATION ON SEED YIELD AND N USE EFFICIENCY OF WINTER OILSEED RAPE

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Abstract
In the conditions of the Right-Bank Forest-Steppe, the placement of winter rapeseed crops after winter wheat usually leads to a delay in sowing the latter and deterioration of autumn plant development. Based on data from a field experiment conducted in 2016/2017, 2017/2018 and 2018/2019, the aim of this study was to investigate how sowing delay affects seed yield, nitrogen uptake by seeds and significant efficiency of nitrogen use by winter rape plants; to check the ability of autumn and spring application of nitrogen fertilizers to compensate for the negative impact of delays in sowing crops; and estimate the minimum autumn development for optimal seed yield. To solve the set tasks, a combination of four sowing dates (from the first week of August to the third week of September) and four autumn nitrogen applications (0, 30, 60 and 90 kg / ha per year) was fixed. In each of these 16 variants, nitrogen application was performed 5 times in the spring (0/0, 40/40, 80/80, 120/120, 140/140 kg / ha, etc.) in order to estimate the individual nitrogen reaction curves. . Nitrogen accumulation by aboveground mass of plants in autumn, seed yield and nitrogen uptake by seeds were determined. It was found that sowing the crop after mid-September significantly reduced yields. Application of nitrogen fertilizers in autumn in the amount of at least 30 kg / ha per year increased the yield and absorption of nitrogen seeds without any significant interaction with the sowing period and spring application of nitrogen fertilizers. Increasing the dose of spring fertilizer application to 130 kg / ha increased seed yield. Nitrogen utilization efficiency decreased with increasing application rate when winter oilseed rape plants used nitrogen applied in the fall to a lesser extent than in the spring. In order to achieve high yields, it was necessary for the above-ground mass of plants to absorb nitrogen at the level of at least 10-15 kg / ha at the end of the autumn vegetation. From an ecological point of view, the optimal autumn development of plants should be achieved by choosing an adequate sowing date, rather than using additional nitrogen in the fall.

Keywords: winter rape, seed yield, sowing period, nitrogen fertilizers, nitrogen absorption in autumn, nitrogen efficiency.

Table. 4, lit. 12.

Formulation of the problem. Winter oilseed rape is one of the most important oilseeds grown in temperate climates. From year to year it is not losing popularity as a source of high quality vegetable oil in the world and Ukrainian market. Therefore, the implementation of new research to improve the elements of technology for growing winter oilseed rape does not lose its relevance. At the same time, in the conditions of the Right-Bank Forest-Steppe, due to soil-climatic and agrotechnical features, there is an unlimited reserve for improvement and search of ways that will fully realize the biological potential of modern winter rape hybrids. Which, in turn, once again outlines the problems of selection and search for favorable sowing dates (in the context of modern climate change) and the level of mineral nutrition.

Analysis of recent research and publications. The best precursors for winter rape are perennial legumes, because they help to destroy weeds, create a good soil structure, clear the field early, but in modern farming conditions are often the predecessors of winter cereals, which causes delayed sowing of winter rape due to late harvesting winter wheat. Lutman and Dixon [1] and Silling et al. [2] observed a decrease in autumn-winter plant development due to delayed sowing of the crop, especially if it was later than September 10, increasing the risk of death in winter [3–5]. While Lutheman and Dixon [1] noted only insignificant indicators of reduced yields, Uzan et al. [6] reported a decrease in the yield of winter rapeseed with a delay in sowing due to a reduction in the length of the growing season and, consequently, the potential period of grain filling. Also Scott et al. [7, 8] noted large yield losses if sowing took place after mid-September.

Materials and methods. The study of the influence of sowing time and application of nitrogen fertilizers on seed yield and efficiency of nitrogen use by winter rape plants was carried out in the experimental field of VNAU, located in the village of Agronomic. The soil of the experimental plot is favorable for the use of mechanized tillage, sowing and harvesting of crops, namely it is characterized by the following agrochemical parameters: the humus content in the arable layer (according to Tyurin) is 2.16%, the soil solution reaction - pH of salt extract 5.6- 5.8, hydrolytic acidity - 2.3-2.7 mg. - eq. per 100 g of soil, the amount of absorbed bases 15 mg. - eq. per 100 g of soil, the degree of saturation of the bases - 79-88%. The soils contain nitrogen available to plants (according to Cornfield) 81-89 mg per 1 kg of soil, mobile phosphorus and exchangeable potassium (according to Chirikov) 205-251 and 83-90 mg per 1 kg of soil, respectively.

