AgroLife Scientific Journal - Volume 13, Number 2, 2024
ISSN 2285-5718; ISSN CD-ROM 2285-5726; ISSN ONLINE 2286-0126; ISSN-L 2285-5718

OPTIMIZING FERTILIZATION AND CROP MANAGEMENT FOR TRITICALE IN THE LĂPUȘ DEPRESSION, ROMANIA

Iuliana CIONCA[1], Alexandru D. COSTIN[2], Teodor RUSU[1]

[1]University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Agriculture, Department of Technical and Soil Sciences, Mănăștur Street 3-5, 400372, Cluj-Napoca, Romania
[2]University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Agriculture, Department of Crop Sciences, Mănăștur Street 3-5, 400372, Cluj-Napoca, Romania

Corresponding author email: iuliana.cionca@usamvcluj.ro

Abstract

Optimizing winter triticale farming technology involves applying agricultural techniques and practices that maximize crop productivity and quality while reducing costs and environmental impact. The research hypothesis was based on the premise that by applying appropriate fertilization and weed control can improve winter triticale production, evaluating for this purpose both soil characteristics, the degree of weediness and winter triticale production. To establish the influence of experimental factors (fertilizer doses: nitrogen, phosphorus and potassium, climatic conditions and herbicides) on winter triticale yield, production and the presence of weeds, a poly-factorial experience was organized on a Typical Luvosol in the Lăpuș Depression, Romania. The experiment was conducted over a period of two years (2022 and 2023), where a variety of winter triticale was studied on four levels of NPK fertilization. At the same time, climatic conditions were registered during the two years. On the level of fertilization with N_{170} and P_{130} the plants have fallen, and production was compromised, especially since there were high amounts of precipitations and gusts of wind recorded.

Key words: *winter triticale, climatic condition, yield, fertilizer.*

INTRODUCTION

Triticale (x *Triticosecale* Wittmack) is a hybrid of wheat (*Triticum spp.* used as the female parent) and rye (*Secale cereale* L. as the male parent) first bred in 1875 (Wójcik-Gront & Studnicki, 2021). This crop offers a large range of cultivars whose development shows a wide range of responses to temperature, photoperiod and vernalization (Giunta et al., 2020). Triticale has become an interesting alternative to wheat or barley as a feed grain at sites with unfavorable growing conditions or in low-input systems (Ewert & Honermeier, 1999). It also provides high grain yields and high biomass even in marginal environments that cannot be used for growing food crops (Woldeyohannes et al., 2019; Küçüközdemir et al., 2021), but also in arid areas that are becoming more widespread due to global climate change (Blum, 2014; Cantale et al., 2016; Bărdaș et al., 2022). High productivity with lower initial investments, better adaptation to moist, acidic and alkaline soils with the lack of nutrients compared to other cereals, good grain quality and high protein content (Woldeyohannes et al., 2019) are some of the proprieties of triticale.

The rapid growth of the global population, combined with the ever-expanding demand for staple cereals intended for both human consumption and animal feed, has exerted significant pressure on agricultural production systems. Furthermore, recent global circumstances have highlighted the importance of each country's domestic production, in comparison to the import of goods, in addressing international challenges (Lalević et al., 2022). Created with the idea of combining the good properties of wheat and rye by intergenus hybridization, triticale is characterized today by the existence of a large number of varieties marked by high tolerance to adverse biotic and abiotic factors (Massimi et al., 2016) which reduces the requirements for chemical protection (Losert, 2017) and fertilization. Triticale is an excellent component for preparing feed mixtures and can partially or completely replace other, more expensive nutrients. Thanks to nutritional values higher than corn, breeders and livestock experts have so far recommended it for the diet of all domestic animals, pointing out that it has given the best results in the diet of poultry and dairy cattle (Đekić et al., 2012; Glamočlija et al., 2018). A plethora authors in the specialized literature mention that mature grain and also green can be used but ensiled alone or in combination with other ensiled legumes. Despite of available results there is still a continuous concern on this subject. To support what has been mentioned, the results of experiments with fertilization are directly or indirectly influenced by numerous factors which include climatic conditions of the region and year, soil fertility, fertilization preceding crops, nutrient composition, time and manner of its introduction (Kirchev et al., 2014; Gerdzhikova, 2014; Madic et al., 2015; Terzic et al., 2018).

