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RESEARCH ON THE ADAPTATION OF TRITICALE VARIETIES TO DIFFERENT FERTILIZATION SYSTEMS IN THE CONTEXT OF CLIMATE CHANGE IN CENTRAL MOLDOVA

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Abstract

This paper presents the results obtained at A.R.D.S. Secuieni regarding the adaptability of the triticale species, under different fertilization systems, in the context of climate change and has as a main purpose to evaluate the efficiency of the cultivation of this species under increasingly variable pedoclimatic conditions. Ten triticale genotypes were studied in two systems under fertilized and unfertilized cropping regimes during 2020/2023. The average yields realized during the analyzed period ranged from 4224 kg/ha to 6503 kg/ha. The most productive variety was Zaraza, in the fertilized system. The fertilized system yielded a 2.3% higher protein content than the unfertilized system (average of 15.5% in the fertilized system and 13.2% in the unfertilized system), which shows the importance of fertilization in increasing the nutritive value of triticale. The Zaraza variety had a maximum protein content of 18%. The unfertilized system's thousand kernel weight is higher than the fertilized system's. Based on the results obtained, the non-fertilized variants had equal or even higher yields and thousand kernel weight than the fertilized variants, but the average protein percentage was higher in the fertilized variants.

Key words*: fertilization, production, protein, triticale, variet.*

INTRODUCTION

Triticale (×*Triticosecale* Wittmack.) is a crop that was created by humans around 1875 by crossing rye (*Secale cereale* L.) and wheat (*Triticum durum* L. or *Triticum aestivum* L.). The purpose of growing triticale was to create a species that could combine the quality and grain yield potential of wheat with the resistance to disease and drought tolerance of rye (Jańczak-Pieniążek, 2023). Developing crop genotypes that meet specific food and industrial needs is the main purpose of plant breeding (Stoyanov, 2023).

This species has high yield potential, good grain quality for fodder use and high resistance to abiotic and biotic stresses (Jańczak-Pieniążek, 2023). Triticale is a good drought-tolerant crop (Stoyanov, 2022).

Interest in cultivating triticale is increasing due to its high yield potential, suitable agronomic properties and high nutritional value of the grain. This species is mainly cultivated for fodder purposes, but several studies suggest its potential for human consumption, including the production of bread (Jańczak-Pieniążek, & Kaszuba, 2024).

Triticale's characteristics include high productivity with low initial investment, better adaptation to moist, acidic and alkaline soils with nutrient deficiencies compared to other cereals, good grain quality and high protein content (Woldeyohannes et al., 2019, Cionca et al., 2024).

A balanced mineral nutrition is essential for grain yield and quality. Soil type, climate and other agro-ecological factors influence mineral nutrition (Rajičić et al., 2023). An important role for high yields in triticale crop is occupied by nitrogen fertilization (Alenicheva et al., 2023). One of the essential minerals for plants is nitrogen (N). It is the main component of protein (Wang et al., 2024).

The world's constantly growing population requires an increase in agricultural production. This is supported by agro-chemical products, such as fertilizers and pesticides, but the harmful effect on the environment has to be taken into account. Therefore, non-chemical and environmentally friendly strategies are

increasingly supported in recent times (Jastrzębska et al., 2023). It is widely grown in a large number of countries, with Poland, Belarus, Germany, France, Germany and Spain among the top producers (Jańczak-Pieniążek, 2024).

Climate change has had a significant impact on the temperature and precipitation regime in the Moldovan region in recent years. This has a direct impact on agriculture and consequently on crop productivity. Under these circumstances, breeding triticale varieties that are able to adapt and produce high yields is essential for maintaining and improving agricultural profitability (Isticioaia et al., 2020). Considering the need to reduce these harmful effects on the environment, the aim of this research is to compare the impact of genotypes and different fertilization systems in the context of thermal and hydric stress in central Moldova on the quantitative and qualitative parameters of triticale species.

MATERIALS AND METHODS

The research was carried out at A.R.D.S. Secuieni to evaluate the influence of genotypes and cropping system on production and quality of ×*Triticosecale* Wittmack.

