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Winter rye yield depending on seeding rates and precursors in the Central Non-Chernozem Region

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Abstract

Background. The use of well-designed agrotechnical methods allows you to harvest winter rye, regardless of weather conditions, with minimal resource and labor costs. In addition, the correct choice of precursors and moisture standards on grain crops increases the efficiency of crop development, optimizes the area of nutrition and solar insolation, resistance to pests and diseases. The effectiveness of the choice of technology elements directly depends on the analysis of their application, depending on the requirements of agricultural technology, crop varieties, as well as the level of soil fertility. The issue of increasing the productivity of winter rye in the Central Non-Chernozem region, through the development and improvement of technology elements with subsequent introduction into agricultural production aimed at increasing the production of high-quality grain crops, is undoubtedly an urgent, important and promising area, which determined the implementation of these studies.

The **purpose** is to determine the efficiency of growing and productivity of winter rye depending on the complex action of precursors and the seeding rate in the Central Non-Chernozem region.

Materials and methods. The research was carried out in the period 2021-2024 in the conditions of the Domodedovo district of the Moscow region. Three variants of the precursor were studied: winter wheat (control), peas for grain, spring rapeseed and five variants of crop seeding rates. The dynamics of the development of winter rye plants against the background of the use of various precursors and seeding rates is determined; the crop structure, yield and quality indicators are determined depending on the factors studied; the economic efficiency of the proposed elements of winter rye cultivation

technology is revealed. All the studies were conducted according to generally accepted methods and the methodology of field work as described by B.A. Dospekhov.

Results. The conducted studies have shown high efficiency of placing winter rye crops after leguminous crops, especially peas for grain, as precursors. The optimal seeding rate for winter rye is 3.5–4.0 million seeds per hectare, which ensures consistently high yields. The use of appropriate agrotechnical measures contributes to the achievement of high and reliable grain harvest rates — from 50.1 to 56.5 quintals per hectare, depending on the weather conditions of a particular season. The average yield was 5.29 t/ha with 3.5 million seeds per hectare and 5.35 t/ha with an increase in crop density to 4.0 million seeds per hectare. The results obtained are recommended for practical implementation in order to increase the productivity of winter crops and optimize production costs.

Keywords: winter rye; precursor; seeding rate; grain yield; Non-Chernozem zone

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Урожайность озимой ржи в зависимости от норм посева и предшественников в Центральном Нечерноземье

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Аннотация

Обоснование. Применение правильно выстроенных агротехнических методов позволяет получать урожай озимой ржи, не зависимо от погодных условий, с минимальными затратами ресурсов и труда. Кроме этого, правильный выбор предшественников и норм посева на зерновых культурах повышает эффективность развития культуры, оптимизирует площадь питания и солнечной инсоляции, резистентность к вредителям и болезням. Эффективность выбора элементов технологии напрямую зависит от анализа их применения в зависимости от требований агротехнологии, сортов культуры, а также уровня плодородия почвы. Вопрос повышения продуктивности озимой ржи в Центральном Нечерноземье, за счет разработки и совершенство-

вания элементов технологии с последующим внедрением в сельскохозяйственное производство, нацеленное на увеличение получения зерна культуры высокого качества, является, несомненно, актуальным, важным и перспективным направлением, что и определило выполнение настоящих исследований.

Цель – определить эффективность выращивания и продуктивность озимой ржи в зависимости от комплексного действия предшественников и нормы высева в Центральном Нечерноземье.

Материалы и методы. Исследования выполнены в период 2021-2024 годы в условиях Домодедовского района Московская область. Изучено три варианта предшественника: озимая пшеница (контроль), горох на зерно, рапс яровой и пять вариантов норм высева культуры. Определена динамика развития растений озимой ржи на фоне использования различных предшественников и норм высева; определена структура урожая, урожайность и качественные показатели в зависимости от изучаемых факторов; выявить экономическая эффективность предлагаемых элементов технологии выращивания озимой ржи. Все исследования проведены согласно общепринятым методикам, и методике полевого дела в изложении Б.А. Доспехова.

Результаты. Проведенные исследования показали высокую эффективность размещения посевов озимой ржи после зернобобовых культур, особенно гороха на зерно, в качестве предшественников. Оптимальная норма высева озимой ржи составляет 3,5–4,0 млн семян на гектар, что обеспечивает стабильно высокий уровень урожайности. Применение соответствующих агротехнических мероприятий способствует достижению высоких и надежных показателей сбора зерна – от 50,1 до 56,5 центнеров с гектара, в зависимости от погодных условий конкретного сезона. Средний показатель урожайности составил 52,9 ц/га при посеве 3,5 млн семян на гектар и 53,5 ц/га при увеличении плотности посева до 4,0 млн семян на гектар. Полученные результаты рекомендуются для практического внедрения с целью повышения продуктивности озимых культур и оптимизации производственных затрат.

