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EFFECT OF SEEDING RATE AND DOSES OF MINERAL FERTILIZERS APPLICATION ON YIELD AND GRAIN QUALITY OF WINTER RYE NEW HYBRID F1, NEMCHINOVSKY 1

Research article

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Abstract

The sod-podzolic soil conditions in the Moscow region, plant density, and application of mineral fertilizers are among the main factors affecting winter rye yield and grain quality. The aim of the research was to study the effect of seeding rate and doses of mineral fertilizer application on the yield and grain quality of winter rye hybrid F1. The experiments were conducted in the 2020 -2022 cropping seasons at the Federal Research Center (FRC) Nemchinovka experimental fields. The new winter rye hybrid F1, Nemchinovsky 1, and three seeding rates were studied: 1, 2, and 3 million germinating grains per ha was Factor A; 30, 60 and 90 kg/ha of different levels of mineral fertilizers was factor B; and the control (T0) $N_0P_0K_0$ (kg ha^{-1}), (T1) $N_{90}P_{60}K_{90}$ (kg ha^{-1}), (T2) $N_{120}P_{90}K_{120}$ (kg ha^{-1}) and (T3) $N_{150}P_{120}K_{180}$ (kg ha^{-1}). The result shows that increasing fertilizer dose at all seeding rates increased winter rye yield. On average, NPK doses with a seeding rate of 2 million germinating grains/ha showed a better growth rate of 0.24 t/ha than the variants where 1 million germinating grains/ha were applied. In the 3 million germinating grains/ha variants, the 2 million germinating grains/ha, the growth rate was 0.19 t/ha.

Keywords: winter rye, variety, technology, yield, and efficiency.

ВЛИЯНИЕ НОРМЫ ВЫСЕВА И ДОЗ ПРИМЕНЕНИЯ МИНЕРАЛЬНЫХ УДОБРЕНИЙ НА УРОЖАЙ И КАЧЕСТВО ЗЕРНА ОЗИМОЙ РЖИ НОВОГО ГИБРИДА F1 НЕМЧИНОВСКИЙ 1

Научная статья

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Аннотация

В условиях дерново-подзолистых почв густота растения и применение минеральных удобрений – одни из основных факторов, влияющих на урожайность и качества зерна. Цель исследований было изучение влияния нормы высева и доз применения минеральных удобрений на урожай и качество зерна гибрида озимой ржи. Исследования были праведны в 2020-2022 гг. на опытных полях «ФИЦ «Немчиновка». В опыте на новом гибриде F1 Немчиновский 1 изучали три нормы высева: 1, 2 и 3 млн. всхожих зерен на га, или 30, 60 и 90 кг/га (фактор А) при различном уровне минеральных удобрений (фактор В): контроль (Т0) $N_0P_0K_0$ (kg ha^{-1}), (Т1) $N_{90}P_{60}K_{90}$ (kg ha^{-1}), (Т2) $N_{120}P_{90}K_{120}$ (kg ha^{-1}) и (Т3) $N_{150}P_{120}K_{180}$ (kg ha^{-1}). При всех нормах высева увеличение дозы удобрений повышало урожайность озимой ржи. В среднем по дозам NPK в вариантах с нормой высева 2 млн. всх. зерен/га рост составлял 0,24 т/га в сравнении с вариантами, где применили 1 млн. всх. зерен/га. В вариантах 3 млн. всх. зерен/га прирост к норме 2 млн. всх. зерен/га получен 0,19 т/га.

Ключевые слова: озимая рожь, сорт, технология, урожайность, эффективность.