The experiments were implemented at A.R.D.S. Secuieni, located at 26°5' east longitude and 46°5' north latitude, in the period 2021/2023. The soil on which the studies were realised is a typical cambic chernozemic (Pintilie et al., 2023). It is characterized by a medium supply of nitrogen (IN: 2.7), a very good supply of phosphorus (P_{AL}: 106.7 mg/kg soil) and potassium (K_{AL}: 208.3 mg/kg soil), a good supply of magnesium (assimilable magnesium: 47.2 mg/kg soil), sulfur (S: 20.5 mg/kg soil), iron (Fe: 50.7 mg/kg soil) and copper (Cu: 3.1 mg/kg soil), a medium supply of manganese (Mn: 18.4 mg/kg soil), zinc (Zn: 2.5 mg/kg soil), organic carbon (Organic C: 1.62%) and humus (2.79%) and a poor supply of boron (B: 19.5 µg/kg soil) and molybdenum (Mo: 6.2 mg/kg), with a neutral pH of 7.20. The soil is non saline (CE in H_20: 144.8 µS/cm; 50.7 mg/100 g soil).

In the fertlized system, 150 kg/ha NPK 18:46:0 was applied in the autumn and 200 kg/ha NH_4NO_3 was applied in the spring at straw elongation. No plant protection products were applied during the growing season.

According to Figure 1, the deviation from the multi-annual average ranged between +0.4°C in May and +5°C in February. Over the three years of the study, an increase in monthly average temperatures of 2.4°C above the multi-year average was noticed. The month with the lowest temperatures was January, with an average over the three years of study of 0.4˚C. The highest temperatures were recorded in August, with an average of 23.3˚C in the experimental years 2020-2023.

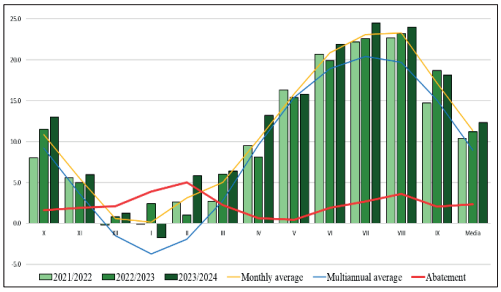

Figure 1. Thermal regime and multiannual average (1962/2023) recorded at A.R.D.S. Secuieni in the period 2020-2023

From the climatic data in Figure 2, the most significant precipitation deficit was recorded in July, -38.7 mm. The average monthly precipitation was higher than the multiannual average in September, with an increase of 17.4 mm.

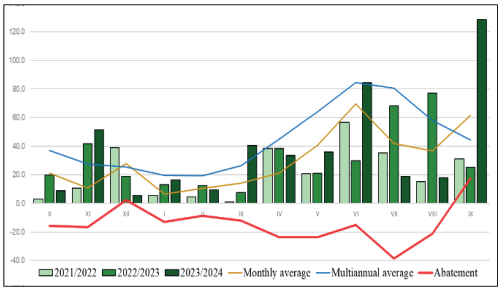

Figure 2. Pluviometric regime and multiannual average (1962/2023) recorded at A.R.D.S. Secuieni in the period 2020-2023

From the above, the three experimental years were characterized as dry and very hot. The average temperature deviation in the three experimental years was +2.4˚C. Regarding

precipitation, the sum of deviations was -169.8 mm. The climatic conditions recorded in the period 2020-2023 were atypical for field crops, with the technological work of establishing and maintaining the crop being realized in a dry and poorly prepared soil, due to the lack of precipitations and high temperatures recorded in the last period.

RESULTS AND DISCUSSIONS

In the studies on triticale production, the average values obtained in 2021 in the fertilized system ranged from 4086 kg/ha (Negoiu) to 7118 kg/ha (Zaraza). For statistical calculation, the control considered was the average yield of the experiment, 5945 kg/ha (Figure 3).

