

Article

Application of New-Generation Growth Regulators and Topdressing Nitrogen Fertilizers Increases Improver Winter Wheat Yield and Grain Quality in South Russia

Yurii Pleskachiov ¹, Sergey Voronov ¹, Serazhutdin Kurbanov ², Francess Sia Saquee ³ and Meisam Zargar ^{3,*} 

¹ Department of Agronomy, Federal Research Center Nemchinovka, 121205 Moscow, Russia

² Department of Agrobiotechnology, Dagestan State Agrarian University, 367032 Makhachkala, Russia

³ Department of Agrobiotechnology, Institute of Agriculture, RUDN University, 117198 Moscow, Russia

* Correspondence: zargar_m@pfur.ru

Abstract: The need for effective nutrient management is crucial for optimizing wheat production and increasing the plant's ability to tolerate different environmental stresses. In this study, we assessed the influence of new-generation PGRs and foliar topdressing nitrogen fertilizer and their interactive effects on wheat yield and quality parameters of grain and flour. A three-year field experiment was conducted on the dark chestnut soil of the Rostov region. We estimated the effect of foliar topdressing liquid nitrogen fertilizer on consumption rates of N32 (N32), N64 (N32 + N32), and N96 (N32 + N32 + N32), as well as new-generation plant growth regulators (PGRs), namely, Zirkon, Silk, and Albit, on the productivity and grain quality of winter wheat Tarasovskaya 70. The results of the experiments indicate that the highest average grain yield over three years was 5.34 t/ha⁻¹ with the application of N96 (N32 + N32 + N32) and Albit PGR. In 2020, due to favorable weather conditions, the greatest grain yield was attained at 6.27 t/ha⁻¹ for N96 (N32 + N32 + N32) and Albit PGR. The highest grain quality with the greatest gluten content >28% was obtained when N96 (N32 + N32 + N32) and PGRs were applied. According to the results, using N96 (N32 + N32 + N32) and PGRs made it possible to obtain “valuable” grain in terms of quality, which is suitable for the production of premium flour. The beneficial interactive effects of N application rates and PGRs on winter wheat yield and quality parameters are worthy of further investigation.

Keywords: liquid nitrogen fertilizer; plant growth regulator; *Triticum aestivum* L.; grain quality; gluten



Citation: Pleskachiov, Y.; Voronov, S.; Kurbanov, S.; Saquee, F.S.; Zargar, M. Application of New-Generation Growth Regulators and Topdressing Nitrogen Fertilizers Increases Improver Winter Wheat Yield and Grain Quality in South Russia. *Agriculture* **2022**, *12*, 1310. <https://doi.org/10.3390/agriculture12091310>

Academic Editors: Othmane Merah, Purushothaman Chirakkuzhiyil Abhilash, Magdi T. Abdelhamid, Hailin Zhang and Bachar Zebib

Received: 25 July 2022

Accepted: 23 August 2022

Published: 25 August 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Wheat (*Triticum aestivum* L.) was one of the first domesticated plants and has remained the most important crop in Europe, West Asia, and North Africa for decades [1,2], and is currently a vital crop cultivated worldwide. In 2019, wheat grain occupied 78.5% of Russia's total grain exports, positioning Russia as the world's largest wheat exporter [3,4]. Notwithstanding the recognized wheat quality market classes in developed countries, producers are still growing high-yield wheat varieties that use their resources in such a way that increases yield but leads to lower protein content in the grain [5].

Among all cereals, winter wheat can be considered one of the most nitrogen-demanding crops [6]. In wheat cultivation, nitrogen is one of the key elements with a pivotal role, including in the biosphere, soil cover development, plant nutrients, and soil fertility [7]. For the growth, development, and formation of the yield of winter wheat, nitrogen is tremendously important, and its absence in winter wheat impedes crop growth and developmental stages throughout the growing period [4]. Its application is considered crucial for an optimal crop yield, improving the grain protein content and other superiority indicators [8]. The split application of fertilizer is a common approach for the optimization of the plant's nutrient uptake and lessening the risk of nutrient losses in conventional

agriculture [9]. In order to effectively increase the grain yield of winter wheat, fertilizer management is key [10].

Irrational fertilizer application has led to serious environmental problems, higher fertilizer losses, and lower returns for farmers [11]. According to Zhichkina et al. [12], winter wheat with a grain yield of 1.5–2 t/ha⁻¹ can consume 80–100 kg of nitrogen from the soil. The yield increases, so the consumption of nitrogen from the soil also increases. The most yield-limiting nutrient for wheat is usually nitrogen (N), even though its optimum level of application is difficult to assess and depends on previous crop and soil type [13].