Introduction

Implementing sustainable food systems that promote healthy lifestyle and a varied diet is one of the most pressing issues in the global community; therefore, winter rye plays an important role in the food system. Rye (*Secale cereale* L.) is a hardy biennial herbaceous plant of the Poaceae family (grasses) that grows very easily, particularly in cold, poor soils. In terms of production, Germany, Poland, Russia, Belarus, Denmark, Ukraine and China are the world's leading rye producers, contributing 3,325.6 thousand metric tons, followed by 2,472.8 thousand metric tons, 1,721.9 thousand metric tons, 845 thousand metric tons, 672.4 thousand metric tons, 593.1 thousand metric tons and 512.2 thousand metric tons in 2021 (https://rosstat.gov.ru/). According to Rosstat, rye crops for the 2021 harvest amounted to 1.05 million hectares against 987.2 thousand hectares a year earlier, while winter rye accounted for 95.5% of all crops, and spring rye – 0.5% in Russia (https://rosstat.gov.ru/). Winter rye is an important food and fodder crop. Rye flour is used for baking various types of bread (Borodino, Riga, peeled, etc.). Whole and crushed rye grain (turf, fodder flour), bran, and straw are used for livestock feed.

Rye bread, especially with simple grinding, significantly exceeds wheat bread in terms of calories but is inferior to it in digestibility; in addition, it contains vitamins A, B, PP, and C, which makes it very valuable in human nutrition [1], [2], [3].

Hybrid rye is a precious resource in terms of producing quality rye bread. It has an optimal combination of high yield and extreme adaptability to external conditions; the average level of heterosis is 14-15%. The effect of heterosis on grain productivity is due to increased productive tillering, the formation of a denser productive stem, and a higher grain content of the ear [4], [5], [6]. Hybrid rye gives a high yield with lower costs for protection products and mineral fertilizers. Therefore, there are similar trends in Russia: the cultivation areas of various hybrids of this crop are increasing annually against the background of a reduction in the sown areas of population varieties of rye.

The results of studies conducted in different regions of the country show that the productivity of rye largely depends on the elements of cultivation technology, primarily on seeding rates, sowing dates, and doses of mineral fertilizers [1], [7], [8]. There is no consensus on these issues in the scientific literature. Some researchers stated that the best grain yield results on more fertile soils are achieved at higher seeding rates and on poor soils at lower ones. In addition, with the high price of mineral fertilizers, it is of particular importance to find the optimal doses and methods of their application to obtain the maximum effect, rational use, the potential of plants, and available resources [9], [10], [11]. Therefore, the research aimed to study the effect of the seeding rate and doses of mineral fertilizers on the yield and grain quality of winter rye hybrid in the Moscow region.

Materials and Methods

2.1. Experimental site

Soil of experimental site is soil-podzolic medium loamy. Field experiments on the varietal agrotechnics of winter grain crops were conducted in field No. 5 of the five-field crop rotation. The soil is characterized by a strongly acidic to moderately acidic reaction in the soil medium (pH 4.3–4.7). The content of mobile phosphorus remains at a high level (155–195 mg/kg), and the content of mobile potassium is high (157–181 mg/kg) (Table 1).

Table 1 - Agrochemical parameters of sod-podzolic medium loamy soil

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pH_{kcl}	Hr, mg-eq per 100 g of soil	P_2O_5	K_2O	Ca^{+2}	Mg^{+2}
		mg/kg		mmol per 100 g of soil	
4,3÷4,7	3,49÷4,61	155÷195	157÷181	6,53÷7,23	1,39÷2,33

2.2. Site weather conditions during the trial period 2020-2022

The weather conditions during the experimental period 2020-2022 for winter Hybrid rye plants were generally favorable (Fig.1). The hydrothermal coefficient was 2.79 in 2020-2021 and 1.52 in 2021-2022. The sugar content in the tillering node was 20 to 23%. An increase in temperature was observed. However, the average ambient temperature in the research years was higher than in previous years. Snow cover was established in January 2020-2021 and December 2021-2022 with mean daily air temperatures of -4.3 and -0.2 °C, respectively. The soil temperature at the tillering nodes was close to zero. The winter months (January and February) were snowy, with 63.5 mm of snowfall in 2020-2021 and 114.2 mm in 2021-2022, higher than the long-term average by 1.3 mm and 52 mm, respectively. Particularly in terms of the amount of rainfall during the spring-summer growing season, from May to July (123-150 mm) was noted, exceeding the average annual values by almost two times in 2020-2022.

