PhD THESIS

Contributions to improving winter wheat cultivation technology, with strict control of applied nitrogen doses, to prevent environmental pollution

SUMMARY of PhD THESIS

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Introduction

Wheat is the most important crop plant, which is cultivated annually on areas that oscillate around 220 million hectares worldwide, and in our country on 2.1-2.3 million hectares.

To achieve high yields and quality indices suitable for the requirements of the milling and baking industry, nitrogen fertilization is a necessity, and scientists are challenged to develop nitrogen management strategies that lead to increased nitrogen use efficiency (NUE).

Winter wheat responds well to the application of mineral fertilizers, although it has a low specific consumption of nutrients, but due to its poorly developed root system it is very demanding when it comes to fertilization, having a reduced capacity to use less soluble nutrients from the soil. It also absorbs the largest amount of nutrients in a short time, from the beginning of straw's elongation to milk ripening.

Excessive nitrogen application can increase wheat production, but causes a decrease in nitrogen use efficiency (NUE) and is not favorable for water use in deeper soil layers during the wheat vegetation cycle (CORMIER, 2015). In contrast, moderate amounts favor root growth in winter wheat (LIU et al., 2018), and doses higher than 200 kg N ha-1 s.a. cause a reduction in root growth in the subsoil layers.

Nitrogen doses must be adjusted according to climatic conditions, and excessive doses must be avoided in drought and heat conditions because they cause a decrease in chlorophyll content, photosynthesis rate and lead to prolonged leaf senescence, preventing the transport of photosynthetic products to the grains, thus decreasing production (SHANGGUAN, 2014).

Research purpose and objectives

Increasing the performance of wheat crops in terms of quantity and quality, which are substantially influenced by the supply of nitrogen (N) from the soil and the doses of fertilizers applied, and manipulating the supply of N is an important strategic tool that wheat growers can use in response to variations in weather conditions, during crop growth, to maximize their profit.

Understanding how nitrogen affects wheat production and quality, knowing that it is an essential nutrient for plants, affecting productivity, nitrogen use efficiency (NUE) and rainfall water use efficiency (RUE).

Applying moderate doses of nitrogen, which favors root growth in winter wheat, on which the absorption of nutrients and water from soil depends, the growth and development of the aerial part, and avoiding excessive doses, which cause a decrease in nitrogen use efficiency (NUE), being unfavorable for use of water from deeper soil layers, causing a decrease in economic efficiency.

Optimizing nitrogen fertilization according to climatic conditions, to obtain a high quality and quantity yield, in order to obtain economic profits and reduce environmental threats to the winter wheat crop and adjusting nitrogen doses in drought and heat conditions.

Increasing nitrogen use efficiency (NUE), by using the right fertilizers and the right combination of nutrients, by fertilizing at the right time, to avoid nutrient losses through volatilization and leaching was the main objective of the research carried out.

Study of the influence of the nitrogen dose applied in autumn (N50) on production, quality indices, morpho-physiological characteristics and rainfall water use efficiency (RUE) in the winter wheat varieties tested.

Study of the influence of additional nitrogen fertilization in phase II, before earing (N100), on production, quality indices, morpho-physiological characteristics and nitrogen use efficiency (NUE), in the winter wheat varieties tested.

Determination of the amounts of nitrogen taken with the harvest, for all winter wheat varieties, in both nitrogen fertilization variants, in all experimental years.

Evaluation of the behavior of Romanian winter wheat varieties in cultivation, regarding the reaction to fertilization with low (N50) and moderate doses of nitrogen (N100), under the climatic conditions of the period 2020-2024 at SCDA Turda.

Working method

The production results come from the national comparative competition culture, the Center-North area, organized annually in five centers, which also includes ARDSTurda, according to the balanced square grid method, with 25 variants in six repetitions, which allows the repetition of the basic scheme from repetitions 1-3, in repetitions 4-6, so that a differentiated fertilization was achieved with 100 kg/ha N a.s. and 50 kg/ha N a.s..

