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PERFORMANCE OF WINTER TRITICALE (*Triticosecale* Wittm.) IN TRANSYLVANIAN PLAIN

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Abstract

The aim of this study is to determine an appropriate genotype for the Transylvanian Plain by analysing the responses of 17 winter triticale genotypes created at NARDI Fundulea to different weather patterns and additional nitrogen fertilisation. Field experiments were conducted at ARDS Turda over three growing seasons (2020/2021, 2021/2022, and 2022/2023). A randomized block design in six replications was used to conduct the experiments, with the first 3 replications additionally fertilized (N_{100} kg ha^{-1}). Grain yield from triticale varied significantly based on nitrogen rates, weather conditions, and genotype. According to biplot analysis, the genotypes Vifor, Cordial, Utrifun, Zaraza, Zori, and Cascador consistently produced the highest yields across the three years of the study, demonstrating a lack of sensitivity to environmental interactions. With notable yield increases (more than 700 kg ha^{-1}) over N_{50}, the genotypes Titan, Tulnic, Zaraza, Zvelt, Zori, Stil, Vultur, and Utrifun have stood out in response to extra nitrogen fertilisation (N_{100}). According to the evaluation of the experimental elements' interactions, the varieties Vifor, Utrifun, and Cordial were determined to be the most appropriate for the Transylvanian region.

***Key words**: additional nitrogen fertilization, winter triticale, yield.*

INTRODUCTION

Common wheat with rye was crossed to create a cereal species known as Triticale (*Triticosecale* Wittm.), which has a strong ability to adapt to different agro-ecological conditions (Đekić et al., 2014). Scientists combined the best qualities of rye (good resistance to diseases, pests, cold, and drought; a large number of spikelets per spike; etc.) with the best qualities of wheat (high and stable yield and early maturity) in an effort to create a species with great adaptability and stable yields (Mălinaș et al., 2020). It can be grown on more marginal soil (desert, acidic, etc.) and adapt to lower tillage techniques (Ciftci and Eleroglu, 2003). Triticale is the crop that adapts to waterlogged and alkaline soils the best. It can also withstand low pH soils, thrive on sodic soils, and resist high boron, high aluminium, and saline soils. Additionally, it is valued for its ability to withstand drought during the growing season (https://grdc.com.au/). This is because it develops a fairly deep root system early on, which makes it easier to use water from deeper soil layers (Ittu et al., 2007). Triticale's advantages are also used in regions where the production of other cereals is limited (Đekić et al., 2014).

Triticale is known as a cereal species with a hight protein content in the grain and a beneficial content of essential amino acids compared with other cereal. Because of its great nutritional content and ability to substitute maize and wheat in the diet, breeders and experts in animal nutrition advise feeding it to all animal species (Đekić et al., 2014, Pintilie et al., 2023).

It is known that triticale genotypes can be classified into three basic types: winter, spring, and facultative (Abdelaal et al., 2019). Globally, triticale production areas are expanding annually due to its biological qualities and improved selection. According to Maričević et al. (2021), in recent years, more than 4 mil ha of triticale have been sawn worldwide. In Romania, triticale is grown on less than 100,000 hectares of agricultural land, despite the fact that it is recommended for animal nutrition. This is due to a small population of cattle. FAOSTAT (2024) reports that the average output of triticale in Romania ranged from 2789 to 4272 kg ha^{-1}, while the area under cultivation varied from 48019 to 82660 ha (Table 1). Transylvania falls under the first development macro-region, which is in the middle and northwest of the country. The area sown to triticale in this macro-region averaged between 25,000 and 28,500 hectares over the 2021-2023 study period, with yields ranging from 3400 to 3800 kg ha^{-1} (Brodeală et al., 2023).