In the production of the winter wheat crop, another key factor in solving problems of physiologically active substances is the inclusion of plant growth regulators (PGRs) in the production stages [14,15]. PGRs are widely applied for lodging control in winter wheat grown at high N rates (Shekoofa1 and Emam, 2008 [16]). According to Kurdyukov et al. [17] and Isaychev et al. [18], much attention had been paid to the development and application of new-generation PGRs with a wide range of physiological activities that constitute an environmentally friendly and cost-effective way to enhance the productive capacity of grain crops, allowing full realization of the potential capabilities of plants. The N fertilization rate is the most important tool available after sowing for ameliorating the growth and development of wheat to produce more grain per unit area [16]. Such management systems serve to enhance N rates and control lodging with PGRs, ultimately increasing wheat yield [19]. There are several phases during wheat growth where PGRs could be used to improve the growth and development of wheat. Studies on various plant growth regulators show that they can stimulate growth and root formation and regulate vital processes in plant cells [20]. PGRs affect plant resistance to the damaging effects of pesticides and cations of heavy metals, increase their antioxidant content, and prevent their intake of heavy metals and radioactive elements [21].

A suitable nitrogen fertilizer management, such as an effective basal/topdressing ratio of nitrogen application, is the most important component of nitrogen fertilizer management, and when combined with PGRs, can be a sustainable strategy to improve crop yield and reduce input costs while reducing environmental risk [10,22]. There is a need to better understand the effects of the interaction of N fertilization and PGRs on winter wheat growth and development, as without balanced mineral nutrition, crops cannot give the desired results [23]. Several studies have investigated the effect of PGR types and field rates on growth and productivity of wheat, but there have only been a few reports concerning their interaction with the use of different N fertilizer rates. Against this backdrop, we investigated the influence of new-generation PGRs and foliar topdressing with liquid nitrogen fertilizer on winter wheat to better understand the interactive efficacy of N fertilization and PGR application using Albit, Zircon, and Silk on winter wheat yield and quality parameters of grain and flour.

2. Materials and Methods

2.1. Site Description and Management

Three years of field experiments were conducted between 2019 and 2021 in the dark chestnut soil of the Rostov region (48°47' E, 39°45' N, 1139 m above sea level). Soil samples were randomly taken from each replication at a depth of 35 cm before sowing. The samples were dried at 60 °C, ground, and computed by the standard methods (Clemson University Agricultural Service Laboratory, Clemson, SC, USA). The soil was classified as loamy sand with a pH of 7.1, organic matter of 1.1%, and nitrogen level of 25 ppm.

The winter wheat plants were grown following a conventional tillage system. The soil was tilled with a field cultivator before planting. A total of 230 kg/ha⁻¹ of fertilizer, with N12-P12-K36, was side-banded and mid-row-banded in the rows for all experimental plots. At the wheat growth stage, 140 kg N/ha⁻¹ (as urea) was added as a topdressing in the double ridge stage. The fertilization was performed considering the soil analysis and characteristics.

2.2. Experimental Procedures and Design

A complete randomized block design with four blocks was employed to arrange the four investigated nitrogen treatments: N32, “one-time application of N 32 kg/ha⁻¹”; N64 (N32 + N32), “two-time application of N 32 kg/ha⁻¹”; N96 (N32 + N32 + N32), “three-time application of N 32 kg/ha⁻¹”; and the nontreated control, “without N application”. The second factor was the new generation of plant growth regulators (PGRs), consisting of Zircon, Silk, and Albit, and the nontreated control. The two central crop rows were used to investigate the differences in crop yields between treatments.

Each experimental year, at the end of October, winter wheat Tarasovskaya 70 was directly sown using a tractor-mounted drill at 200 to 220 kg/ha⁻¹ with a seeding rate of 4.5 million seeds/ha⁻¹ at a depth of 3 cm. The Tarasovskaya 70 wheat cultivar is classified as strong wheat in the experimental region.

The protein content, gluten, and quality were determined on a SpectraStar 2600-XT analyzer (Westborough, MA, USA). Plot sizes were 2 m wide by 11 m long, comprising six crop rows (row width = 32 cm). Seeds were sowed with a Great Plains seeder (Great Plains Manufacturing, Inc., Salina, KS, USA) at a target seeding rate of 1.6 million seeds/ha⁻¹.