Two types of fertilizers were administered to ensure the necessary nitrogen doses in the N50 and N100 fertilization variants, respectively a binary one (NPK, 20:20:0) applied in autumn (phase I), before sowing, and a nitrogen-based one (ICAN, nitrocalcar), applied in phase II, before wheat earing (at booting stage).

The statistical calculation for production, protein and wet gluten content was performed using the Polifact program, after taking data from each experimental year from 2020-2024, from the two fertilization variants, for each variety, and the graphic representation was performed using the Excel program.

The determination of protein and wet gluten content was carried out using the Perten IM 9500 analyzer, and the hectoliter mass with the samovar balance, with a measuring vessel capacity of ¼ l.

The Rain Use Efficiency (RUE) factor expresses the number of kilograms of grains produced per / per millimeter of rainfall during the winter wheat growing season and is expressed in kg ha-1mm-1. It was calculated for each variety separately, over the five years of experience.

Nitrogen Use Efficiency was calculated by the difference method:

NUE (%) = (NF100)-(NF50) / R, where: NF100 represents the amount of nitrogen taken with the harvest in the fertilization variant with 100 kg/ha nitrogen a.s., NF50- the amount of nitrogen taken with the harvest in the fertilization variant with 50 kg/ha N a.s., and R the nitrogen dose applied in phase II, respectively 50 kg nitrogen a.s./ha. The conversion factor of protein content into nitrogen was 6.25.

During the wheat growing season, observations and determinations influenced by climatic conditions (heading date) and nitrogen dose (plant height) were made.

Winter wheat production and NUE in the year 2020

The climatic conditions of 2019/2020 were quite difficult for the winter wheat crop at ARDS Turda, and the nitrogen chemical fertilizers applied before heading (May 14) had a low level of utilization due to the drought in the first two decades of May.

The average production of Romanian varieties (SR) was 8270 kg ha-1 in the variant with 100 kg/ha nitrogen s.a. and 7879 kg ha-1 in the N50 variant, the production increase due to nitrogen fertilizers being only 391 kg ha-1. Among the varieties created at SCDA Turda, the highest productions were recorded in 2020 for the Cezara variety, in the N100 variant, being 8549 kg ha-1 and 8055 kg ha-1 in the N50 fertilization level.

The highest nitrogen use efficiency (NUE) values in 2020 were recorded for the FDL Miranda variety (77.03%) and the lowest for Semnal (34.36), and for the varieties created at SCDA Turda, the NUE values were between 46.33 (Andrada) and 60.34% (Codru). The highest amount of nitrogen taken with the harvest, at the N100 fertilization level, was at FDL Abund, and at the N50 fertilization level at Ursita. The results obtained are consistent with those obtained worldwide and confirm that late nitrogen application (before heading) increases nitrogen use efficiency (RAUN & JOHNSON, 1999).

Winter wheat production and NUE in the year 2021

Production increases due to nitrogen fertilizers applied on May 18, 2021 ranged between 420 kg ha-1 for the Codru variety and 1356 kg ha-1 for the FDL Miranda, but the average for Romanian winter wheat varieties was 858 kg ha-1 (Fig. 1). In 2021, chemical nitrogen fertilizers, in the form of nitrocalcar (ICAN), were better utilized by winter wheat, an aspect reflected in the production level obtained in the N100 fertilization variant.

The average production of Romanian winter wheat varieties, in the fertilization variant with 100 kg of active substance nitrogen per hectare, in 2021, was 8890 kg ha-1, the best results being obtained, in order, by: FDL Miranda, Cezara, Otilia, Semnal, Ursita, Luminița, Voinic, Codru, with productions over 9 t/ha.