Table 1. Romania's triticale area (ha) and average yield (kg ha^{-1}) fluctuations since 2012

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
ha	48019	72529	76713	75722	82660	80115	78990	78770	73790	64550	56990	59462
kg ha^{-1}	2789.1	3378.3	3587.6	3500.8	3480.0	4138.6	4272.1	3986.3	3196.6	4015.6	3376.2	3315

Every agricultural crop system attempts to produce high and consistent yields. The implementation of appropriate in-field technology, careful selection of seed genotypes, and suitable agroclimatic conditions can all help achieve these goals (Biberdžić et al., 2012; Madić et al., 2018).

The interconnections between genotype and environment define its adaptation. Plants are influenced by both genetic and environmental factors during the vegetative cycle, which ultimately determines the genotype's real genetic potential (Kucukozdemir et al., 2021): The more ecological conditions satisfy its agrobiological requirements, the higher its level (Postolati et al., 2019).

Genotype, environmental factors, and their interactions all affect winter triticale yield, which can be increased with more N fertilisation. Like other cereals, winter triticale requires nitrogen fertilisation above all other agrotechnical measures in order to produce high quality (Alaru et al., 2004; Rajičić V. et al., 2023) and large yields (Alazmani, 2015; Gerdzhikova et al., 2017; Bielski et al., 2020; Stefanova-Dobreva and Muhova, 2023). Based on their studies, several researchers have recommended 120 kg ha^{-1} N rates for achieving these objectives (yield and quality), including Oral (2018), Rajičić et al. (2020), Mălinaș et al. (2020), Stefanova-Dobreva and Muhova (2023), and Rajičić et al. (2023). As a solution to enhancing nutrient deficits during the growing season, foliar fertilisation was proposed by Szpunar-Krok et al. (2021) for managing inadequate plant nutrition caused by drought, intensive plant growth, or agrotechnical errors.

The study's objectives were to determine a suitable genotype for the Transylvanian Plain by analysing the behaviour of 17 winter triticale genotypes developed at NARDI Fundulea in response to various weather conditions and supplementary nitrogen fertilisation.

MATERIALS AND METHODS

Research Methods

Field experiments were conducted at ARDS Turda over three growing seasons (2020/2021, 2021/2022, and 2022/2023). Seventeen winter triticale genotypes from NARDI Fundulea were tested as biological material, specifically: TF2, Plai, Titan, Stil, Haiduc, Negoiu, Odă FD, Pisc, Tulnic, Cascador, Utrifun, Vifor, Vultur, Zori, Zvelt, Zaraza and Cordial. The first eight genotypes were registered prior to 2015, TF2 being the oldest cultivar (since 1984).

The type of soil was a Phaeozem soil with a loamy-clay texture, a neutral pH of 6.8-7.2, clay content between 51.8% and 55.5%, humus content of 2.20-3.12%, total nitrogen of 0.162-0.124%, phosphorus levels of 0.9-5 ppm, and potassium levels well supplied at 126-140 ppm. Agrochemical analyzes were conducted on soil samples collected from the arable layer (0-20 cm). The experimental layout was a randomized block design with six replications, with the first 3 replications additionally fertilized. We utilized a Wintersteiger Plot Seed Drill for precise sowing at a seeding rate of 500 germinating grains m^{-2}, with a sowing depth of 4 cm and a row spacing of 12.5 cm. Each harvestable plot covered an area of 6.25 m^{-2}. Unfertilised peas were the preceding harvest.

Additional fertilisation was conducted in two stages: in autumn (before sowing) with $N_{50}P_{92}K_0$ kg ha^{-1} active substance (N_{50}) and in spring, at head swollen sheath, with N_{50} kg ha^{-1} a.s. more (N_{100}).

Sekator Progress 0.150 l/ha, Amino 600 SL 0.6 l/ha, Apis 0.2 l/ha, Falcon 0.6 l/ha, and Vital 0.2 l/ha were the sole phytosanitary treatments used in the spring. Each year of the trial was conducted with this kind of treatment.

Harvesting was performed using a Wintersteiger Plot Combine equipped with a 1.4 m working width.