All plant growth regulators (PGRs) were applied as seed treatment and foliar application at the tillering stage of wheat plants. The active substances of plant growth regulators are described below.

Zircon: A plant immunity inducer, it has fungicidal activity, provides plant tolerance in drought conditions, and ameliorates plant metabolism. The application dose was 0.35 L/ha⁻¹. This plant immunity inducer is manufactured from the natural raw material of purple echinacea.

Silk: A plant growth regulator (PGR), consisting of natural organic compounds that affect the vital processes of plants and accelerate photosynthesis. The application rate of Silk was 0.5 L/ha⁻¹. It influences the metabolism, promotes the growth and development of plants, stimulates immunity, and increases plant resistance to numerous fungal and bacterial diseases. The composition of Silk includes bark, needles of the Siberian fir, triterpenic acids of natural origin, and biological supplements.

Albit: A PGR with antistress activities. Active substances of Albit: beta-hydroxybutyric acid 6.2 g/kg + magnesium sulfate 29.8 g/kg + potassium phosphate 91.1 g/kg + potassium nitrate 91.2 g/kg + urea 181.5 g/kg. The application dose of Albit was 0.3 L/ha⁻¹.

The nontreated controls did not receive any mineral fertilizers during the experiment as a control of soil fertility. We report the canopy evolution during different growing stages throughout the experiments.

2.3. Assessment of Wheat Yield and Components

Four one-meter planting rows in each experimental plot were randomly chosen for the determination of the wheat yield and yield parameters. The spike and numbers and plant height were recorded before the wheat was harvested. The 1000-grain weight and grain yield were counted with the grain moisture adjusted to 12%.

Wheat grain samples were analyzed for bulk density, referred to as mass per hectoliter. Thousand-grain weight was determined with a grain counter (Contador, Kitzingen, Germany). Vitreousness was determined according to the standard method proposed by Warechowska et al. [24]. Vitreousness was estimated by cutting 100 wheat grains and counting the grain numbers that have completely or partially vitreous flour on the cross-section surface, measured as a vitreous kernels percentage (0–100%).

2.4. Data Analysis

For normality and constant variance, whole experimental data were tested before analyzing the data. SAS version 9.2 (SAS Institute Inc., Cary, NC, USA) was used to consider data from all field experiments, using a mixed procedure with replication as the random experimental factor. Each experimental year was computed individually. The least squares mean statement in SAS, with the Tukey adjustment at $p = 0.05$, was applied for

mean comparisons. Data obtained from the various measured dates, involving average yield and yield components, were analyzed using repeated measures. As there was a significant interaction between year and experimental factors, the data analysis and the mean comparisons of data were conducted separately. The grain gluten percent was investigated considering ICC-158 (ICC, 1992), applying the Glutomatic System (Perten Instruments Sweden, Hagersten, Sweden).

3. Results and Discussion

In control plots, where fertilizers were not applied, the average yield for 3 years was 3.70 t/ha^{-1} (Table 1). In 2020, with favorable weather conditions, the highest yield in the control plots reached 4.15 t/ha^{-1} . At the same time, the grain nature of the examined wheat variety was higher than 760 g/L in all cases. The grain had a high vitreousness of more than 76% , which confirms the high potential of the wheat variety chosen for this study. Though the wheat yield was high, the gluten content was 23.6% on average for nontreated control plots, which limits the use of grain for the processing of high-quality flour and thus baking purposes. Following the classification of grain according to GOST 34702-2020 (baking wheat) (www.docs.cntd.ru, accessed on 10 June 2021), wheat grains with a mass fraction of gluten from 22% to 25% are considered filler and thus require an “improver” to make them suitable to produce premium flour. These findings are in agreement with those of Foca et al. [25] and Blandino et al. [26].

Table 1. Efficacy of experimental treatments on wheat grain yield and yield quality from 2019 to 2021.

