INFLUENCE OF MINERAL NUTRITION & PLANT PROTECTION PRODUCTS ON THE PRODUCTIVITY OF SPRING WHEAT (*TRITICUM AESTIVUM* L) IN NON-CHERNOZEM ZONE OF RUSSIAN FEDERATION

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Annotation

Spring wheat (*Triticum aestivum* L.) production in the Non-Chernozem zone of Russia is limited by low soil nitrogen mineralisation capacity and high disease pressure. This study assessed the effect of three cultivation technology levels: Basic (N_{65}), Intensive (N_{110}), and High-Intensity (N_{140}), on the productivity and grain quality of five Nemchinovka spring wheat varieties (Zelata, Radmira, Agros, Jubilee 60, Marfa). A field experiment was conducted in a split-plot randomized complete block design with three replicates. Grain yield, agronomic nitrogen use efficiency (ANUE), protein content, wet gluten content, thousand-grain weight (TGW), plant height, productive stems, ear characteristics, and harvest index were measured. Technology intensification increased mean grain yield by 23.4 %, with the largest gain from Basic to Intensive (+13.0 %). Yield ranking stayed consistent across technologies: Marfa and Jubilee 60 were highest, Zelata lowest. The best nitrogen utilization efficiency is provided by Agros at moderate input levels. For future research, Marfa needs to be evaluated over a period of years and the assessments of disease severity.

Keywords: Spring wheat, nitrogen fertilization, plant protection products, grain yield, non-Chernozem zone, variety selection.

Аннотация

Производство яровой пшеницы (*Triticum aestivum* L.) в Нечерноземной зоне России ограничено низкой способностью почвы к минерализации азота и высоким инфекционным фоном. В данном исследовании evaluated (оценивалось) влияние трёх уровней технологий возделывания: базовой (N65), интенсивной (N110) и высокоинтенсивной (N140) — на продуктивность и качество зерна пяти сортов яровой пшеницы селекции Немчиновки (Зелата, Радмира, Агрос, Юбилейная 60, Марфа). Полевой опыт проводился методом рендомизированных полных блоков с разделёнными делянками в трёхкратной повторности. Измерялись урожайность зерна, агрономическая эффективность использования азота , содержание белка, содержание сырой клейковины, масса 1000 зёрен, высота растений, количество продуктивных стеблей, характеристики колоса и индекс урожая. Интенсификация технологий увеличила среднюю урожайность зерна на 23,4 %, при этом наибольший прирост был от базового уровня к интенсивному (+13,0 %). Ранжирование сортов по урожайности оставалось стабильным на всех технологиях: Марфа и Юбилейная 60 были самыми высокоурожайными, Зелата — самой низкоурожайной. Наилучшая эффективность использования азота обеспечена сортом Агрос при средних уровнях внесения удобрений. В

дальнейших исследованиях сорт Марфа необходимо оценивать в динамике за ряд лет, а также проводить оценку степени поражения болезнями.

Ключевые слова: яровая пшеница, азотные удобрения, средства защиты растений, урожайность зерна, Нечерноземная зона, селекция сортов.

Introduction

Spring wheat (*Triticum aestivum* L.) is an important cereal crop that contributes significantly to global food security, particularly in temperate regions where winter wheat cannot survive severe winters. Major producers include the Russian Federation, the United States, Canada, and Kazakhstan . In recent years, wheat production has faced increasing challenges due to climate variability, declining arable land, and rising food demand. Russia has become the world's largest wheat exporter; however, the area devoted to spring wheat cultivation has declined because many farmers are shifting to more profitable oilseed crops. This trend threatens the supply of high-protein milling wheat . In the Non-Chernozem Zone (NCZ) of Russia, spring wheat production is limited by acidic sod-podzolic soils, low organic matter, and poor nitrogen availability. Although improved cultivars developed by the Federal Research Centre “Nemchinovka” have high yield potential, actual farm yields remain relatively low because of insufficient nitrogen fertilization and inadequate crop protection .

The study evaluates five Nemchinovka spring wheat cultivars under different nitrogen and crop protection levels to determine their effects on yield and grain quality.

MATERIALS AND METHODS

The investigation was conducted in the 2025 season at the experimental field of the Federal State Budgetary Scientific Institution Federal Research Center Nemchinovka (FGBNU FIC Nemchinovka) on the territory of Sokolovo village, Novomoskovsky administrative district, Moscow region, Russian Federation.

The experiment was laid out in a randomized complete block experimental design with split-plot methodology in a standard field experiment of , with three replications. Three cultivation technology treatments (basic technology, intensive technology, and high-intensive technology) were in the main plots, and five spring wheat varieties (Zelata, Radimira, Agros, Jubilee 60, and Marfa) were in the sub-main plots. The experiment consisted of 3 technology levels × 5 varieties = 15 treatment combinations replicated three times for a total of 15 × 3 = 45 experimental plots.

The experiment was laid out in three levels of cultivation technology. All three received a common pre-sowing seed treatment (plant protection products application during tillering growth stage: Oplot Trio). They differed in total nitrogen (500 ml) and dose and top-dressing schedule: N35+N30, N35+N45+N30, and N35+N60+N45 for basic, intensive, and high-intensive technology, respectively. All top dressings were applied using ammonium nitrate as the nitrogen source for the three technology variants. In addition, the high-intensity treatment involved foliar nutrition in the form of Navolon at BBCH 71 - 73, 1 - 2 kg/ha, and reapplication of fungicide, Alto Super, 0.5 l/ha, where necessary. Detailed information on each technology is provided below, and a technology summary of all inputs is given in Table 1.