Weather conditions

Weather conditions (rainfall, temperatures) at the experimental site were monitored by the Turda Meteorological Station and are shown in Figure 1.

Normal fall temperatures were only measured in 2021; the other two years showed positive deviations from the 65-years average. Winter temperatures were warm across the three research years, with January 2023 showing a significant deviation of 6.1°C from the long-term average. Additionally, April's average temperatures were colder than the 65-years average by 1.2°C (2022, 2023) to 2.1°C (2021). While 2021 and 2022 experienced regular rainfall, 2023 was considered extremely rainy having a deviation of 138 mm, of which 88.8 mm occurred during the triticale growing season (January: 21 mm, February: 7.9 mm, June: 59.9 mm). It's important to note that in 2023, there was a severe dearth of precipitation during the most critical months for triticale plant growth and development (March, April, May, and the first 10 days of June). This was reflected in the grain harvest.

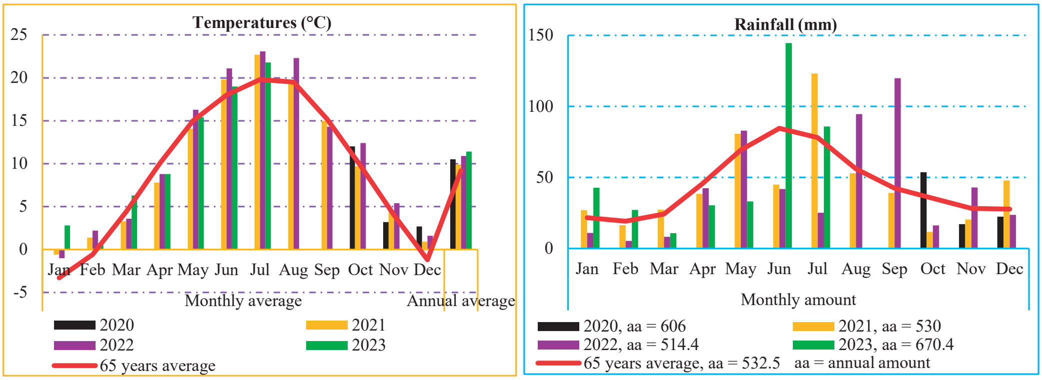

Figure 1. Weather conditions of the experimental site, Turda Meteorological Station

Statistical Analysis

The Poly Fact Software Version 2020 and Microsoft Excel software 2012 were used to statistically analyse the collected data using the standard analysis of variance (ANOVA). The Poly Fact program allowed the execution of Least Significant Difference (LSD) tests at significance levels of 5%, 1%, and 0.1%. Biplot analysis in Past 4.03 was used to identify a suitable genotype for the Transylvanian Plain (to determine which winter triticale genotypes achieve high yields under different environmental conditions to an optimal nitrogen dose).

RESULTS AND DISCUSSIONS

Over the three years of study, grain yield varied on average from 7880 to 8508 kg ha^{-1}. In 2021, the triticale crop experienced the most favourable growth and development conditions reaching an average yield of 8500 kg ha^{-1} that significantly exceeded the mean of the experimental results, as shown in Figure 2. Due to the drought that occurred during the spring months of March, April, and May, as well as the first decade of June, the average yield in 2023 did not exceed 8000 kg ha^{-1}. In accordance with Mălinaș et al. (2020), who conducted an 8-year study (2012-2019) on six winter triticale genotypes, the lowest yields were achieved in dry years, such as 2012. Similar to wheat, drought during the boot stage had the greatest impact on decreasing grain output, our results being in line with those obtained from studies conducted in Mexico by Perez et al. (2007) on drought challenges in different growing stages in triticale.

Alaru et al. (2004) reported that the highest grain output occurred in 2002, when the weather was warm and dry from anthesis to harvest, and the lowest in 2003, when the spring was cold and the summer was humid. According to research by Bielski et al. (2020), winter triticale yields varied greatly throughout the course of the three-year trial, averaging 4.56 t ha^{-1} in 2013, 4.62 t ha^{-1} in 2014, and 3.82 t ha^{-1} in 2015.