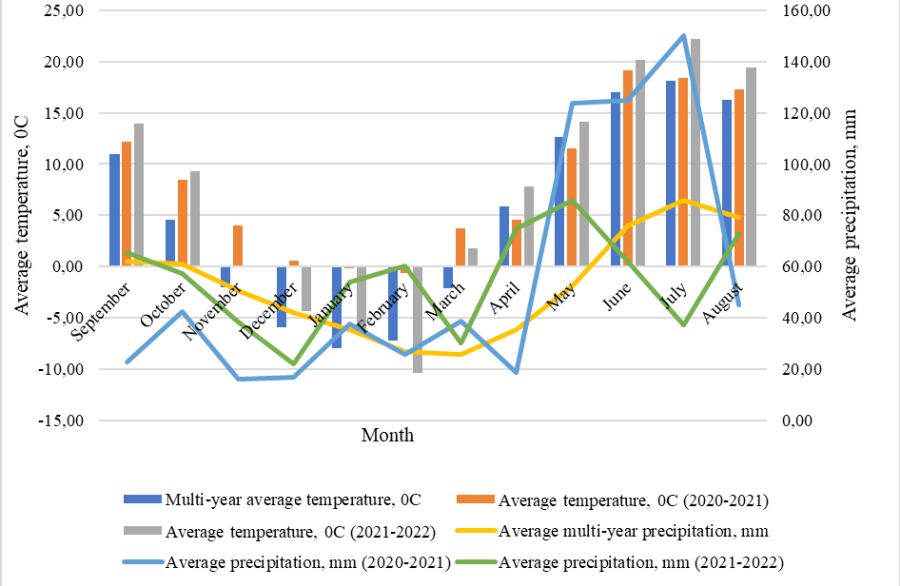

Figure 1 - Weather conditions in 2020-2022
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Note: Nemchinovka weather station

Monthly rainfall in April was 18.6 mm, almost two times less than the average annual values. The first 10 days of May, the 20-day and 30-day periods of June, as well as the first 10 days of July, were characterized by higher values of mean daily air temperature compared with the long-term average (Figure 2). Monthly rainfall in April was 74.6 and 18.5 mm, in May – 123.8 and 85.7 mm in 2020-2021 and 2021-2022, respectively. When air temperatures were high in June and July, precipitation was less than the average annual values. The hydrothermal coefficient for the spring-summer period was 2.35 in 2020-2021 and 1.36 in 2021-2022.

2.3. Experimental Design

The experiments were carried out in 2020-2022 on the experimental fields of the Federal Research Center Nemchinovka. The soil of the experimental plots is loamy, characterized by low natural fertility with a humus content of 2.0 to 2.5%. The soil PH ranges between 4.0 to 5.0. The experiment was carried out according to a two-factor scheme.

The experiment was carried out according to a two-factor scheme [12], [13]. In the experiment on the new hybrid F1 Nemchinovsky 1, three seeding rates were studied: 1, 2 and 3 million germinating grains per ha, or 30, 60 and 90 kg/ha (factor A), different application level of mineral fertilizers (factor B), and control (T0) 0 NPK, (T1) N90P60K90 (N30P60K90 – main application, N60 – in spring to tillering), (T2) N120P90K120 (N30P90K120 – main application, N60 in spring to tillering and N30 in the booting phase) and (T3) N150P120K180 (N30P120K180 is the main application, N60 in the spring in tillering, N30 in the booting stage, N30 in heading). Varieties of winter crops are sown on the predecessor of annual grasses. To protect plants from weeds, diseases and pests, pesticides were used: fungicide Impact Super, SC 0.5 kg/ha (225 g/l Tebuconazole + 75 g/l Flutriafol), herbicide Lintur, VDG 180 g/ha (659 g/kg Dicamba acid + 41 g/kg triasulfuron) and insecticide Danadim, EC 1 l/ha (Dimethoate 400 g/l).