Factor A	Factor B	2019	2020	2021	Average Yield 2019–2021	Average Yield A × B	Increase t/ha ^{−1}	Gluten %	Nature g/L	Grain Vitreousness %
		Yield						Average	Average	Average
		t/ha ^{−1}								
Control	Control	3.24 d	4.15 gh	3.72 g	3.70	3.79	0	23.5 d	767	75
	Zircon	3.26 d	4.27 g	3.75 g	3.76			23.6 d	771 bc	76 c
	Silk	3.32 d	4.22 g	3.81 fg	3.78			23.6 d	771 bc	76 c
	Albite	3.38 d	4.39 f	3.94 f	3.90			23.8 d	773 bc	77 c
N32	Control	3.61 c	5.08 de	4.69 de	4.46	4.61	0.82	25.2 c	779 b	79 bc
	Zircon	3.70 c	5.14 d	4.91 d	4.58			25.3 c	781 b	80 bc
	Silk	3.76 c	5.25 d	4.83 c	4.61			25.3 c	782 b	80 bc
	Albite	3.89 bc	5.49 c	5.02 bc	4.80			25.4 c	783 b	81 b
N64 (N32 + N32)	Control	4.07 b	5.63 bc	5.12 b	4.94	5.04	1.25	26.9 b	787 b	82 b
	Zircon	4.16 b	5.70 b	5.15 b	4.99			27.1 b	791 ab	83 b
	Silk	4.21 ab	5.74 b	5.19 b	5.04			27.1 b	791 ab	83 b
	Albite	4.29 ab	5.92 ab	5.33 ab	5.18			27.2 b	794 ab	83 b
N96 (N32 + N32 + N32)	Control	4.31 a	5.95 ab	5.44 ab	5.23	5.34	1.55	28.5 a	800 a	85 ab
	Zircon	4.38 a	6.10 a	5.48 a	5.32			28.7 a	803 a	87 a
	Silk	4.41 a	6.13 a	5.53 a	5.35			28.7 a	803 a	87 a
	Albite	4.49 a	6.27 a	5.65 a	5.47			28.9 a	805 a	88 a
LSD ₀₅		0.08	0.12	0.14						

Means followed by different letters are significantly different by Tukey's protected LSD ($p \leq 0.05$).

Our study was performed according to the farm management system, climate, and soil conditions in the experimental area. Our goal was to examine the new PGRs' interaction with the different N fertilization systems to improve wheat grain yield and yield quality. Although the interaction effect of PGRs × N was not statistically significant, PGRs significantly affected gluten percentage, nature, and grain vitreousness in most cases. Table 1 shows significant differences between different N × PGR interactions in terms of average grain yield from 2019 to 2021.

One-time topdressing of wheat plants with N32 in autumn afforded an increase in grain yield by 0.82 t/ha^{-1} . The data recorded for the application of N32 and non-PGRs over the three years showed an average of 4.61 t/ha^{-1} wheat grain yield. The trend in grain yields according to Table 1 shows that an increase in the amount of nitrogen fertilizer applied resulted in a respective increase in the grain yield. This is evident in the average yields as compared to the addition of nitrogen fertilizer. Fuertes-Mendizabal et al. [27] revealed that not only increasing the nitrogen fertilization rate but also splitting the nitrogen

into two or more soil amendments had a beneficial efficacy on wheat quality. The highest grain yield was observed for N96 with an average yield of 5.34 t/ha^{-1} . Simultaneously with the increase in yield, the quality of grain also increased with the addition of nitrogen fertilizer. This is usually expected, since the presence of more nitrogen available to the plant would result in more protein and gluten content in the grain, thus confirming data reported by Blandino et al. [26] and Varga and Svečnjak [28] concerning common improver winter wheat.

The 1000-grain weight (40.6 g) and virtuousness (87%) also favorably increased with the application of nitrogen fertilizer N96. According to our results, the flour obtained from all nitrogen treatments has medium to high strength and is considered to have good baking properties. Good quality bread is obtained from valuable wheat flour (grade 4). Our results emphasize that the cultivation of a strong variety of winter wheat, with a low level of nitrogen nutrition, leads to the formation of grain with reduced gluten content.

The data of this study show that, as far as the nitrogen management of improver wheat is concerned, N application is needed to achieve the established quality requirements of these crops in temperate conditions. These findings are inconsistent with previous investigations on winter wheat [26,29]. N fertilizer is a vital element for plant development. It is investigated as a major constituent of several biomolecules involving protein and chlorophyll; thus, it also has a significant role in different physiological processes of plants [30]. Optimal use of PGRs with proper field rates in combination with N fertilizer is considered one of the most effective practices for increasing crop yields. This can improve growth regulation and the development of plants [31,32]. Our results indicate that the plant height was not significantly affected by the application of the various nitrogen treatments. On the other hand, the number of stems relatively increased, with N96 kg/ha^{-1} giving the highest number of stems with the value of 342 stems/m^2 , which is 12 stems/m^2 more than the nontreated control. The number of grains per spike (8.3), 1000-grain weight (3.2 g), and the weight of the grain per spike (1.73 g) were significantly enhanced by increasing N application during the experimental years (Table 2). Our results are in agreement with those of Shekoofa1 and Emam [16], as their findings indicated that the number of spikes in winter wheat generally grows as the N application rate increases, while mean kernel weight usually decreases.