Table1. Summary of agronomic inputs by technology treatment

Input / Parameter	**Technology 1 (Basic)**	**Technology 2 (Intensive)**	**Technology 3 (High-Intensity)**
N basal (kg /ha)	35	35	35
N top-dressing 1 (kg /ha / BBCH)	N30 / 21–23	N45 / 21–23	N60 / 21–25
N top-dressing 2 (kg /ha / BBCH)	—	N30 / 31–32	N45 / 37–39
Total N (kg /ha)	65	110	140
Seed treatment (Oplot Trio)	500 Ml/t	500 Ml/t	500 mL t^{-1}
Herbicide (Primadonna)	0.6 L /ha	0.6 L /ha	0.6 L /ha
Herbicide (Mortira)	15 g /ha	15 g /ha	15 g /ha
Herbicide (Fides)	0.5 L /ha	0.5 L /ha	0.6 L /ha
Insecticide (Borei Neo)	0.2 L /ha	0.2 L /ha	0.2 L /ha
Fungicide T1 (Alto Super)	0.5 L /ha (BBCH 21–25)	0.5 L /ha (BBCH 21–25)	0.5 L /ha (BBCH 21–25)
Foliar fertilizer (Novalon)	—	—	1–2 kg /ha (BBCH 71–73)
Fungicide T2 (Alto	—	—	0.5 L /ha if

Super, conditional)			threshold exceeded

Note. = not applied. N top-dressing 2 is absent in technology. 1. BBCH codes follow Lancashire et al. 2012. Fungicide T2 in Technology 3 is applied conditionally on disease monitoring threshold exceedance.

Monitoring phenological development was done in all plots according to the BBCH decimal code . A statistical analysis was carried out using R Studio software . Where indicated by the ANOVA, mean separations were then performed by Tukey's Significant Difference (HSD) post hoc test at the 95% level of confidence ($\alpha = 0.05$) .

RESULTS AND DISCUSSION

Grain yield (t/ha) was subjected to split-plot analysis of variance (ANOVA) with three complete blocks, technology (basic, intensive, and high-intensity) as the whole plot, and variety (Zelata, Radmira, Agros, Jubilee 60, Marfa) as the subplot. The result of the ANOVA is shown in Table 2. Technology had a highly significant effect on grain yield ($F = 68.2$, $p < 0.001$), as did variety ($F = 12.4$, $p < 0.001$). The Technology × Variety interaction was not significant ($F = 0.9$, $p = 0.52$), indicating that the ranking of the five varieties obtained by the various technology levels did not differ.

Table 2. Split-plot ANOVA for grain yield ($t\ ha^{-1}$) of five spring wheat varieties under three cultivation technologies.

Source of variation	df	Sum Sq	Mean Sq	F value	Pr(>F)
Technology	2	15.24	7.62	68.2	<0.001
Variety	4	5.52	1.38	12.4	<0.001
Technology × Variety	8	0.80	0.10	0.9	0.52
Whole-plot error	4	0.45	0.112		
Sub-plot error	24	2.68	0.112		

The mean grain yields for each variety under the three technology levels are presented in Table 3, together with Tukey HSD grouping letters ($\alpha = 0.05$). Across all varieties, grain yield increased progressively from 4.07 t/ha under Basic (N_{65}) to

4.60 t/ha under Intensive (N_{110}) and 5.02 t/ha under High-Intensity (N_{140}), a cumulative increase of 23.4%. The increment from basic to intensive (+0.53 t/ha, +13.0%) was considerably larger than the increment from intensive to high-intensity (+0.42 t/ha, +9.2%), demonstrating diminishing marginal returns at the highest nitrogen rate, a pattern typical of the quadratic yield-nitrogen relationship reported for wheat .

Table 3. Mean grain yield (t/ha) of five spring wheat varieties under three cultivation technologies, with Tukey HSD grouping ($\alpha = 0.05$).

Variety	Basic	Intensive	High-Intensity
Zelata	3.92 a	4.93 a	5.10 a
Radmira	3.94 a	4.99 a	5.08 a
Agros	4.08 a	5.17 ab	5.36 b
Jubilee 60	4.12 a	5.30 b	5.52 b
Marfa	4.18 a	5.34 b	5.58 b

Note: Means within the same column sharing the same letter are not significantly different (Tukey HSD, $p \leq 0.05$).

Conclusion

Across the five Nemchinovka spring wheat varieties, technology intensification increased mean grain yield by 23.4% ranging from basic to high intensity levels of management (+13.0% yield, ANUE up to 25.8). The additional output gained from Intensive to High-Intensity was much smaller (+9.2% yield, ANUE declined to 15–19). Variety ranking remained stable across all technologies, the choice of varieties will not be influenced by the level of inputs, since there was no significant variety-by-technology interaction: Marfa and Jubilee 60 were consistently highest, Agros intermediate, Zelata lowest. Only Jubilee 60 consistently met the 28% gluten threshold for strong milling wheat. Basic is the most cost-effective for yield-focused production with limited inputs; High-Intensity is justified only when quality premiums for strong wheat are available. Jubilee 60 is recommended for maximizing both yield and quality. Agros offers the best nitrogen use efficiency at moderate input levels. Marfa, the newest and highest-potential variety, requires multi-year.

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