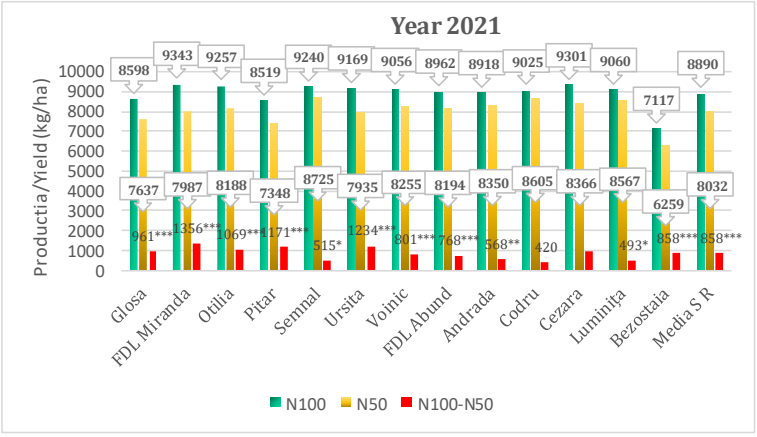

Fig. 1. Yields of winter wheat varieties in 2021 at ARDS Turda

In 2021, NUE values increased, and the highest value (102.68%) was recorded for the FDL Miranda variety. The results obtained, presented in Table 1, demonstrate that nitrogen management is specific to each variety, but also depends greatly on the timing of application, the dose used and climatic conditions and are similar to those obtained by IAN et al. (2005).

Table 1

Nitrogen use efficiency of winter wheat varieties in the year 2021

Variety	Grain Nitrogen N100 (%)	Grain Nitrogen N50 (%)	Nitrogen uptake N100 Kg/ha	Nitrogen uptake N50 Kg/ha	N100-N50 Nitrogen uptake Kg/ha	NUE (%)
Glosa	2.083	1.760	179.114	134.411	44.702	89.40
FDL Miranda	1.845	1.515	172.360	121.019	51.341	102.68
Otilia	1.946	1.698	180.104	138.999	41.105	82.21
Pitar	2.005	1.717	170.789	126.150	44.638	89.28
Semnal	1.867	1.626	172.529	141.834	30.696	61.39
Ursita	1.947	1.693	178.539	134.324	44.215	88.43
Voinic	1.928	1.733	174.600	143.043	31.557	63.11
FDL Abund	1.899	1.653	170.206	135.430	34.776	69.55
Andrada	1.950	1.629	173.937	136.005	37.932	75.86
Codru	1.979	1.734	178.623	149.245	29.378	58.76
Cezara	1.925	1.661	179.026	138.943	40.083	80.17
Luminița	1.874	1.645	169.748	140.910	28.838	57.68

Winter wheat production and NUE in the year 2022

The average production of Romanian varieties, in 2022, was 8202 kg ha-1 in the technological variant in which 100 kg of active substance nitrogen per hectare was applied and 7437 kg ha-1, when 50 kg/ha of nitrogen were administered in autumn, the production increase due to nitrogen fertilizers applied in phase II, before heading, being 766 kg ha-1 (Fig. 2).

The largest production increases due to nitrogen fertilization before heading in 2022 are reported for the varieties: Otilia (1252 kg/ha), Cezara (1140 kg/ha), FDL Miranda (1066 kg/ha).

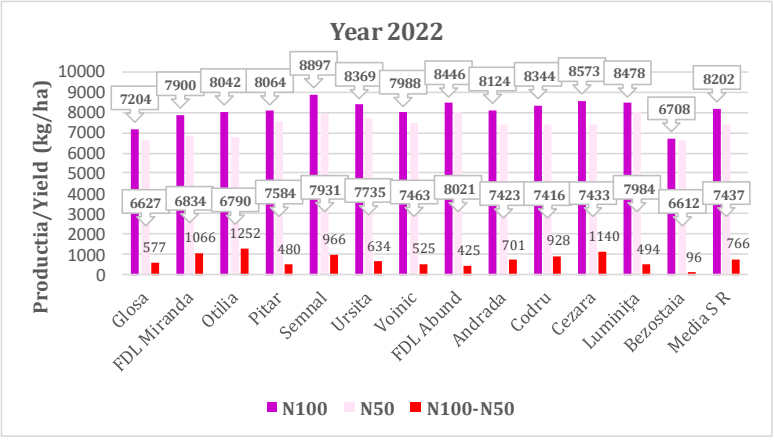

Fig. 2. Yields of winter wheat varieties in 2022 at ARDS Turda

The results obtained in 2022 demonstrate that Romanian winter wheat varieties are adapted to the specific climatic conditions of our country, reacting favorably both to climate change and to moderate and reduced doses of nitrogen.