In winter triticale, Kirchenv and Georgieva (2017) showed that the growing season significantly affected grain yield; however, Lalević et al. (2022) found no discernible impact from the year.

The analysis of variance in the Rajičić et al. (2020) study shows that the year had a significant effect on grain yield. In accordance with Đekić et al. (2014), an increase in the winter triticale grain production is additional proof of the year's highly significant effects.

As demonstrated by Rajičić et al. (2023) the influence of meteorological conditions on the yield components and quality of triticale grains was also quite substantial. Triticale grains produced a very high yield and quality for the majority of the 2015 - 16 production year due to good weather conditions.

Nitrogen fertilisation is a key agronomic component of winter triticale grain yield production (Abdelaal et al., 2019; Bielski et al., 2020). The nitrogen dose and plant stage at which it is applied have an important effect on obtaining higher triticale yields. Nitrogen fertilisation, usually applied from the tillering to the booting stage, is meant to make up for nutritional deficiencies that occur during the growing season. This is done in order to rectify poor plant nutrition that may have been brought on by agrotechnical errors, harsh plant growth, or drought (like we experienced in 2023). According to Alaru et al. (2004), higher amounts of N applied in the spring during the triticale's EC30 stage enhanced grain production, but when applied later, at the EC47 stage, significantly increased test weight and protein content and decreased stem height.

As demonstrated by our research, output significantly increased when higher nitrogen doses were administered during the booting stage. The application of increased fertilisation (N_{100}) was significant throughout the three years of the study, particularly in the final year, as evidenced by the differences from the control (N_{50}) of 600 kg ha^{-1} in 2021, 557 kg ha^{-1} in 2022, and 785 kg ha^{-1} in 2023 (Figure 2).

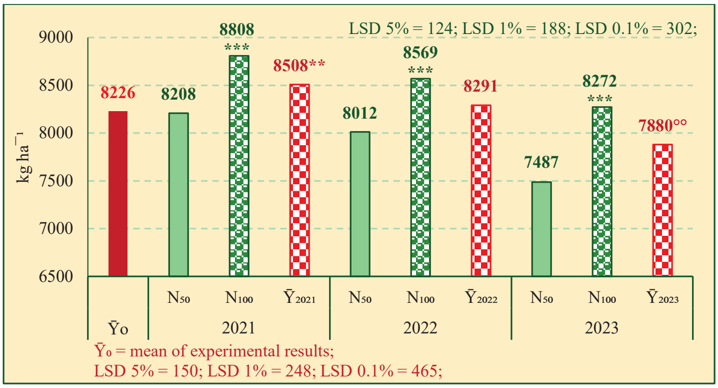

Figure 2. The effects of weather conditions and additional nitrogen fertilization on winter triticale yield

Significant differences between genotype performances were noted, as illustrated in Figure 3. Thus, analysing the influence of the genotype factor, it's observed that the Vifor, Cordial and Utrifun genotypes outperformed the control (Go – mean of the genotypes) by 864 kg ha^{-1}, 773 kg ha^{-1} and 688 kg ha^{-1}, respectively. The Cascador, Zori, and Zaraza genotypes are the next highest yielding cultivars, according to the Duncan test. In contrast, the TF2, Pisc and Titan genotypes showed yield decreases of 1012 $kgha^{-1}$, 532 kg ha^{-1} and 517 kg ha^{-1}, respectively, compared to the control's mean yield (Go = 8226 kg ha^{-1}). According to our results, the most productive varieties in the Transylvania area were Vifor, Cordial, and Utrifun, which produced average yields of 9090 kg ha^{-1}, 9000 kg ha^{-1}, and 8914 kg ha^{-1}, respectively. Mălinaș et al. (2020) claimed that the most productive variety was Haiduc, with an 8-year average yield of 6933.14 kg ha^{-1}. Thus, it emphasises the good adaptability and, at the same time, high yield capacity of the newest genotypes.