Spraying of crops was carried out by "Amazone US - 605". Varieties of winter crops were sown according to the predecessor of annual grasses on September 07 (field No. 5). The total experimental Field area was 1.5 ha, out of which 1.2 ha was utilized for cultivation. The total size of the plot for each technology was 40 m^2, and the accounting area was 10 m^2. All treatments were replicated four times.

After harvesting the predecessor, the soil was tilled twice by disked Katros. Then fertilizers were applied, the soil was cultivated, and after 14 days, cultivation was carried out using an Amazone seeder. Harvesting was done by combining "Sampo-500".

2.4. Observations, sampling, and data analysis

The crude protein content was also determined in the laboratory according to the traditional Kjeldahl method (Nx6.25), and the grain gluten content was determined according to [12], [13].

Statistical processing of the research results was performed according to Dospekhov (1985) in the computer version of "AGROS" 2.07 [15].

Main results

3.1. Yield of F1 hybrid of winter rye Nemchinovsky 1 at different fertilizer doses and seeding rates (2020-2022)

The research's relevance was to optimize hybrids' plant nutrition forms, and to realize their biological productivity potential. Therefore, three seeding rates were studied in the experiment on F1 hybrid Nemchinovsky 1: 1, 2, and 3 million germinating grains per hectare, or 30, 60, and 90 kg/ha. The yield of winter rye and other crops largely depends on the number of plants per unit area. Studies have shown that increasing the seeding rate from 1 to 3 million germinating grains per hectare under this year's conditions increased grain yield per hectare. These data agree with those of López Córdova et al. (2019),

Popov et al. (2019), and Shishkov et al. (2023). According to Popov et al. (2019) under 2019 conditions, the yields ranged from 2.65 t/ha in the control to 7.08 t/ha when the maximum dose of N150P150K150 was applied, in 2018, respectively, from 1.01 to 4.81 t/ha, which is 1.5-2.6 times less. In average NPK doses, in variants with a seeding rate of 2 million germinating grains/ha, the increase was 0.24 t/ha compared to variants where 1 million germinating grains/ha were applied. For the 3 million germinating grains/ha variants, the 2 million germinating grains/ha growth rate was obtained at 0.19 t/ha (Table 2). Thus, yield increased in the growing seasons of 2020-2022, with an increasing seeding rate of F1 hybrid Nemchinovsky 1. Hybrids of winter rye are characterized by short-stemmed, resistant to lodging, increased ear fineness, form a denser stalk by the time of harvesting, which provides, with strict adherence to cultivation technology, an increase in yield by 12-20% compared to population varieties [17]. The low production of the control soils can be attributed to factors characteristic of acid soils: acid pH, Al and Mg toxicity, nutrient deficiencies (Ca, Mg, P, K, B and Zn) [18]. In addition, on control plots, the absence of organic inputs is accompanied by a loss of organic matter and nutrients, soil acidification, reduced biomass and microbial activity, and phosphorus insolubilization, all of which lead to a significant drop in crop yields.

Table 2 - Yield of F1 hybrid of winter rye Nemchinovsky 1 under different conditions and seeding rates

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Fertilizer dose (factos A)	Seeding rate (factor B)			average (A)	Profit	
	1 million. germinating grains per ha	2 million. germinating grains per ha	3 million. germinating grains per ha		т/ha	%
T0	4,82	4,91	5,04	4,92	–	–
T1	4,88	5,06	5,25	5,06	0,14	3
T2	6,13	6,58	6,71	6,27	1,35 1,21	27 24
T3	7,38	7,64	7,92	7,35	2,42 2,29	49 45
average (B)	5,68	5,92	6,11	HCP_{05} =0,12 т/га		
	NCR_{05} =0,14 т/га					
NCSR05 in the experiment = 0.24 t/ha						

