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EFFECT OF NITROGEN FERTILIZATION ON THE FORMATION OF YIELD ELEMENTS IN WINTER RYE

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ABSTRACT
This article scientifically investigates the influence of soil and climatic conditions, varietal characteristics, and modern cultivation technologies—specifically the timing and application of mineral fertilizers (nitrogen, phosphorus, and potassium)—on the yield and grain quality of winter rye. The results of the scientific experiment revealed a direct correlation between the plant's main stem height and grain yield. Furthermore, it was demonstrated that split nitrogen fertilization during critical stages of the growing season (tillering, stem elongation, and heading/ear emergence phases) positively affects plant height, 1000-grain weight, number of grains per ear, and overall yield components. The highest grain yield, reaching 73,3 c/ha, was achieved in the variant with three-way split nitrogen application during the season, which exceeded the control variant by 58,3 c/ha.

Keywords: Winter rye, productivity, grain quality, stem height, nitrogen fertilization, organogenesis, mineral fertilizers, ear components.

INTRODUCTION
Winter rye productivity and grain quality are complex traits determined by the biological characteristics of the variety, regional soil and climatic conditions, and applied agronomic practices. Meeting the crop's nutritional demands at an optimal

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level throughout the growing season—particularly by managing an effective mineral nutrition regime—is essential for achieving high yields and superior grain quality. Plant growth, development, and stem height serve as key indicators of ongoing physiological processes and exhibit a direct correlation with productivity metrics. Consequently, enhancing the formation of yield components (1,000-grain weight, number and weight of grains per ear) and substantially increasing overall grain yield through split nitrogen applications—not only at the initial stages but also during critical later phases such as tillering, stem elongation, and heading—holds significant scientific and practical importance.

According to the recommendations of R. Siddikov and S. Tulepov [8, pp. 6–8], under the agroclimatic conditions of our Republic, winter cereal crops planted in open fields at early dates should receive 10 percent of their annual nitrogen fertilizer rate at the beginning of the tillering period. For optimal effectiveness, it is advisable to apply nitrogen fertilizers in three split applications: the first early spring feeding at 25 percent of the annual rate, the second feeding during the stem elongation phase at 50–55 percent, and the third feeding during the heading (ear emergence) phase at 20–25 percent. Applying fertilizers either too early or too late fails to yield optimal agronomic results.

In the studies by N.M. Belous, I.M. Bogdevich et al. [9, pp. 341–347], it was found that applying mineral fertilizers to winter rye at a rate of $N_{140}P_{60}K_{120}$ kg/ha had a highly effective impact on productivity indicators. However, increasing fertilizer rates up to $N_{240}P_{90}K_{180}$ kg/ha did not yield a positive effect on grain productivity. It was also determined that higher fertilizer rates led to an increased protein content in winter rye grain. Furthermore, an excessive increase in nitrogen nutrition during the early stages of development results in disproportionately weaker root system development relative to the aboveground green biomass.

As noted by J.W. Erisman, M.A. Sutton et al. [10, pp. 636–639], global agriculture is increasingly dependent on synthetic nitrogen compounds, without which the production of even half of the world's current food supply would be impossible. The application of mineral fertilizers remains one of the primary methods for

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increasing crop yields in sod-podzolic soils, where mineral fertilizers significantly enhance rye productivity by 30 to 45 percent.

LOCATION, CONDITIONS, AND METHODS OF THE RESEARCH

Field experiments were conducted on the long-irrigated typical sierozem soils of the educational-experimental farm of the Tashkent State Agrarian University, which are non-saline and characterized by a deep groundwater table. In the plow layer (0–30 cm) of the experimental plots, the humus content was 1,152%, total nitrogen 0,126%, total phosphorus 0,159%, mobile phosphorus 80,8 mg/kg, and exchangeable potassium190 mg/kg, indicating that the soil is moderately supplied with mobile phosphorus and poorly supplied with exchangeable potassium.

The experiments were carried out in wide-row furrows. Each variant consisted of four furrows, of which the two outer furrows served as guard (protection) rows, and the two middle furrows served as the accounting (harvest) plots.

The total area of each variant was 100 m^2 (3,6 meters wide and 28 meters long), with an accounting plot area of 50 m^2. All phenological observations and biometric measurements in the experiment were conducted within the accounting plots.

The experiment was laid out in four replications, with all replications arranged in a single tier (randomized complete block design or systematic layout, as applicable). Prior to setting up the experiment, soil samples were collected from each variant using the envelope method across two soil layers, and based on these samples, the agrochemical and agrophysical properties of the soil were determined.

RESULTS OF THE RESEARCH AND THEIR DISCUSSION

In this study, the influence of soil and climatic conditions, varietal characteristics, and the timing of mineral fertilizer (nitrogen, phosphorus, and potassium) applications on the yield and grain quality of winter rye was comprehensively investigated. The analysis of the obtained scientific data demonstrated a direct correlation between the plant's main stem height and grain yield, confirming that

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the optimal management of agrotechnical factors throughout the growing season ensures superior performance and high productivity indicators.

However, it was confirmed that implementing split and timely nitrogen fertilization during critical stages of plant organogenesis significantly improves yield and quality metrics. Applying nitrogen fertilizers in increments across the tillering, stem elongation, and heading (ear emergence) phases effectively accelerated plant growth and development processes.