In 2022, for seven of the varieties, NUE values exceeded 100%, and the highest was recorded for the Sennal variety (Table 2), although the amounts of nitrogen taken at the N100 fertilization level were close to those in previous years. In the N50 fertilization variant, the amount of nitrogen applied was lower in 2022, compared to 2020 and 2021, with the highest value being recorded for the Luminița variety.

Table 2

Nitrogen use efficiency of winter wheat varieties in the year 2022

Variety	Grain Nitrogen N100 (%)	Grain Nitrogen N50 (%)	Nitrogen uptake N100 Kg/ha	Nitrogen uptake N50 Kg/ha	N100-N50 Nitrogen uptake Kg/ha	NUE (%)
Glosa	2.163	1.750	155.837	115.999	39.838	79.68
FDL Miranda	1.970	1.600	155.598	109.344	46.254	92.51
Otilia	2.059	1.667	165.601	113.203	52.398	104.80
Pitar	2.075	1.541	167.344	116.854	50.490	100.98
Semnal	1.997	1.533	177.655	121.566	56.089	112.18
Ursita	2.038	1.536	170.594	118.810	51.784	103.57
Voinic	2.019	1.605	161.294	119.766	41.527	83.05
FDL Abund	1.902	1.494	160.677	119.866	40.811	81.62
Andrada	2.070	1.530	168.199	113.542	54.657	109.31
Codru	2.021	1.557	168.616	115.452	53.163	106.33
Cezara	2.013	1.597	172.557	118.690	53.867	107.73
Luminița	1.870	1.541	158.573	123.017	35.555	71.11

Winter wheat production and NUE in the year 2023

In 2023, the best productions were obtained in the varieties: Codru, Cezara and Semnal, on the N100 fertilization level (Figure 3), the average production of Romanian varieties being 8609 kg ha-1 in the variant in which 100 kg of active substance nitrogen per hectare was applied and 7409 kg ha-1, in the N 50 variant, the production increase due to nitrogen fertilizers applied before heading being 1200 kg ha-1.

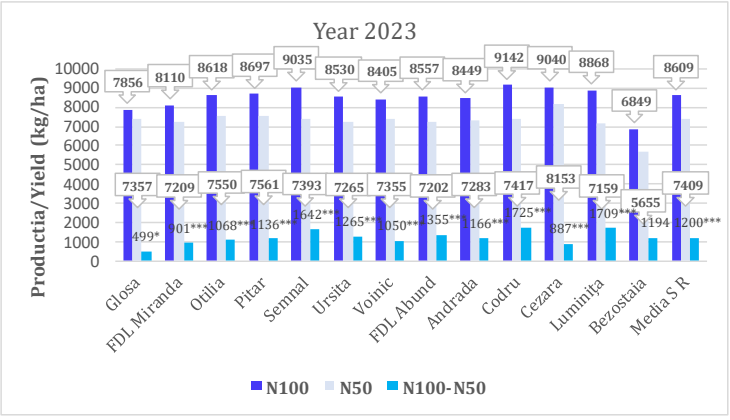

Fig. 3. Yields of winter wheat varieties in 2023 at ARDS Turda

The highest productions in the N50 fertilization variant in 2023 were obtained on Cezara variety, and the smallest difference was recorded between N100 and N50 variants (887 kg ha-1).

The production results obtained in 2023 at winter wheat, under conditions of ARDS Turda, highlight the importance of choosing the timing of nitrogen fertilizer application, being confirmed by similar results obtained by WANG et al. (2023).