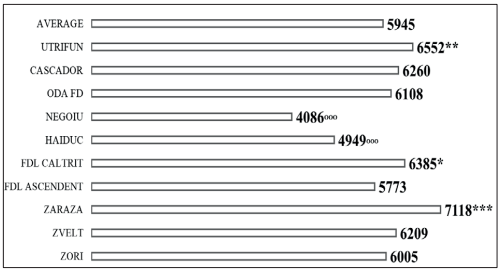

Figure 3. Average triticale yields (kg/ha) obtained in the fertilised system in 2021

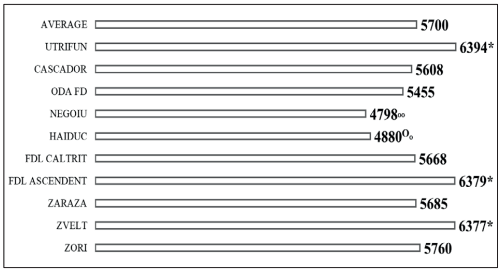

Figure 4. Average triticale yields (kg/ha) obtained in the fertilised system in 2022

In 2021, the yield increases statistically interpreted as highly significant were obtained for the variants sown with the variety Zaraza, with a difference from the control of +1173 kg/ha. Distinctly significant was the variety seeded with Utrifun, with a difference from the control of +607 kg/ha. Significant was the FDL Caltrit variety with a yield of 6385 kg/ha. The varieties Cascador (6260 kg/ha), Oda FD (6108 kg/ha), FDL Ascendent (5773 kg/ha), Zvelt (6209 kg/ha) and Zori (6005 kg/ha) had no statistically significant differences from the control. Results statistically interpreted as negative highly significant were obtained for the variants seeded with the varieties Negoiu (4086 kg/ha) and Haiduc (4949 kg/ha) (Figure 3).

In the next year, the experience average was 245 kg/ha less than the 2021 average. The control variant considered this year was the same as last year, the average of the variants of 5700 kg/ha. Three of the variants sown in the fertilized system in 2022 had significant yield increases, namely the variants seeded with Utrifun, FDL Ascendent and Zvelt. Five of the variants had no statistically significant differences from the control, these being the variants sown with Cascador (5608 kg/ha), Oda FD (5455 kg/ha), FDL Caltrit (5668 kg/ha), Zaraza (5685 kg/ha) and Zori (5760 kg/ha). The yield increases interpreted as negatively distinctly significant were obtained for the variants sown with the variety Negoiu and Haiduc. The variety seeded with Negoiu had a difference from the control of -908 kg/ha, while the variety seeded with Haiduc had a difference from the control of -820 kg/ha (Figure 4).

In the third experimental year, hydric and thermal stress influenced negatively the yield of triticale grains. The average of the experiment was 4765 kg/ha, the lowest average of all the studied years. This was also the control experiment. Very significant yield increases were recorded in the variants sown with the varieties Utrifun (5527 kg/ha), Cascador (5589 kg/ha), Oda FD (5366 kg/ha) and Zaraza (5366 kg/ha). The highest difference from the control was +824 kg/ha in the variety sown with Cascador. There were no statistically significant differences from the control in the variants seeded with FDL Caltrit and FDL Ascendent, with yields of 4769 kg/ha and 4784 kg/ha. The variants sown with Negoiu (3786 kg/ha), Haiduc (3863 kg/ha), Zvelt (4258 kg/ha) and Zori (4340 kg/ha) were interpreted as highly significant negatives (Figure 5).

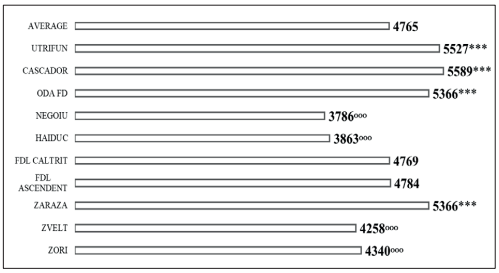

Figure 5. Average triticale yields (kg/ha) obtained in the fertilised system in 2023