Table 2. Wheat components affected by the influence of nitrogen applications (average for 2019–2021).

Treatments	Plant Height (cm)		Stem Numbers (Stem/ m^2)		Number of Grains per Spike		1000-Grain Weight (g)		Grain Weight per Spike (g)	
	Control +/-		Control +/-		Control +/-		Control +/-		Control +/-	
Control	88	0	330	0	34.3	0.0	37.4	0.0	1.28	0.0
N32	88	0	330	0	39.1	4.8	39.7	2.3	1.55	0.27
N64	88	0	333	3	41.9	7.6	40.2	2.8	1.68	0.40
N96	89	1	342	12	42.6	8.3	40.6	3.2	1.73	0.45
LSD ₀₅	0.019	-	0.003	-	0.093	-	0.005	-	0.047	-

To elaborate on our findings, an increase in N nutrition was accompanied by an increase in the number of stems only when two or three topdressings were used, including N64 (N32 + N32) and N96 (N32 + N32 + N32) (Table 2). Since the tillering of winter wheat occurs both in autumn and in spring, the autumn fertilization did not affect the formation of productive stems. The maximum number of stems was formed during the third fertilization of nitrogen, i.e., when tillering had already ended. Consequently, with the lowest rate of nitrogen (N32 kg/ha^{-1}), these stems were already formed, but due to the lack of N nutrition, they did not become productive. The number of grains per spike, 1000-grain weight, and the grain weight per spike increased desirably with the enhanced application of N nutrition and were also of the greatest values when the highest N nutrition, N96 (N32 + N32 + N32), was applied. N nutrition is widely illustrated as the

most significant factor that affects storage proteins as well as the technological quality of the wheat grain; low protein content is also attributed to nitrogen stress [26]. The increase in the mentioned parameters in our study by enhancing N rate application might be related to the role of nitrogen in increasing rapid early growth, uptake and utilization of other essential nutrients such as potassium and phosphorous, enhancing protein content through synthesizing amino acids, and controlling the overall plant growth.

According to our results (Table 1), the topdressing with N32 kg/ha⁻¹ fertilizer during the wheat tillering stage in autumn afforded more than 13 kg of grain for each kg of nitrogen fertilizer used. It is also evident that the grain gluten percentage significantly increased and remained in the valuable category in terms of quality. The second application of N32 kg/ha⁻¹ fertilizer during the spring tillering stage also resulted in an increased yield and a relatively higher quality of grain. The third topdressing application was during the early sprouting stage. Per our results (Table 1), three-time topdressing (N96 kg/ha⁻¹)—that is, during the autumn tillering stage, spring tillering stage, and the early sprouting stage—remains an effective agronomic practice to improve the yield and quality of wheat grain. Our results in grain yield and gluten in response to nitrogen topdressing application were consistent with the results of Qin et al. [13].

The results obtained show that on dark chestnut soils in the conditions of the Rostov region, plant nutrition with a rate of 96 kg/ha⁻¹ is an effective option for improving both wheat yield and grain quality. For every kilogram of N fertilizer, almost 25 kg of wheat yield was obtained, which is a suitable result considering existing standards (Table 1). Our findings are in agreement with previous studies on winter wheat [26,29].

The use of plant growth regulators (PGRs) for treating grain and vegetative plants also provided a significant increase in grain yield, but this treatment was less effective than the application of nitrogen fertilizers (Table 1). A clear pattern in the effectiveness of PGRs depending on the level of N nutrition has not been established. On average, according to factor A (N32 topdressing treatment), the increases in wheat yield by the use of PGRs reached 0.11, 0.20, 0.13, and 0.15 t/ha⁻¹. The results show that Albite was the most effective PGR for wheat yield, with an average increased yield of 0.25 t/ha⁻¹, and the least effective was Zircon, with an average increased yield of 0.08 t/ha⁻¹ (Table 1). PGRs are widely used in winter wheat grown at high N rates. Generally, it is believed that the application of PGRs increases grain yield [13]. In another study, Peake et al. [33] stated that the application of PGRs improved the grain of most winter wheat cultivars, which have sufficient N supply.