Choosing the optimal time to apply nitrogen fertilizers in phase II (before earing) led to the highest production gains and increased nitrogen use efficiency (NUE) according to the data in Table 3, 2023 being the year in which they were best utilized by winter wheat, thus limiting environmental pollution.

Table 3

Nitrogen use efficiency of winter wheat varieties in the year 2023

Variety	Grain Nitrogen N100 (%)	Grain Nitrogen N50 (%)	Nitrogen uptake N100 Kg/ha	Nitrogen uptake N50 Kg/ha	N100-N50 Nitrogen uptake Kg/ha	NUE (%)
Glosa	2.077	1.581	163.153	116.299	46.854	93.71
FDL Miranda	1.954	1.547	158.437	111.538	46.899	93.80
Otilia	1.971	1.563	169.878	118.022	51.856	103.71
Pitar	2.035	1.610	177.001	121.702	55.299	110.60
Semnal	1.950	1.565	176.219	115.686	60.533	121.07
Ursita	2.024	1.637	172.647	118.914	53.734	107.47
Voinic	2.088	1.661	175.496	122.152	53.345	106.69
FDL Abund	1.966	1.694	168.265	122.031	46.234	92.47
Andrada	2.003	1.602	169.250	116.645	52.606	105.21
Codru	1.909	1.627	174.502	120.689	53.813	107.63
Cezara	1.883	1.581	170.241	128.883	41.359	82.72
Luminița	2.077	1.610	184.171	115.231	68.939	137.88

Winter wheat production and NUE in the year 2024

The highest productions were obtained in the varieties: Ursita, FDL Abund, Cezara and Codru, on the N100 fertilization level (Figure 4), the average production of Romanian varieties, in 2024, being 9833 kg ha-1 in the variant in which 100 kg of active substance nitrogen per hectare was applied and 9039, in the N 50 variant, the production increase due to nitrogen fertilizers, applied before heading, being 794 kg ha-1.

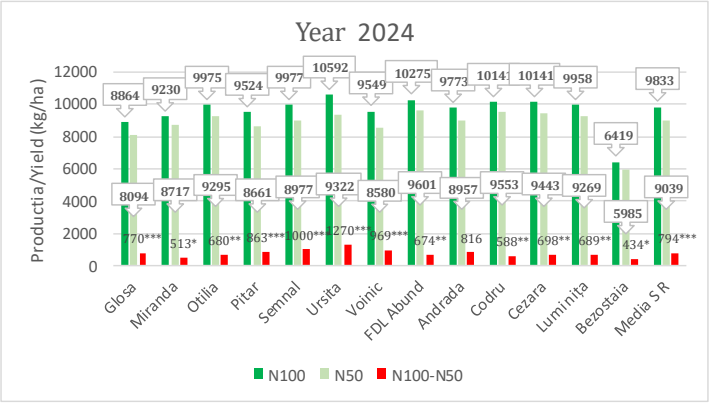

Fig. 4. Yields of winter wheat varieties in 2024 at ARDS Turda

In 2024, nitrogen fertilizers were applied on April 28, before heading (wheat heading two weeks earlier this year than normal), and the precipitation in the third decade

favored their utilization, an aspect that is reflected in the productions obtained in the N100 fertilization variant.

In 2024, winter wheat varieties were closer in terms of NUE values, ranging between 52.09 (FDL Miranda) and 77.54% (Ursita), according to results presented in the following table.

Table 4

Nitrogen use efficiency of winter wheat varieties in the year 2024

Variety	Grain Nitrogen N100 (%)	Grain Nitrogen N50 (%)	Nitrogen uptake N100 Kg/ha	Nitrogen uptake N50 Kg/ha	N100-N50 Nitrogen uptake Kg/ha	NUE (%)
Glosa	2.042	1.824	180.967	147.635	33.333	66.67
FDL Miranda	1.869	1.680	172.490	146.446	26.045	52.09
Otilia	1.909	1.747	190.403	162.402	28.001	56.00
Pitar	2.014	1.779	191.851	154.097	37.755	75.51
Semnal	1.970	1.781	196.507	159.862	36.645	73.29
Ursita	1.984	1.838	210.145	171.376	38.770	77.54
Voinic	1.880	1.765	179.521	151.420	28.101	56.20
FDL Abund	1.890	1.730	194.156	166.059	28.098	56.20
Andrada	1.760	1.614	172.005	144.602	27.403	54.81
Codru	1.838	1.630	186.432	155.752	30.680	61.36
Cezara	1.766	1.579	179.131	149.124	30.007	60.01
Luminiţa	1.790	1.579	178.288	146.376	31.912	63.82