The area of the accounting area is 50 m2; repetition in the experiment three times; placement of options is systematic in one tier. The agro-technological measures carried out, in addition to those studied in the experiment, are recommended for the growing area [9].

Establishment and conduct of experiments, key observations and records were carried out according to the "Methods of field experiment" B. O. Dospekhov [10].

To solve the set tasks, a combination of four sowing dates (from the first week of August to the third week of September) and four autumn nitrogen applications (0, 30, 60 and 90 kg / ha per year) was fixed. In each of these 16 variants, nitrogen was applied 5 times in the spring (0/0, 40/40, 80/80, 120/120, 140/140 kg / ha, etc.) in order to estimate the individual nitrogen response curves.

Results. The concept of the study was to increase the seeding rate at a late sowing date, to compensate for the decrease in seed germination in such a way as to combine both studied factors [11, 12]. However, given the average value for three years, the plant density was quite the same for all sowing dates, ranging from 37 to 47 plants / m2 at the end of autumn development and from 36 to 40 plants / m2 at the beginning of spring growth, so it is not little effect, and no significant interaction between sowing date and plant density, was observed.

According to the results of our research, it was found that sowing of winter rape in September leads to a significant decrease in yield ($p < 0.05$) (Table 1). The yield obtained for sowing in the first and third weeks of August was at the level of 5 t / ha, for sowing in the first and third weeks of September there was a decrease in yield by 0.3 and 1.2 t / ha, respectively. Application of nitrogen fertilizers in autumn significantly increased seed yield by 0.6 t / ha, compared to the options without fertilization, and fertilization at a dose of 90 kg / ha of nitrogen. The interaction between sowing time and nitrogen application in autumn was not significant at $p = 0.05$.

Table 1

Influence of sowing period and application of nitrogen fertilizers in autumn on yield of winter rapeseed, t / ha (average for 2016-2019)

Sowing time	Nitrogen fertilizer rates applied in autumn after sowing				
	0	30	60	90	Average sowing time, t / ha
Yield, t / ha					
First week of August	4,72	4,87	5,02	5,12	4,93
Third week of August	4,74	4,94	5,16	5,18	5,01
First week of September	4,05	4,74	4,86	4,98	4,66
Third week of September	3,42	3,71	3,84	4,06	3,76
Average fertilizer rate, t / ha	4,23	4,56	4,72	4,83	-

Source: made by the author on the basis of own research

The application of nitrogen fertilizers in the spring to fertilization increased yields (for evaluation of the model parameters, see Table 2). However, nitrogen doses exceeding 116-136 kg / ha, depending on the sowing period, did not provide a further increase in yield. Comparison of functional parameters showed that the sowing period affected the yield level only to a certain extent (to a state of insignificant or no changes after the period of exposure, activity or progress) in the range from 4.23 t / ha for sowing in the third week of September to 5, 56 t / ha for sowing in the third week of August. In contrast, the nitrogen application rate at the intersection of the linear model and the yield plateau (Nopt), as well as the linear slope remained unchanged (Table 2), indicating that the interaction between sowing dates and spring fertilization was insignificant.

A similar pattern occurred when comparing the effects of spring fertilization at different doses of nitrogen in the fall (to assess the parameters of the model, see Table 2). The application of nitrogen fertilizers in autumn provided an increase in yield from 4.48 t / ha in the unfertilized version of the control to 5.12; 5.20 and 5.32 t / ha in variants with application of 30, 60 and 90 kg / ha of nitrogen, respectively.

A similar trend was observed in the study of nitrogen uptake by seeds. Delay in sowing led to a decrease in nitrogen uptake by seeds ranging from 112 kg / ha a. s. for sowing the crop at the latest to 141 kg / ha a. s. for sowing in the third week of August. The application of an additional 30 kg / ha of nitrogen in the autumn increased nitrogen uptake by 9 kg / ha, thus leaving 21 kg / ha of nitrogen (= 70% of the applied amount) in the system (Table 3). A further increase in the autumn application rates to 60 and 90 kg / ha of nitrogen per year increased nitrogen uptake by 14 and 18 kg / ha, thus increasing the excess nitrogen to 46 (77%) and 72 kg / ha (80%), respectively.