Ключевые слова: озимая рожь; предшественник; норма высева; урожайность зерна; Нечерноземная зона

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Introduction

Despite the advantages of winter rye in terms of its economic, morphological, and biological characteristics, there has been a decline in the area sown with this crop in the Russian Federation [1]. At the end of the last century, winter rye

occupied 12-15 million hectares in some years, with the main areas concentrated in the Non-Chernozem, Central Black Earth, and Volga regions. Currently, crops in Russia cover less than 1 million hectares (in 2023, 830 thousand hectares). According to data from regional ministries, in 2024, less than 5,000 hectares were allocated for winter rye in the Moscow region and about 9,000 hectares in the Ryazan region, which is insufficient for this crop and commercial demand for it.

The capacity of winter rye is more stable than that of other crops, especially cereals in the region. Analyzing data on winter rye yields over the past decade in the Non-Chernozem region, we note that yields are still insufficiently high at 2,5-3,5 t/ha, which can be explained by significant direct violations in grain crop production technology.

Choosing a precursor for winter cereals, including winter rye, is a very challenging task in modern crop production. An essential condition for obtaining high yields of winter rye is its placement in crop rotation after the best precursors, which are largely determined by the timing of harvesting, the amount of organic matter left behind, and the phytosanitary background [3; 6; 7]. For the conditions of the Central Non-Chernozem regions, it is recommended to harvest early-maturing crops, such as winter crops for green-cut fodder and perennial grasses, plow to a normal depth, and then keep the soil loose and free of weeds until sowing. After legume-oat mixtures of peas, processing can be carried out in different ways: in wet years, plowing is advisable, in dry years, surface treatment is advisable. After late-harvested row crops, surface treatment should be used primarily [2; 4; 5; 8; 10; 16; 23].

In order to ensure high-quality soil cultivation in occupied fallow fields, it is very important to preserve moisture from excessive evaporation [9]. To this end, the period between the start of harvesting fallow-grown crops and soil cultivation should be as short as possible [13; 15; 17; 20]. Among the techniques that improve the quality of soil cultivation for winter crops in occupied fallow fields, increasing the speed of soil cultivation units deserves attention [11; 14]. Increasing the speed significantly improves soil crumbling, reduces ridging and fluffiness, and also shortens the time required to prepare the soil for sowing [12; 21].

Combined plowing units are crucial for processing after harvesting precursors. When processing with such units, a number of operations are overlapped, better soil cutting quality is ensured, and moisture losses are reduced [18; 19].

Combining proper soil preparation before sowing winter crops with the use of herbicides facilitates weed control in the future.

Measures to improve soil quality and achieve high yields of winter rye also include variety selection, fertilization, choosing the right sowing dates based on soil and climate conditions, and soil cultivation.

Therefore, the aim and objectives of the research were to determine the effectiveness of cultivation and capacity of winter rye depending on the combined effect of precursors and seeding rates in the Central Non-Chernozem Region.

Materials and methods

The research was conducted between 2021 and 2024 at the experimental field of the All-Russian Research Institute of Agrochemistry, Barybino micro-district, Domodedovo district, Moscow region.

Experimental design: factor A (previous crop in the crop rotation) – three variants: 1) winter wheat (control), 2) grain peas, 3) spring rapeseed; factor B (winter rye seeding rate) – five variants: 1) 2.5 million grains per 1 ha (control), 2) 3.0 million grains per 1 ha, 3) 3.5 million grains per 1 ha, 4) 4.0 million grains per 1 ha, and 5) 4.5 million grains per 1 ha.

Agrotechnical measures in the experiments are generally accepted for the central part of the Non-Chernozem zone. After harvesting the previous crop, disc harrowing to a depth of 12-14 cm; after 1.5 weeks, plowing to a depth of 18-20 cm; after 1 week, pre-sowing cultivation to a depth of 6-8 cm. Sowing is carried out using the continuous row method to a depth of 2-3 cm, with the seeding rate according to the scheme. Sowing time – first ten days of September. After sowing, rolling was carried out. Seed treatment immediately before sowing with Tercia, SC, 2.5 l/t, consumption 10 l/t. The protection system included the use of insecticide and fungicide treatments.

These field studies were conducted on sod-podzolic heavy loam soil of medium cultivation with the following agrochemical characteristics of the plow layer (0–20 cm): soil reaction: pH KCl – 5.46 (moderately acidic); N-NO₃ – 9.6 mg/kg; N-NH₄ – 1.9 mg/kg (low); P₂O₅ – 160 mg/kg (elevated); K₂O – 173 mg/kg (elevated); humus – 2.0–2.2% (low).