The PC 1 (principal component) analysis of the genotype x weather conditions interaction (Figure 4) shows that 79.87% of the variance is explained, suggesting that winter triticale genotypes located closer to the PC 2 line of the biplot are less susceptible to environmental interactions. Conversely, triticale genotypes located further from the biplot's origin exhibit notable interaction effects and are more vulnerable (Erdemci, 2018; Wodebo et al., 2023; Chețan et al., 2024). The genotype x weather conditions interaction results in distinct responses among genotypes: Vifor, Plai, Stil and TF2 yielded higher in the 2022 conditions, whereas the other 13 genotypes performed better in 2021. Accordingly, biplot analysis indicates that the Vifor, Cordial, Utrifun, Zaraza, Zori and Cascador genotypes exhibit a lack of sensitivity to environmental interactions, consistently achieving the highest yields over the three years of the study. Notably, TF2, Pisc, Stil and Titan produced the lowest yields in all three experimental years. The Vultur genotype proved to regularly achieve yields that were comparable to the average of experience.

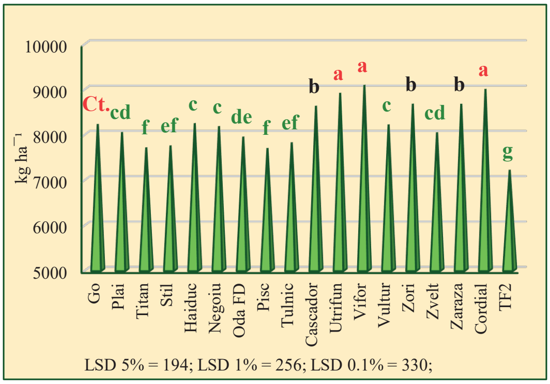

Figure 3. Duncan classification of winter triticale genotypes according to average yield obtained

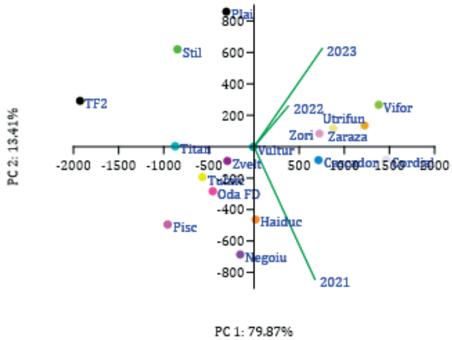

Figure 4. Graphics of Past4.03.exe biplot analysis on winter triticale genotypes' grain yield to determine the interaction between genotype and weather

Following the study, all 17 winter triticale genotypes under observation showed increases in grain yield with N dose, with gains ranging from 426 kg ha^{-1} (Odă FD) to 871 kg ha^{-1} (Titan), as depicted in Figure 5. Different triticale genotypes responded differently to nitrogen supplementation, emphasising that genotypes differ in N uptake, and it depends on the environment (Belete et al., 2018).

In Past 4.03, as illustrated in Figure 6, we employed biplot analysis to identify the genotypes that provide high yields when additional N fertiliser is applied. To additional nitrogen fertilisation (N_{100}), the genotypes Titan, Tulnic, Zaraza, Zvelt, Zori, Stil, Vultur, and Utrifun have distinguished themselves with significant yield increases (over 700 kg ha^{-1}) compared to N_{50}, these results justifying the need for its use. Genotypes that generated comparable yields at both nitrogen doses were identified, the outcome suggesting that the additional rate of N does not necessarily justify its use. Thus, the supplementary nitrogen dose (N_{100}) had minimal impact on the Odă FD, Pisc, and Negoiu genotypes, showing the slightest increases in grain yield. Vifor, Utrifun, and Cordial delivered the highest yields for both nitrogen rates used (N_{50}, N_{100}), confirming the genetic determinism of their yield potential.