Table 2

Calculated parameters of the linear plateau principle model that quantify the relationship between the application of nitrogen fertilizers after sowing winter oilseed rape and seed yield

Sowing time	Nitrogen fertilizer rates applied in autumn after sowing	n	R^2	Plateau*	N_{opt}*1	difference
Yield, t / ha						
1st week of August		240	0,65	5,47	$117,7^{ns}$	$0,0172^{ns}$
3rd week of August		239	0,66	5,56	$125,2^{ns}$	$0,0162^{ns}$
1st week of September		240	0,49	5,22	$136,2^{ns}$	$0,0147^{ns}$
3rd week of September		240	0,27	4,23	$116,4^{ns}$	$0,0153^{ns}$
Yield, t / ha						
	N_0	240	0,41	4,48	$121,4^{ns}$	$0,0185^{ns}$
	N_{30}	240	0,44	5,12	$127,3^{ns}$	$0,0159^{ns}$

	N_{60}	239	0,39	5,20	$119,1^{ns}$	$0,0152^{ns}$
	N_{90}	240	0,41	5,32	$127,7^{ns}$	$0,0138^{ns}$

** Plateau - plateau level of yield and nitrogen absorption, respectively; * [1]Nopt - rate of nitrogen fertilizer and nitrogen uptake at the end of autumn vegetation, respectively at the intersection of the linear model and the plateau (i.e. the minimum amount of nitrogen required to obtain maximum yield).*

Source: made by the author on the basis of own research

Table 3

Influence of interaction of sowing term and applied nitrogen fertilizers in autumn on nitrogen removal with harvest of winter rapeseed, (kg / ha) (average for 2016-2019)

Sowing time	Nitrogen fertilizer rates applied in autumn after sowing				
	0	30	60	90	Average sowing time, t / ha
Uptake of nitrogen by crop yield, kg / ha					
1st week of August	133	156	140	143	138
3rd week of August	134	138	145	146	141
1st week of September	116	136	140	143	133
3rd week of September	100	110	114	123	112
Average fertilizer rate, t / ha	121	130	135	139	-

Source: made by the author on the basis of own research

As spring nitrogen fertilization increased not only seed yield but also nitrogen concentration (data not shown), the nitrogen rate required to achieve maximum yield (Nopt) was higher for nitrogen uptake (160–195 kg / ha) than for seed yield. (about 116–136 kg / ha) at all sowing dates. In addition, the linear deviation decreased with sowing delay.

In combination with spring nitrogen application, its autumn application was positively correlated only with the plateau level from 149 to 166 kg / ha, while Nopt and deviations were similar. Autumn application of nitrogen fertilizers did not affect the concentration of nitrogen in the seeds; as a result, the increase in nitrogen uptake was mainly due to higher seed yields.

The concentration of oil in the seeds was the highest during the first sowing dates, and decreased with a delay in sowing. Fertilization led to a decrease in the concentration (content) of oil, while the application of nitrogen fertilizers after sowing did not affect this figure. The deviation reached the highest level for sowing in August, as a result of which the formation of indicators of quantitative oil content was similar to the formation of seed yield with a significant impact on this indicator of sowing (2.17; 2.19; 2.03 and 1.61 t / ha per first, second, third and fourth sowing dates, respectively), for the application of nitrogen fertilizers after sowing in autumn - 1.84; 1.99; 2.06 and 2.10 t / ha when applying N_0; N_{30}; N_{60} and N_{90}, respectively, and when applying fertilizers - 1.44; 1.99; 2.20; 2.18 and 2.18 t / ha at a dose of N_0, N_{80}, N_{160}, N_{240}, N_{280}, respectively. No significant interactions were noted.

The obvious efficiency of nitrogen utilization outlines the additional nitrogen uptake by seeds due to fertilization in relation to the corresponding amount of nitrogen applied.