Statistical analysis showed that only stem numbers were significantly affected by PGRs, which increased by 5.5 stems/m² compared to the control when PGR Albite was applied (Table 3). Other wheat parameters, such as the number of grains per spike, 1000-grain weight, nature of the grain, and grain weight per spike, also vary under the influence of different PGRs. Albite better affected the various wheat parameters and components compared to the other PGRs. Zircon and Silk did not significantly affect wheat yield and components, except for the number of stems, attaining 334.8 and 334.5 stems/m², respectively (Table 3).

Table 3. Wheat components affected by the influence of growth regulator applications (average for 2019–2021).

Growth Regulators	Yield			Plant Height			Stem Numbers			Number of Grains per Spike			Nature of Grains		1000-Grain Weight		Grain Weight per Spike	
	t/ha ⁻¹	% Increase		cm	% Increase		Stem/m ²	% Increase		Number	% Increase		g/L	% Increase	g	% Increase	g	% Increase
Control	4.58	0.0	0.0	90.3	0.0	0.0	331.5	0	0.0	38.9	0	0.0	783	0	0.0	39.3	0	0.0
Zircon	4.66	0.08	1.7	90.8	0.5	0.5	334.8	3.3	1.2	39.4	0.5	1.3	787	4	0.5	39.4	0.1	0.3
Silk	4.70	0.12	2.6	90.8	0.5	0.5	334.5	3.0	0.9	39.4	0.5	1.3	787	4	0.5	39.4	0.1	0.3
Albite	4.84	0.26	5.7	91.3	1.0	1.1	337.0	5.5	1.7	40.0	1.1	2.6	789	6	0.8	39.6	0.3	0.8
LSD ₀₅	0.026	-	-	0.011	-	-	0.006	-	-	0.004	-	-	0.099	-	-	0.008	-	-

4. Conclusions

Our findings confirm that the three foliar topdressing N fertilization treatments combined with the use of Albite PGR are desirable options to improve the yield and quality of winter wheat grains. We thus conclude that with three-time topdressing of liquid N fertilizers, we can achieve better wheat yield and quality. Our findings indicate that not only enhancing the N application dose but also splitting the N into two or more soil amendments has a beneficial effect on wheat yield and quality; thus, the highest wheat yield was attained for N96, with an average yield of 5.34 t/ha⁻¹. With the increase in yield, the quality of grain is also enhanced by the increasing addition of N fertilization. This is usually expected, as the presence of more N available for the plant would result in more protein and gluten content in the grain. Treatment of seeds and spraying during the growing season should be performed with PGR Albite at rates of 30 g/ton and 0.04 L/ha⁻¹, respectively. The application of PGRs tended to result in increased yield, though not as expected. There was no significant difference between the three examined experimental PGRs regarding wheat yield and yield components. Thus, nitrogen application is an essential factor in plant yield.

Author Contributions: Data curation, Resources, Supervision, Formal analysis and Investigation, Y.P.; Methodology, Y.P. and M.Z.; Project administration and Writing—original draft, S.V. and S.K.; Supervision; Writing—review and editing, M.Z. and F.S.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: This work was supported by RUDN University Strategic Academic Leadership Program.

Conflicts of Interest: No potential conflicts of interest are reported by the authors.