In particular, the highest biological and economic indicators were recorded in variant 5, where nitrogen fertilizers were applied in three split applications during the growing season (during the tillering, stem elongation, and heading phases).

Effect of nitrogen fertilization on the formation of yield components in winter rye: Table 1

№	Treatment	Plant height,cm	1000-grain weight,g	Per spike		Grain yield, c/ha
				Number of grains	Grain weight, g	
1	No fertilizer (control))	102	30	31	0,93	**15,0**
2	PK (background	106	32	32	1,02	**36,4**
3	Background + N_{200} kg/ha at tillering	114	34	35	1,19	**54,6**
4	Bacground + N_{100} kg/ha tillering 100 kg/haat stem elongation	118	34	36	1,22	**65,5**
5	**Background + N_{75} kg/ha at tillering + 75 kg/ha at stem elongation + 50 kg/ha at flowering**	**120**	**35**	**37**	**1,29**	**73,3**

As can be seen from the experimental results presented above, a relatively low main stem height of 102 cm was recorded in the control variant where mineral fertilizers were not applied. In the PK background variant, where only phosphorus and potassium fertilizers were applied, the main stem height reached 106 cm.

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Across all variants where nitrogen fertilizers were applied, the main stem height was significantly higher compared to both the control variant and the PK mineral background.

The maximum main stem height of 120 cm was recorded in variant 5, where nitrogen fertilizers were applied in three split applications throughout the growing season. This indicator exceeded the control variant by 18 cm.

Furthermore, it was determined that mineral nutrition—particularly targeted nitrogen application during the growing season—had a significant positive effect on the formation of yield components in the winter rye crop, specifically the 1000-grain weight, the number of grains per ear, and the grain weight per ear.

One of the important yield components of winter rye is the 1000-grain weight. In the experiment, the 1000-grain weight of rye was 23,8 g in the control variant and 25,7 g in the PK background variant. In the variants where nitrogen fertilizers were applied, this metric ranged from 26,4 g to 27,3 g. The highest 1000-grain weight, reaching 28,2 g, was observed in the variant where nitrogen fertilizers were applied in three split applications throughout the growing season, exceeding the unfertilized control variant by 4,4 g.

Here is the revised, grammatically polished, and professionally adapted version of your text using precise agricultural and academic terminology (with decimal numbers and count units formatted to standard international scientific convention):

Other critical yield components of winter rye include the number of grains per ear and the grain weight per ear. These two metrics are closely interconnected and play a pivotal role in increasing overall grain yield. In the control variant, the number of grains per ear was 31, and the grain weight per ear was 0,93 g. In the mineral background variant, where only phosphorus and potassium fertilizers were applied, the number of grains per ear was 32, and the grain weight per ear reached 1,02 g.

Relatively high indicators for both the number of grains per ear and grain weight were recorded in variant 5, where nitrogen fertilizers were applied in three split applications throughout the growing season—specifically during the tillering, stem elongation, and heading (ear emergence) phases. In this variant, the number of grains per ear reached 37, and the grain weight per ear was 1,29 g. Consequently,

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compared to the control variant, this treatment resulted in 5 more grains per ear and an increase of 0,36 g in grain weight per ear. Furthermore, the high effectiveness of mineral fertilizers was clearly reflected in the final grain yield of winter rye.

During the cultivation of winter rye, total biological productivity is considered one of the primary criteria, incorporating the total amount of plant dry mass. The level of biological productivity reflects how effectively the crop assimilates solar radiation, nutrients, and moisture.

The higher this indicator, the more active the plant's photosynthetic activity becomes, subsequently increasing its coefficient of performance. Winter rye is cultivated primarily to obtain grain, straw, and green mass; thus, all aboveground parts of the plant are utilized as feed in livestock production. Consequently, enhancing the total biological productivity of winter rye holds immense scientific and practical value.

The conducted analyses demonstrated that the highest grain yield was achieved in the final variant (variant 5), exceeding the unfertilized control variant by 58,3 c/ha and surpassing the phosphorus-potassium (PK) background variant by 36,9 c/ha.

These findings confirm that achieving a high and high-quality grain yield in winter rye depends not solely on the total fertilizer rate, but crucially on its split application in accordance with the plant's phenological development stages (tillering, stem elongation, and heading). This approach creates the most favorable physiological environment for optimizing plant stem height and the full formation of yield components (grain number and weight).

CONCLUSION

The results of this scientific research demonstrate that, alongside soil and climatic conditions and varietal characteristics, the application of mineral fertilizers—particularly targeted nitrogen nutrition timed precisely to the plant's organogenesis stages—plays a decisive role in achieving high yields and superior grain quality in winter rye.

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A direct correlation exists between the plant's main stem height and grain yield, wherein enhanced stem growth establishes a favorable foundation for the optimal development of yield components.

Applying nitrogen fertilizers not as a single dose, but split into increments during critical phases of the growing season—specifically the tillering, stem elongation, and heading (ear emergence) stages—significantly improves the 1,000-grain weight, the number of grains per ear, and overall productivity metrics.

The highest performance was recorded in the variant where nitrogen fertilizers were applied in three split applications throughout the season, yielding 73,3 c/ha, which exceeded the unfertilized control variant by 58,3 c/ha.

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