The climate of the area is temperate continental. The growing season of 2021/2022 was warm with above-average air temperatures in all months except September and May, and wet in all months except October, March, and June (hydrothermal index of the growing season was 2.71). The growing season of 2022/2023 was relatively warm, with autumn and winter temperatures exceeding the long-term average and close to normal in the spring and summer. Autumn was extremely wet, with a dry August; dry April and moisture deficit in May (hydrothermal index 2.16). The growing season of 2023/2024 was closest to the long-term average, with a very warm and dry September and an excessively wet spring and summer (hydrothermal index 1.76).

Results and discussion

The studies highlight the effect of precursor factors and seeding rates on the overwintering and survival rates of winter rye plants. In different years, the overwintering rate of winter rye ranged from 79.6% to 80.6% and averaged 80.0%, exceeding the control (previous winter wheat) by 2.2 to 3.0 (2.8–3.9%) at LSD_{05} by factor A, which was in the range of 0.48–0.49 and thus determined a significant difference (Fig. 1).

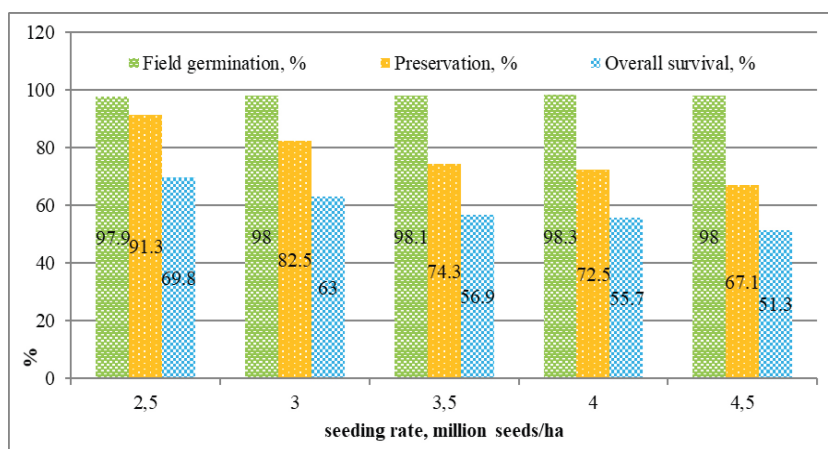


Fig. 1. Field germination, preservation, and overall survival rates depending on factors (example: precursor – winter wheat)

The previous spring rapeseed crop had a significant impact on the overwintering of winter rye, but not in all years, only in 2022 by 0.9 (1.2%) and in 2023 by 1.0 (1.3%). In 2024, the difference between the variant and the control was insignificant, at 0.2 (0.3%). The differences in winter rye overwintering according to the seeding rate factor between all variants and the control did not exceed 1.0% in all years of the study. At LSD_{05} by factor B ranging from 0.61 to 0.63% in different years, the overwintering index significantly exceeded the control (seeding rate of 2.5 million grains per 1 ha) with a difference of 0.7–0.8% only for variants with a seeding rate of 3.5 million grains per 1 ha in 2022 and 2024 and a variant with a seeding rate of 4.0 million grains per 1 ha in 2024.

In terms of the seeding rate for spring-summer preservation, a completely opposite relationship was observed: as the seeding rate increased from the control rate of 2.5 million grains per hectare to a high rate of 4.5 million grains per hectare, the preservation rate fell sharply. On average over three years, the

indicator decreased from 93.0% in the control to 67.0% at a seeding rate of 4.5 million grains per 1 ha. Obviously, the large feeding area of winter rye plants with a low seeding rate and low seeding density served as a reliable protection for the crop from death. On average, increasing the seeding rate from 2.5 to 3.0 million grains per hectare increased plant losses by 9.1 (9.8%), with a seeding rate of 3.5 million grains per hectare, losses increased by 17.3 (18.6%), and with seeding rates of 4.0 and 4.5 million, the decline in survival exceeded 20% and amounted to 22.2% and 28.0%, respectively.

Hence, analysis of the stages of the growing season for winter rye plants in an experiment studying various seeding rates for winter rye with optimal precursors allows us to conclude that in the first half of its development in the fall after sowing, the crop primarily responds to its precursor. With a small mass of developing seedlings, the seeding rate has a negligible effect on the overwintering of winter rye. In autumn, the best conditions for crop preservation are created after grain peas.