We advise using the N_{100} fertilisation treatment when the prior plant was a pea, based on the results. It is safe to say that our findings are comparable to those of other researchers. Oral (2018) reported that the experimental plots fertilised with 120 kg N ha^{-1} produced the highest results for majority components and grain yield. According to Mălinaş et al. (2020), fertilising with N_{100} increased the yields of all six of the winter triticale varieties studied. Stefanova-Dobreva and Muhova (2023) concluded that mineral fertilisation at a rate of 120 kg N ha^{-1} significantly affected all of the characteristics of the Colorit, Attila, and Boomerang genotypes under study, including number of spiklets per spike, number of grains per spike, plant height, grain weight, and grain yield. The treatment with 120 kg ha^{-1} nitrogen fertilisation delivered the highest grain yield of triticale during the three-year trial (4.80 t ha^{-1}), while the control treatment without nitrogen fertilisation gave the lowest (3.17 t ha^{-1}), as determined by Bielski et al. (2020). Lalević et al. (2022) noted that the nitrogen fertilisation variant of 120 kg ha^{-1} generated the highest average yield (6.60 t ha^{-1} in the 1st and 6.37 t ha^{-1} in the 2nd year) among all the fertilisation variants studied in both testing years. Rajičić et al. (2023) found that applying fertilisers that contained NPK, lime, and manure (120 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1}, 60 kg K_2O ha^{-1} + 5.0 t ha^{-1} lime + 20 t ha^{-1} manure) had a significant impact on winter triticale yield.

After applying nitrogen fertiliser at a rate of 120 kg ha^{-1} to spring triticale varieties, Katarzyna et al. (2015) and Abdelaal et al. (2019) obtained comparable results.

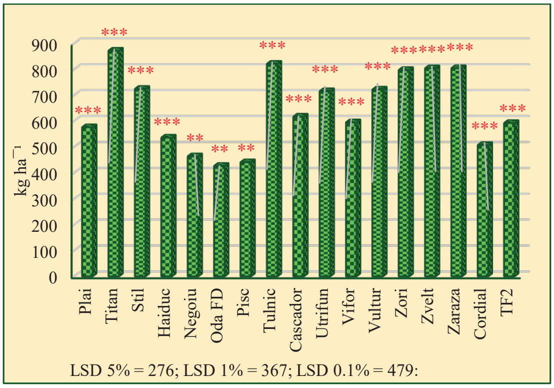

Figure 5. The gains in grain yield attained following additional fertiliser was applied

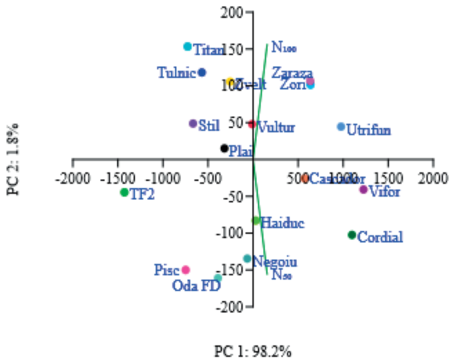

Figure 6. Graphics of Past4.03.exe biplot analysis of winter triticale genotypes' grain yield to assess how fertilisation and genotype interact

The crop's requirement for nitrogen to produce high yields is mostly determined by the genotype, soil type, fertility, and moisture content, as well as the prior plant, growing region, and year-round weather (Muntean et al., 2014). The soil's characteristics, along with the yearly variations in the climate, lead to notable variations in crop yields (Pintilie et al., 2023).

The analysis of variance and F-test results in our study showed that the experimental factors (weather conditions, fertilisation, and genotype) and the weather conditions x genotype interaction had a significant ($p < 0.1\%$) effect on the winter triticale yield. Therefore, our findings are consistent with those of Alaru et al. (2004), who concluded that weather had the most significant influence on winter triticale production and quality, followed by nitrogen rates and genotype. Mălinaș et al. (2020) found that the yield of triticale grain varied significantly ($p < 0.001$) based on the variety, experimental year, and nitrogen treatments. In their analysis of the consequences of different fertiliser types and growing seasons on triticale grain yield, yield components, and protein content over three production years, Rajičić et al. (2023) found that the results varied between the years researched and between fertilisation types.