References

1. Weiss, E.; Zohary, D. The Neolithic Southwest Asian Founder Crops. *Curr. Anthropol.* **2011**, *52*, S237–S254. [\[CrossRef\]](#)
2. Zargar, M.; Bayat, M.; Romanova, E.; Izadi-Darbandi, E. POST herbicide programs utilizing tribenuron for cleavers (*Galium aparine* L.) control in winter wheat cultivars. *J. Arch. Agron. Soil Sci.* **2020**, *66*, 1235–1243. [\[CrossRef\]](#)
3. Shchedrin, V.N.; Abramenko, I.P.; Manzhina, S.A. Regulatory and legal aspects of sustainable functions of advanced development agro-industrial territories based on the use of reclamation technologies. *Sci. J. Russ. Sci. Res. Inst. Land Improv. Probl.* **2021**, *2*, 11–16. [\[CrossRef\]](#)
4. Kostić, M.M.; Tagarakis, A.C.; Ljubičić, N.; Blagojević, D.; Radulović, M.; Ivošević, B.; Rakić, D. The Effect of N Fertilizer Application Timing on Wheat Yield on Chernozem Soil. *Agronomy* **2021**, *11*, 1413. [\[CrossRef\]](#)
5. Jaenisch, B.R.; Silva, A.O.; DeWolf, E.; Ruiz-Diaz, D.A.; Lollato, R.P. Plant Population and Fungicide Economically Reduced Winter Wheat Yield Gap in Kansas. *Agron. J.* **2019**, *111*, 650–665. [\[CrossRef\]](#)
6. Ladha, J.K.; Pathak, H.; Krupnik, T.J.; Six, J.; Kessel, C. The efficiency of Fertilizer Nitrogen in Cereal Production: Retrospects and Prospects. In *Advances in Agronomy*; Elsevier: Amsterdam, The Netherlands, 2014; pp. 85–156. [\[CrossRef\]](#)
7. Zhou, B.; Serret, M.D.; Pie, J.B.; Shah, S.S.; Li, Z. Relative Contribution of Nitrogen Absorption, Remobilization, and Partitioning to the Ear During Grain Filling in Chinese Winter Wheat. *Front. Plant Sci.* **2018**, *9*, 1351. [\[CrossRef\]](#)
8. Ma, G.; Liu, W.; Li, S.; Zhang, P.; Wang, C.; Lu, H.; Wang, L.; Xie, Y.; Ma, D.; Kang, G. Determining the Optimal N Input to Improve Grain Yield and Quality in Winter Wheat with Reduced Apparent N Loss in the North China Plain. *Front. Plant Sci.* **2019**, *10*, 181. [\[CrossRef\]](#)
9. Školníková, M.; Škarpa, P.; Ryant, P.; Kozáková, Z.; Antošovský, J. Response of Winter Wheat (*Triticum aestivum* L.) to Fertilizers with Nitrogen-Transformation Inhibitors and Timing of Their Application under Field Conditions. *Agronomy* **2022**, *12*, 223. [\[CrossRef\]](#)
10. Zhang, Z.; Yu, Z.; Zhang, Y.; Shi, Y. Split nitrogen fertilizer application improved grain yield in winter wheat (*Triticum aestivum* L.) via modulating antioxidant capacity and 13C photosynthate mobilization under water-saving irrigation conditions. *Ecol. Process.* **2021**, *10*, 1–13. [\[CrossRef\]](#)
11. Zargar, M.; Pakina, E.; Plushikov, V.; Vvedenskiy, V.; Bayat, M. Efficacy of reducing linture doses and biological components for an effective weed control in wheat fields. *Bulg. J. Agric. Sci.* **2017**, *23*, 980–987.