Since there was no significant interaction between nitrogen application in autumn and spring, the efficiency of autumn application was presented on the basis of the average value of spring fertilization and vice versa (table 4).

Table 4

Influence of interaction of sowing term and nitrogen fertilizers on efficiency of use of nitrogen by plants of winter rape (%) (average for 2016-2019)

Sowing time					
Nitrogen fertilizer rates applied in autumn after sowing	1st week of August	3rd week of August	1st week of September	3rd week of September	average
N_0	-	-	-	-	-
N_{30}	8,4	13,0	44,4	32,6	24,6
N_{60}	14,0	18,5	40,0	22,5	23,7
N_{90}	11,1	13,2	30,3	25,0	19,9
average	11,1	14,9	38,2	26,7	-
Doses of fertilization with nitrogen fertilizers					
N_0	-	-	-	-	-
N_{80}	53,1	47,8	41,3	41,9	46,0
N_{160}	47,0	43,6	42,6	34,3	41,9
N_{240}	35,9	35,1	31,6	26,2	32,2
N_{280}	31,9	31,5	28,1	22,1	28,4
average	42,0	39,5	35,9	31,1	-

Source: made by the author on the basis of own research

The efficiency of nitrogen application from autumn application decreased with an increase in the amount of nitrogen from 25% with application of 30 kg / ha to 20% in areas that received 90 kg / ha; however, this decrease was not significant at p = 0.05. The sowing period significantly affected the efficiency of nitrogen use, showing the lowest rate - 11% for sowing in the first week of August, the highest - 38% for sowing in the first week of September. At the same time, early crops used more nitrogen applied in the spring, compared to late crops. Increasing the dose of spring fertilizers significantly reduced the efficiency of nitrogen use from 46% (80 kg / ha) to 28% (280 kg / ha).

Seed oil concentration was highest at early sowing and fell if sowing was delayed. Likewise, spring N significantly decreased oil concentration while autumn N had no effects. The slope was steepest if plant establishment occurred in August. In consequence, oil yield showed a similar pattern as seed yield with significant effects of sowing method (2.17, 2.19, 2.03, and 1.61 t / 1 in SD 1, SD 2, SD 3, and SD 4, respectively), autumn N (1.84, 1.99, 2.06, and 2.10 tha / 1 in the 0, 30, 60, and 90 kg N / ha treatment, respectively) and spring N application (1.44, 1.99, 2.20, 2.18, and 2.18 t / ha in the 0, 80, 160, 240, and 280 kg N / ha treatment, respectively). No significant interactions were observed.

The experimental conditions allowed studying the influence of sowing period, autumn and spring application of nitrogen fertilizers and their interaction on the yield of winter rapeseed and the ability of seeds to absorb nitrogen. The results confirmed the current recommendation that under the climatic conditions of the Right Bank Forest-Steppe of Ukraine, winter oilseed rape should ideally be sown between mid and late August, while sowing after mid-September leads to a significant reduction in yield. It should be noted that under favorable weather conditions in spring, winter rapeseed, sown in the third week of September, yielded more than 5 t / ha, but as long-term weather forecasts are currently unavailable, there is a risk of reduced yields by shifting sowing to late September.

In combination with late sowing in production conditions, additional nitrogen is often used in autumn to ensure adequate development of winter rape plants before winter. According to the obtained data, there was no significant interaction between the sowing period and nitrogen application in autumn, as well as spring fertilization for seed yield. However, the ways that allowed the autumn application of nitrogen to significantly increase the seed yield during the first sowing period require further research.

Conclusions. The presented results confirmed that sowing of winter rape from the third week of August to the first week of September is the optimal sowing period in the conditions of the Right-Bank Forest-Steppe of Ukraine. Even in variants where the plants have reached the optimal parameters for wintering, the application of nitrogen fertilizers after sowing provided an increase in seed yield. However, positive economic results should be considered from an environmental point of view, as the efficiency of nitrogen use in these options was characterized by lower rates, and the ways of nitrogen application in autumn to increase yields are still unclear. The minimum dose of nitrogen that was necessary to achieve high yields (in the absence of adverse conditions - severe frost in winter, drought in spring) was set at 10 kg / ha in a. s.

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