Influence of nitrogen doses on protein content

The average protein content in the grain was 12.48% in the N100 fertilization variant and 10.62% in the N50 variant, 1.86% less (Table 5). Some studies have shown that, under high-fertility soil conditions, applying moderate doses of nitrogen can significantly increase the protein content of wheat grains, while excessive application of nitrogen to such soils will attenuate the increase in protein content. This may be due to the high nitrogen supply capacity of soils with high fertility, and wheat, being highly dependent on soil nutrients, consumes more nitrogen from the soil and less chemical fertilizer, the effect of nitrogen application on protein content being weaker.

Table 5

The influence of nitrogen fertilization on protein content of winter wheat

Symbol	Nitrogen dose	Protein content of grain (%)	Protein % Check	Dif (%) check .(control)	Testul Duncan
N_{100}	100	12.48	100.0	Check	a
N_{50}	50	10.62	85.1	-1.86^{000}	b
(LSD) 5%				0.05	
(LSD) 1%				0.07	
(LSD) 0.1%				0.10	

The average protein content, in both fertilization variants (Figures 5 and 6) was higher in the Glosa variety, respectively 13.16% (N100) and 11.08% (N50). Among the varieties created at ARDS Turda, Andrada ranked best in terms of protein content, with an average content of 12.44%.

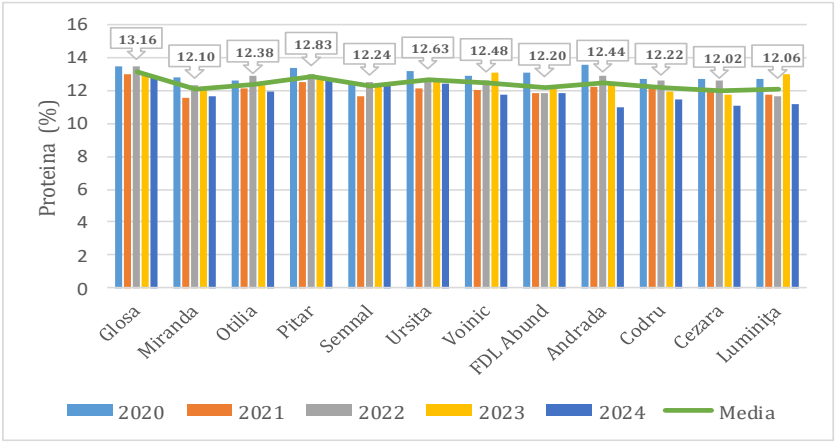

Fig. 5. Protein content of winter wheat varieties în the N100 variant of fertilization

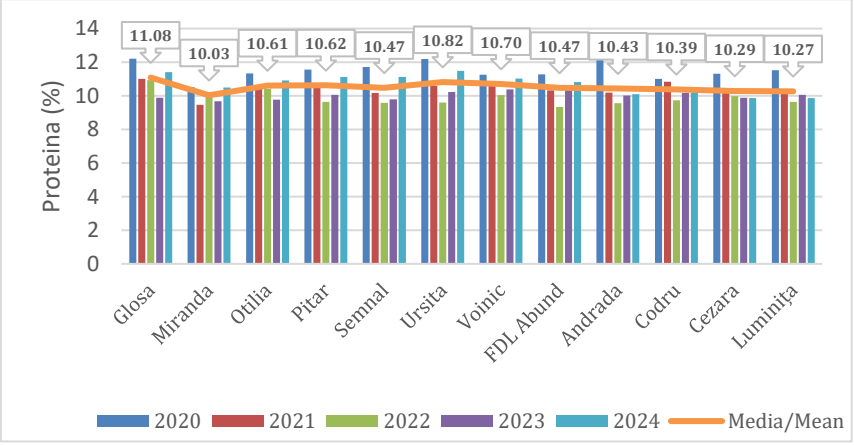

Fig. 6. Protein content of winter wheat varieties în the N50 variant of fertilization