12. Zhichkina, L.; Zhichkin, K.; Vlasov, A.V.; Belyaev, A.M.; Borobov, V.N.; Lyubimova, N.G. The effectiveness of nitrogen fertilizing in the cultivation of winter wheat. *IOP Conf. Ser. Earth Environ. Sci.* **2022**, 979, 012015. [\[CrossRef\]](#)
13. Qin, R.; Noulas, C.; Wysocki, D.; Liang, X.; Wang, G.; Lukas, S. Application of Plant Growth Regulators on Soft White Winter Wheat under Different Nitrogen Fertilizer Scenarios in Irrigated Fields. *Agriculture* **2020**, *10*, 305. [\[CrossRef\]](#)
14. Alabushev, A.V.; Popov, A.S.; Ovsyannikova, G.V.; Sukharev, A.A. The effect of sowing dates and for crops on productivity and grain quality of the winter soft wheat variety “Krasa Dona” in the southern part of the Rostov region. *Grain Econ. Russ.* **2020**, *1*, 4–10. [\[CrossRef\]](#)
15. John, K.N.; Valentin, V.; Abdullah, B.; Bayat, M.; Kargar, M.H.; Zargar, M. Weed mapping technologies in discerning and managing weed infestation levels of farming systems. *Res. Crops* **2020**, *21*, 93–98.
16. Shekoofa, A.; Emam, Y. Effects of Nitrogen Fertilization and Plant Growth Regulators (PGRs) on Yield of Wheat (*Triticum aestivum* L.) cv. Shiraz. *J. Agric. Sci. Technol.* **2008**, *10*, 101–108.
17. Kurdyukov, Y.F.; Loshchinina, L.P.; Popova, Z.P.; Shubitidze, G.V.; Kuz'michev, F.P.; Tret'yakov, M.V. Winter and spring wheat yield depends on the type of crop rotations and for crops in the arid steppe of the Volga region. *Russ. Agric. Sci.* **2012**, *38*, 8–10. [\[CrossRef\]](#)
18. Isaychev, V.; Andreev, N.; Bogapova, M. The influence of growth regulators on the productive capacity of spring wheat. *BIO Web Conf.* **2020**, *17*, 106. [\[CrossRef\]](#)
19. Piñera-Chavez, F.J.P.; Berry, P.M.; Foulkes, M.J.; Jesson, M.A.; Reynolds, M.P. Avoiding lodging in irrigated spring wheat. I. Stem and root structural requirements. *Field Crop. Res.* **2016**, *196*, 325–336. [\[CrossRef\]](#)
20. Yakhin, O.I.; Lubyantsev, A.A.; Yakhin, I.A.; Vakhitov, V.A. Protective role of bioregulator stifen under the negative effect of cadmium. *Russ. Agric. Sci.* **2007**, *33*, 233–235. [\[CrossRef\]](#)
21. Etesami, H.; Maheshwari, D.K. Use of plant growth-promoting rhizobacteria (PGPR) with multiple plant growth-promoting traits in stress agriculture: Action mechanisms and future prospects. *Ecotoxicol. Environ. Saf.* **2018**, *156*, 225–246. [\[CrossRef\]](#)
22. Trost, B.; Prochnow, A.; Meyer-Aurich, A.; Drastig, K.; Baumecker, M.; Ellmer, F. Effects of irrigation and nitrogen fertilization on the greenhouse gas emissions of a cropping system on sandy soil in northeast Germany. *Eur. J. Agron.* **2016**, *81*, 117–128. [\[CrossRef\]](#)
23. Kadushkina, V.P.; Grabovets, A.I.; Biryukova, O.V.; Kovalenko, S.A. Grain quality of breeding spring durum wheat varieties. *Sci. J. Russ. Sci. Res. Inst. Land Improv. Probl.* **2018**, *4*, 266–276. [\[CrossRef\]](#)
24. Warechowska, M.; Stepień, A.; Wojtkowiak, K.; Nawrocka, A. The impact of nitrogen fertilization strategies on selected qualitative parameters of spring wheat grain and flour. *Pol. J. Nat. Sci.* **2019**, *34*, 199–212.
25. Foca, G.; Ulrici, A.; Corbellini, M.; Pagani, M.; Lucisano, M.; Franchini, G.; Tassi, L. Reproducibility of the Italian ISQ method for quality classification of bread wheats: An evaluation by expert assessors. *J. Sci. Food Agric.* **2007**, *87*, 839–846. [\[CrossRef\]](#)
26. Blandino, M.; Vaccino, P.; Reyneri, A. Late-Season Nitrogen Increases Improver Common and Durum Wheat Quality. *Agron. J.* **2015**, *107*, 680–690. [\[CrossRef\]](#)
27. Fuertes-Mendizabal, T.; Aizpurua, A.; Gonzalez-Moro, M.; Estavillo, J. Improving wheat breadmaking quality by splitting the N fertilizer rate. *Eur. J. Agron.* **2010**, *33*, 52–61. [\[CrossRef\]](#)
28. Varga, B.; Svečnjak, Z. The effect of late-season urea spraying on grain yield and quality of winter wheat cultivars under low and high basal nitrogen fertilization. *Field Crops Res.* **2006**, *96*, 125–132. [\[CrossRef\]](#)
29. Zebbarth, B.J.; Botha, E.J.; Rees, H. Rate and time of fertilizer nitrogen application on yield, protein and apparent efficiency of fertilizer nitrogen use of spring wheat. *Can. J. Plant Sci.* **2007**, *87*, 709–718. [\[CrossRef\]](#)
30. Gojon, A. Nitrogen nutrition in plants: Rapid progress and new challenges. *J. Exp. Bot.* **2017**, *68*, 2457–2462. [\[CrossRef\]](#)
31. Dotto, L.; Silva, V. Beet seed priming with growth regulators. *Semin. Ciênc. Agrar.* **2017**, *38*, 1785–1798. [\[CrossRef\]](#)
32. Leilah, A.A.A.; Khan, N. Interactive Effects of Gibberellic Acid and Nitrogen Fertilization on the Growth, Yield, and Quality of Sugar Beet. *Agronomy* **2021**, *11*, 137. [\[CrossRef\]](#)
33. Peake, A.S.; Bell, K.L.; Fischer, R.A.; Gardner, M.; Das, B.T.; Poole, N.; Mumford, M. Cultivar × management interaction to reduce lodging and improve grain yield of irrigated spring wheat: Optimising plant growth regulator use, N application timing, row spacing and sowing date. *Front. Plant Sci.* **2020**, *11*, 401. [\[CrossRef\]](#) [\[PubMed\]](#)