Analyzing Figure 6, we can see that the average of the unfertilized experiment is slightly lower than the average of the fertilized experiment in 2021, respectively 5774 kg/ha. This yield was also considered as the experiment control. This year, yields ranged between 3809 kg/ha (Negoiu) and 6844 kg/ha (Utrifun). The yield increases were interpreted as very significant in the variants sown with Utrifun and Zvelt, which had yields of 6844 kg/ha and 6648 kg/ha. Distinctly significant is the yield increase obtained for the Cascador variety. The variant seeded with Zaraza variety, which recorded a yield of 6303 kg/ha is interpreted statistically significant. The varieties Oda FD (5313 kg/ha), FDL Caltrit (5956 kg/ha), FDL Ascendent (6189 kg/ha) and Zori (5591 kg/ha) have no statistically significant differences from the control. The only variants that were interpreted as negative highly significant are the ones sown with Negoiu (3809 kg/ha) and Haiduc (4638 kg/ha).

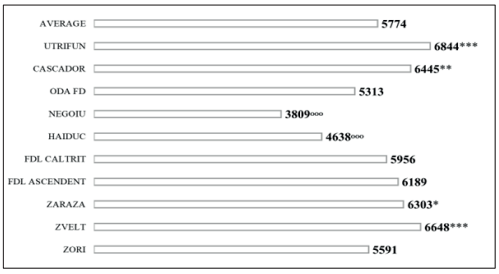

Figure 6. Average triticale yields (kg/ha) obtained in the unfertilised system in 2021

In the next crop year, 2022, the experience average, which was the control, was 6014 kg/ha. The only variety that recorded significant yield increases was Utrifun with a yield of 6919 kg/ha, and a difference from the control of +905 kg/ha. Eight of the ten varieties tested did not register statistically significant differences, including Cascador (6050 kg/ha), Oda FD (6081 kg/ha), Haiduc (5425 kg/ha), FDL Caltrit (6498 kg/ha), FDL Ascendent (6355 kg/ha), Zaraza (5821 kg/ha), Zvelt (5659 kg/ha) and Zori (6379 kg/ha). The Negoiu variety, with a yield of 4955 kg/ha, and a difference from the control of -1059 kg/ha, is interpreted statistically as a negative distinctly significant yield increase (Figure 7).

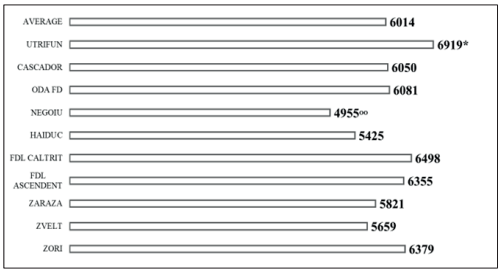

Figure 7. Average triticale yields (kg/ha) obtained in the unfertilised system in 2022

In 2023, the yields in the unfertilized system were higher than in the fertilized system, due to thermal and hydric stress, averaging 587 kg/ha higher than in the variants on which chemical fertilizers were applied. Very significant yield increases were recorded in the variants seeded with Utrifun, with a difference of +395 kg/ha compared to the control; FDL Caltrit, with an increase of 559 kg/ha compared to the control; FDL Ascendent, with an increase of 636 kg/ha compared to the control and Zaraza, which recorded the highest yield in the unfertilized system, 6089 kg/ha, with a difference of +737 kg/ha compared to the control. Significant yield increases were registered in the Zori variety with a yield of 5545 kg/ha. The variants seeded with Cascador (5468 kg/ha) and Zvelt (5222 kg/ha) have no statistically significant differences from the control. The variants sown with the variety Oda FD (4827 kg/ha), Negoiu (4287 kg/ha) and Haiduc (4437 kg/ha) were interpreted negative highly significant. Negoiu variety recorded the lowest yield (4287 kg/ha) in this experimental year in the unfertilized system (Figure 8).