Yields in the first year of the trial varied from 6860 kg ha^{-1} (TF2, N_{50}) to 9544 kg ha^{-1} (Cordial, N_{100}). The yield variance in 2022 ranged from 7327 kg ha^{-1} (Tulnic, N_{50}) to 9680 kg ha^{-1} (Vifor, N_{100}). Similar to 2021, TF2 and Cordial genotypes achieved the lowest yields (6092 kg ha^{-1}, N_{50}) and highest yields (9529 kg ha^{-1}, N_{100}) in the last year of research. In all experimental settings, the genotypes Vultur and Haiduc exhibit yields comparable to the control (Go), with the reported differences being negligible, according to an analysis of the impact of the interaction between experimental factors on yield (Table 2). The genotypes that can more efficiently absorb nitrogen, producing constantly higher yields (even under less favourable circumstances, as was the case in 2023), are clearly depicted in Figure 7. These include Vifor, Utrifun, Cordial, Zaraza, Zori, and Cascador, some of the most recent genotypes (registered after 2015).

Table 2. Significance of interactions between experimental factors on triticale yield (kg ha^{-1})

Years	2021		2022		2023	
Genotypes	N_{50}	N_{100}	N_{50}	N_{100}	N_{50}	N_{100}
Go – control	8208	8808	8012	8569	7487	8272
Plai	°°	°°°	ns	ns	ns	ns
Titan	°°	ns	°	ns	°°	ns
Stil	°°°	°°°	ns	ns	ns	ns
Haiduc	ns	ns	ns	ns	ns	ns
Negoiu	*	ns	ns	ns	°	°°
Oda FD	ns	ns	ns	ns	ns	°°
Pisc	ns	ns	ns	°	°°°	°°°
Tulnic	°	ns	°°	°°	ns	ns
Cascador	*	ns	ns	ns	ns	ns
Utrifun	*	**	*	ns	***	***
Vifor	***	ns	***	***	**	***
Vultur	ns	ns	ns	ns	ns	ns
Zori	ns	**	ns	ns	*	*
Zvelt	ns	ns	°	ns	ns	ns
Zaraza	ns	ns	ns	ns	**	***
Cordial	***	**	ns	ns	***	***
TF2	°°°	°°°	ns	ns	°°°	°°°
LSD	5%	476	1%	628	0.1%	808

ns = not significant; *, °, **, °°, ***, °°°- significant at the 5%, 1% and 0.1% positive and negative probability levels respectively.

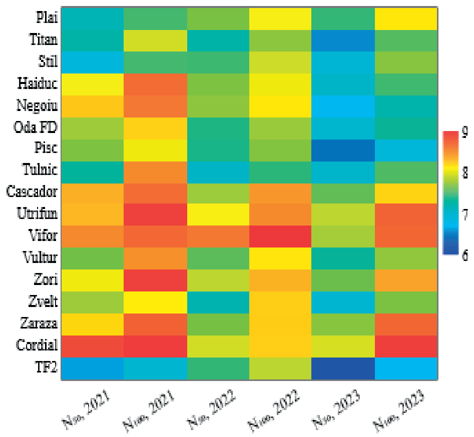

Figure 7. Graphic illustration of the interactions between experimental factors on triticale yield (t ha^{-1})

CONCLUSIONS

Winter triticale behaves well in Transylvanian circumstances, according to the results. The output from the N_{100} fertilisation was suitable, despite the fact that the years had different climates. Yields varied from 6092 kg ha^{-1} (TF2, N_{50}, 2023) to 9680 kg ha^{-1} (Vifor, N_{100}, 2022), considering the interactions of experimental conditions. Due to their excellent average yields, the genotypes Vifor, Utrifun, Cordial, Zaraza, Zori, and Cascador are the most suitable for the Transylvania region.

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