The studies present and analyze data on winter rye yields at various seeding rates for winter grain (winter wheat), legumes (grain peas), and oilseeds (spring rapeseed) precursors by year and on average for the study.

In 2022, based on all factors and variants, the lowest winter rye yield in all years of the study was obtained, averaging 4.44 t/ha according to the experiment. Among the precursors studied, the best crop for winter rye was legumes (peas), with an average yield of 4.89 t/ha in 2022. The increase over the control (previous winter wheat) for this variant was significant, amounting to 0.67 t/ha or 15.9% at LSD_{05} by factor A 0.119 t/ha. Spring rapeseed was insignificantly lower than the control by 0.03 t/ha (0.7%).

It is particularly essential to note that only with legumes as the precursor crop was the yield of winter rye higher than 5 t/ha – 5.01 t/ha with a seeding rate of 3.5 million grains per 1 ha and 5.06 t/ha with a seeding rate of 4.0 million grains per 1 ha.

In 2023, the average annual yield of winter rye significantly exceeded the previous year's average by 0.44 t/ha (10.0%), reaching 4.88 t/ha. As in 2022, the best precursor crop for winter rye yields exceeding 5 t/ha was grain peas at all seeding rates except the control rate. The average yield increase compared to the control (winter wheat) was quite significant: 0.53 t/ha or 11.4% at LSD_{05} by factor A 0.129 t/ha.

Although the yield of winter rye in 2024 was the highest in all years of the study – 4.98 t/ha, it only slightly exceeded the average value of the previous year – by 0.1 t/ha (2.0%). The average yield of the most unsuccessful year, 2022, was significantly exceeded in 2024 – by 0.54 t/ha or 12.2% of winter rye grain.

The differences between the field trial variants in 2024 differed slightly from those described in previous years. As expected, the best precursor was legumes, with an average yield of winter rye of 5.46 t/ha and a yield increase of 0.74 t/ha or 15.7% compared to the control precursor winter wheat. Spring rapeseed, unlike in 2022, was comparable, but slightly exceeded the control by 0.03 t/ha (0.6%) at LSD_{05} by factor A 0.126 t/ha. The average winter rye yields over the years, depending on the factors, are presented in Table 1.

Table 1.

**Winter rye yield at different seeding rates for optimal precursors (t/ha),
average for 2022–2024**

A - precursor	B – seeding rate (million grains per 1 ha)					Average for A
	2.5	3.0	3.5	4.0	4.5	
Winter wheat	4.36	4.44	4.61	4.68	4.53	4.52
Peas	4.99	5.08	5.29	5.35	5.15	5.17
Spring rapeseed	4.45	4.52	4.66	4.74	4.62	4.60
Average for B	4.60	4.68	4.85	4.92	4.77	4.76

LSD_{05} , t/ha, average: AB – 0.278; A – 0.124; B – 0.161.

The average yield of winter rye in field trials over three years was 4.76 t/ha. In terms of the precursor crop factor, legumes (grain peas) significantly exceeded the control (the precursor crop was winter wheat) by an average of 0.65 t/ha (14.4%), showing an average winter rye yield of 5.17 t/ha. Spring rapeseed, with an average winter rye yield of 4.6 t/ha in the study, exceeded the control variant by only 0.08 t/ha (1.8%).

In terms of seeding rate factor, the variant that showed the significant results with an average winter rye yield of 4.92 t/ha and a 0.32 t/ha increase over the control (4.6 t/ha with a seeding rate of 2.5 million grains/ha) (7.0%) was the variant with a seeding rate of 4.0 million grains per hectare. Less dense sowing with a seeding rate of 3.5 million grains/ha was slightly inferior to the best variant, providing an average winter rye yield of 4.85 t/ha and a yield increase of 0.25 t/ha (5.4%) compared to the control.

Dense sowing with a seeding rate of 4.5 million grains/ha also exceeded the control in terms of winter rye yield, however, the average values for the experiment were lower than for the variants presented above – yield 4.77 t/ha; yield increase of 0.17 t/ha (3.7%). Increasing the seeding rate from 2.5 million to 3.0 million grains/ha on average in the study slightly increased the yield by 0.08 t/ha (1.7%).

Conclusion

Thus, for practical application by agricultural producers, it can be confidently recommended to plant winter rye after a legume precursor (grain peas) and to use seeding rates of 3.5 million and 4.0 million grains per hectare. By combining these elements of winter rye cultivation technology, it is possible to obtain high, stable yields ranging from 5.01 t/ha to 5.65 t/ha in different years of the study and an average of 5.29 t/ha at a seeding rate of 3.5 million grains/ha and 5.35 t/ha at a seeding rate of 4.0 million grains/ha.

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