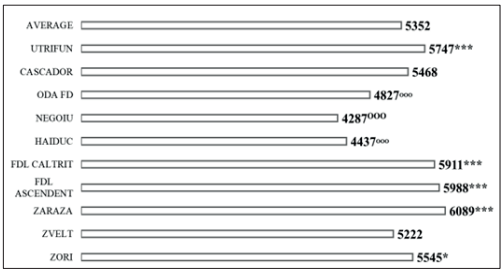

Figure 8. Average triticale yields (kg/ha) obtained in the unfertilised system in 2023

During the research on triticale yield, the average values obtained in the fertilised system ranged from 4224 kg/ha (Negoiu) to 6158 kg/ha (Utrifun). The average yield in the fertilized system during the study years is 5470 kg/ha. It can be noticed that the variants sown with Utrifun and Zaraza varieties have very significant yield increases, with a difference from the control of +688 kg/ha, respectively +587 kg/ha. With an average yield of 5819 kg/ha, the Cascador variant is interpreted as distinctly significant. The varieties Oda FD (5643 kg/ha), FDL Caltrit (5607 kg/ha), FDL Ascendent (5645 kg/ha), Zvelt (5615 kg/ha) and Zaraza (6057 kg/ha) have no statistically significant differences from the control. The average yield increases obtained in the variants seeded with the varieties Negoiu (4224 kg/ha) and Haiduc (4564 kg/ha) were recorded as negative highly significant (Figure 9).

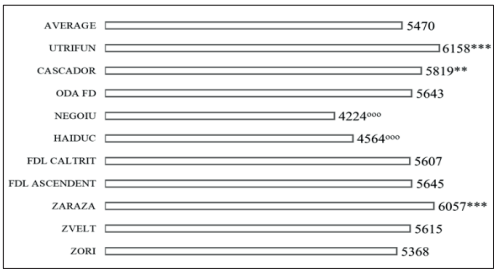

Figure 9. Average triticale yields (kg/ha) obtained in the fertilised system in 2021-2023

Comparing the average yields in the fertilized and unfertilized systems, we can see that for nine out of the ten varieties tested yields were slightly higher in the unfertilized system, proving that a variety's productivity is closely related to its adaptability to environmental conditions, even though fertilization can increase the yield. The average of the unfertilized system over the three years was 5713 kg/ha, 243 kg/ha higher than the average of the variants on which chemical fertilizers were applied. As in the fertilized system, the variants sown with the Utrifun variety stood out with a high yield and a very significant yield increase. The difference from the average is +790 kg/ha. Distinctly significant are the variants sown with FDL Caltrit (6121 kg/ha) and FDL Ascendent (6177 kg/ha). With a yield of 6071 kg/ha, the variants seeded with the variety Zaraza recorded a significant yield increase. Without statistically significant differences were the varieties sown with Cascador (5988 kg/ha), Oda FD (5407 kg/ha), Zvelt (5843 kg/ha) and Zori (5838 kg/ha). Negative highly significant statistical interpretation is obtained for the variants seeded with the varieties Negoiu and Haiduc, with a difference from the control of -1363 kg/ha, respectively -880 kg/ha (Figure 10).

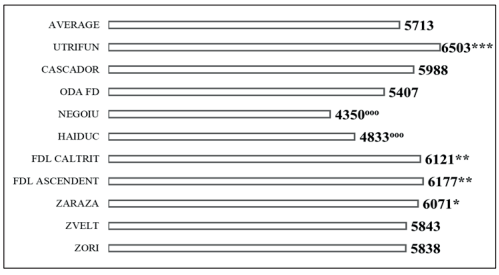

Figure 10. Average triticale yields (kg/ha) obtained in the unfertilised system in 2021-2023

Analyzing the protein content of triticale grains, the average of the fertilized system in the three years studied is 15.5%, 2.3% higher than the average of the unfertilized system. In 2022, the average protein content of triticale grains was the highest in the three experimental years. A difference between the mean of the fertilized system and the mean of the unfertilized system can be observed, thus observing the positive influence of chemical fertilizer application to triticale crop on protein content. Zaraza variety stands out with the highest protein content of 18% in fertilized system in 2022 and 2023. However, in 2021 it recorded an average protein content of only 14%. The variety that recorded the lowest

values was FDL Caltrit (13.8%). In the unfertilized system, the average protein content of triticale grains was 13.2%. The experimental year 2021 recorded the highest percentages, with a maximum of 17% (Zvelt, Haiduc), and a minimum of 15.2% (Zaraza). The next year recorded the lowest values, ranging from 10.1% (Utrifun) to 11.6% (Cascador). In 2023, the Zvelt soil stood out with the highest recorded value of 13.4%, while the FDL varieties Caltrit and Haiduc recorded the lowest values of 11.8% (Figure 11).