The conclusion that emerges from this study is that, in order to give value to the wheat harvest, both quantitatively and qualitatively, phase II nitrogen fertilization is absolutely necessary.

Conclusions and recommendations

Wheat responds well to fertilizer application because its root system is poorly developed, explores a small volume of soil and has a low capacity for solubilization and absorption of nutrients.

Winter wheat has a long vegetation period, between 250-270 days, and the maximum consumption of nutrients takes place in a short period, generally 90-100 days in the Transylvanian Plain area, from the beginning of straw elongation (calendarically, the beginning of April) to grain filling (end of June), during which it must have sufficient quantities of mineral elements available, in easily accessible forms.

The previous plant is very important for winter wheat, and the pea for grains contributes to obtaining high values of nitrogen use efficiency (NUE), leaving a

significant amount of nitrogen in the soil, which allows the use of moderate and low doses of nitrogen to maintain the state of soil fertility and to avoid pollution as much as possible.

In all winter wheat varieties studied, production increases in the presence of nitrogen, and the F value for the triple interaction AxNxS shows that wheat production is the result of a complex interaction between factors, of the genotype with the environment represented by the climatic conditions of the crop year and with the applied technology.

The average production of the Andrada variety in the five experimental years was 8681 kg ha-1 in the N100 fertilization variant and 7960 kg ha-1 in the N50 variant, and the largest production increases due to nitrogen fertilizers were recorded in 2023 (1166 kg ha-1) and the lowest in 2020 (350 kg ha-1).

The Codru variety reacted best to the application of nitrogen fertilizers in phase II, in 2023, the production increase being 1725 kg ha-1, and the average production in the five years was 8954 kg ha-1 in the N100 fertilization variant, and in the N50 variant with 849 kg ha-1 lower.

Production of the Cezara variety exceeded 9 t/ha in the N100 variant in two of the five experimental years, and in 2024 it exceeded 10 t/ha; in three years production exceeded 8 t/ha in the N50 variant (2020, 2021 and 2023) and 9 t/ha in 2024.

The average production of the Luminița variety in the five years of experimentation was 8942 kg ha-1 in the N100 variant and 8128 kg ha-1 in the N50 fertilization variant, and the increase in production due to the application of nitrogen fertilizers in phase II was, on average, 814 kg ha-1, the highest being recorded in 2023 (1709 kg ha-1).

Originality of the thesis and innovative contributions

Testing Romanian winter wheat varieties, currently in cultivation, under fertilization conditions with moderate doses of nitrogen, which can contribute to mitigating the negative effect of water deficit in drought years, increasingly frequent in recent times, given that excessive application of nitrogen in these conditions worsens the degree of stress, not being conducive to the growth and development of wheat.

Optimizing nitrogen fertilization according to climatic conditions, to obtain a high quality and quantity yield, in order to obtain economic profits and reduce environmental threats to the winter wheat crop and adjusting nitrogen doses in drought and heat conditions.

Applying nitrogen before earing, which led to better use of rainfall water and increased NUE values, and the physiological explanation is that nitrogen fertilizers can extend the period of growth and filling grain by a number of days that matters in the photosynthesis process.

The comparison of production results and quality indices from the N100 and N50 fertilization variants and the observations regarding the reaction to nitrogen fertilization of Romanian winter wheat varieties, over a period of five years, allowed highlighting the fact that they correspond to the requirements of farmers increasingly interested in making wheat cultivation more efficient and reducing the degree of pollution.