Note: 2020-2022

3.2. Crude protein content and fodder productivity of F1 hybrid of winter rye Nemchinovsky 1 (2020-2022)

With increasing intensity of cultivation of winter rye varieties gives a clear tendency to increase nitrogen consumption by plants, and its accumulation in the grain was observed. The crude protein content in the grain as a qualitative indicator of the baking quality for the industries also increased. Application of a large dose of NPK increased the collection of crude protein on hybrid F1 Nemchinovsky 1 by seeding rates – 62-76% (Table 3). These data are consistent with the data of López Córdova et al. (2019) in which the maximum content (16.5%) of protein was observed at a dose of 150 kg/ha, the minimum content of grain protein (14.78%) – at a dose of 0 kg/ha. Application of fertilizers in doses of N30P30K30, N120P120K120 and N150P150K150 provided a second quality class in terms of crude protein content in winter rye grain [11]. A similar regularity is traced by varieties and technologies on the yield of fodder units of the main production of winter rye. On the other hand, while it does take into account the cost of fertilizers, the optimal dose approach does not take into account the impact of NPK fertilization on crop quality and the costs associated with spreading NPK fertilizers, fungicides and growth regulators, nor the effects of nitrogen dose splitting on yield [16].

Thus, the application of all agro-technological methods of cultivation of winter rye, rational use of mineral fertilizers and nitrogen fertilizers with the involvement of methods of soil and plant nutrition diagnostics, and the different use of plant protection techniques are the decisive factors in increasing the yield and protein content of rye grain products.

Table 3 - Crude protein content and fodder productivity F1 hybrid of winter rye Nemchinovsky 1

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Seeding rate (factor B)	Fertilizer dose (factos A)	Crude protein %	Crude protein yield, kg/ha	+/- to control kg/ha %	Quantitative unit of crude protein yield t/ha	+/- to control	
				+/- to control kg/ha %		Quantitative unit t/ha	%
1 million. germinati	T0	12,9	621	–	5,69	–	–
	T1	13,3	647	26/4	5,76	0,07	1

ng grains	T2	14,7	871	224/36	7,00	1,31	23
	T3	14,2	1004	383/62	8,35	2,67	47
2 million. germinating grains per ha	T0	12,4	610	–	5,79	–	–
	T1	12,9	651	41/7	5,96	0,17	3
	T2	14,0	893	283/46	7,52	1,73	30
	T3	14,1	1032	422/69	8,66	2,87	50
3million. germinating grains per ha	T0	12,1	608	–	5,95	–	–
	T1	12,1	633	25/4	6,19	0,24	4
	T2	14,6	952	344/57	7,68	1,73	29
	T3	14,1	1071	463/76	8,99	3,04	51
NCR05 by experience			32,4		0,29		
NCR05 by factor A			16,3		0,15		
NCR05 by factor B			18,9		0,17		

Note: 2020-2022

Conclusion

Thus, farms in the Moscow region can obtain the planned yield level, providing the region's internal needs in fodder and food grain of winter rye. According to our results, the higher the plant density and dose of mineral fertilizers, the higher the yield. Under the conditions of the year, the increase in seeding rate of F1 hybrid Nemchinovsky 1 from 1 to 3 million germinated grains per ha provided an increase in yield by 7-10%. At (T3) N150P120K180 (kg ha^{-1}) grain yield per hectare increased by 49% to the control (extensive technology) and amounted to 7.9 t/ha at a seeding rate of 3 million germinating grains per hectare. The accumulation of crude protein in grain varied by varieties from 11 to 15%. Therefore, future research is recommended to establish the best option.

Конфликт интересов

Не указан.

Рецензия

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Conflict of Interest

None declared.

Review

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