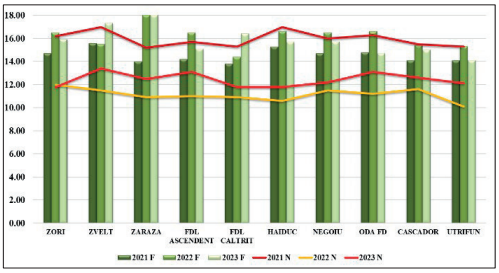

Figure 11. Protein content (%) of triticale varieties from A.R.D.S. Secuieni in the period 2021/2023 in the fertilised and unfertilised system

According to figure 12, an increase in the thousand-kernel weight (TKW) can be observed in the unfertilized system in almost all the varieties studied. The difference between the average of the variants on which fertilizer was applied and those on which it was not is 4.2 g. In the fertilized system in 2021, the highest weight was obtained on the variants sown with the variety Negoiu, of 53.47 g. The lowest value was recorded in the variety Cascador (36.38 g). The highest TKW values were obtained in this crop year from the three years studied (2021). In the following year, values ranged from 32.52 g (Zori) to 41.58 g (Zvelt). The values recorded in the year 2023 in the fertilized system had a maximum of 42.40 g (Zaraza) and a minimum of 30.20 g (FDL Ascendent). Analyzing the unfertilized experiments, we can observe that the TKW values are higher than the values of the experiments on which chemical fertilizers were applied. The variants seeded with Haiduc variety recorded the maximum of 50.17 g in 2022. The minimum was obtained by variety Oda FD (35.6 g).

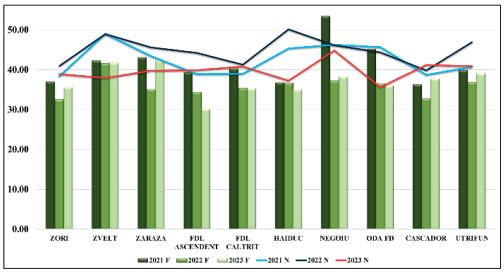

Figure 12. Thousand-kernel weight (grams) recorded for triticale varieties within A.R.D.S. Secuieni in the period 2021/2023 in the fertilised and unfertilised system

CONCLUSIONS

Yields ranged from 3786 kg/ha for variants sown with the variety Negoiu in 2023, fertilized, to 7118 kg/ha for variants seeded with the variety Zaraza in 2021, fertilized. In the three years of the study, the Negoiu variety was the least productive, and the Utrifun variety had the highest yields.

Looking at the average of the experiments, we can say that the yields in the unfertilized system were higher than in the fertilized system. The average of the most productive variety, Utrifun, on the non-fertilized variants was 6503 kg/ha, 345 kg/ha more than the average of the fertilized system. The lowest average values recorded were 4350 kg/ha in the unfertilized system (Negoiu) and 4224 kg/ha in the fertilized system, also for the variants sown with Negoiu.

The fertilization with chemical fertilizers positively influenced the quality of triticale grains. The average of the fertilized system is 15.5% and that of the unfertilized system is only 13.2%. The highest value in the fertilized system was 18% (Zaraza), the same value in the unfertilized system was 17% (Zvelt, Haiduc).

While in general, fertilization leads to increased grain mass, in this study, the thousand kernel weight of the unfertilized system is higher than that of the fertilized system. The highest values were recorded for the Negoiu variety, 53.47 g on the fertilized variants and for the Haiduc variety, 50.17 g on the unfertilized variants. FDL Ascendent obtained the lowest values in the fertilized system (30.20 g) and Oda FD in the unfertilized system (35.60 g). The

difference between the two systems average was 4.4 g.

AKNOWLEDGEMENTS

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