Due to constant changes in agroecological conditions and soil characteristics, especially when we talk about its fertility, researching the mineral nutrition of triticale and determining optimal amounts and ratios of nutrients in specific agroecological conditions is essential (Lalević et al., 2022). To achieve adequate production and yield quality, one of the most important factors is a well-balanced nutrient regimen, where the full effect of NPK nutrients can only be realized if other key factors influencing yield are optimized, with weather conditions being the primary factor (Janušauskaitė, 2014). Besides climatic conditions, one of the most important agro-technical factors on which the grain yield depends and enables farmers to use the production potential of cereals is mineral nutrition (Dumbravă et al., 2016), the use of nitrogen has a huge impact on grain yield. In intensive agricultural production, only by applying a sufficient amount of nitrogen in the periods of vegetation when it is most needed by plants (Janušauskaite, 2013), high productions can be mentioned. At the same time, there is also important to mention that conventional soil tillage helps to limit weeds in field (Gozubuyuk et al., 2014). Conventional tillage, also named as traditional, which characterizes with comparatively deep (up to 22-30 cm) soil moldboard ploughing, is often used as soil tillage system (Darguza & Gaile, 2020; Rieger et al., 2008; Jug et al., 2011; Hiel et al., 2018). A series of researchers highlight the importance of mineral fertilization for achieving high yields, particularly nitrogen (Nikolić et al., 2012; Hospodarenko et al., 2022; Hirzel et al., 2020) which has the greatest impact on yield elements, both through its presence in the soil and its deficiency, which in critical phases can lead to irreversible loss of yield (Estrada-Campuzano et al., 2012). When we consider the quantities of mineral fertilizers, different data are given in the literature precisely because of the different climatic conditions and soil factors, variety potential and preceding crop (Gerdzhikova et al., 2017; Nikolić et al., 2012).

Nitrogen (N) is an essential mineral element for plants and is the main component of protein (Wang et al., 2024). Ensuring an adequate nitrogen level contributes to vigorous growth in triticale plants, including the development of roots, stems, and leaves (Ma et al., 2023). Nitrogen is a major component of chlorophyll, the pigment that enables plants to capture sunlight and convert it into energy through photosynthesis (Zhang et al., 2021). Sufficient nitrogen levels enhance photosynthetic efficiency, which in turn supports plant growth and yield (Noor et al., 2023). Adequate nitrogen supply is essential for achieving high yield (Zhai et al., 2022). Nitrogen plays a key role in spike formation, as well as in the size and quality of the grains, directly influencing both the quantity and quality of triticale harvests (Rajičić et al., 2020). Well-nourished plants with sufficient nitrogen are more resistant to stress conditions, such as drought or disease attacks (Rea et al., 2022). Nitrogen can also enhance triticale's resistance to frost and other adverse environmental conditions (Sułek et al., 2024).

Phosphorus (P) stimulates root development, helping the plant absorb water and nutrients from the soil more efficiently (Khan et al., 2023). A strong root system is essential for triticale, especially in the early growth stages (Esnarriaga et al., 2020). Phosphorus is a key component of ATP (adenosine triphosphate), the molecule that provides energy for most biochemical processes in plants (Khan et al., 2023). Therefore, phosphorus supports photosynthesis and other essential processes for plant growth and development (Kayoumu et al., 2023). Phosphorus contributes to the formation and development of flowers and seeds, directly influencing the yield and quality of triticale production (Rajičić et al., 2020). Adequate phosphorus supply can lead to faster maturation and a higher yield (Johan et al., 2021). Phosphorus also helps the plant become more resistant to biotic stress (such as diseases and pests) and abiotic stresses (such as drought or extreme temperatures) (Khan et al., 2023). Phosphorus is essential in the synthesis of nucleic acids (DNA and RNA) and proteins, which are fundamental to all cellular growth and development processes (Kolodiazhnyi, 2021).

Potassium (K) helps plants regulate their water balance by controlling the opening and closing of stomata (Hasanuzzaman et al., 2018). This process helps prevent excessive water loss through transpiration, especially under drought conditions (Yang et al., 2021). Potassium stimulates root growth, enabling the plant to absorb water and nutrients from the soil more efficiently (Sustr et al., 2019). A well-developed root system is essential for supporting a healthy and vigorous triticale crop (Jastrzębska et al., 2023). A plant well-supplied with potassium is more resistant to diseases, pests, and abiotic stresses (such as drought or extreme temperatures) (Hasanuzzaman et al., 2018). Potassium contributes to improving grain quality by increasing protein content and grain size (Azzawi et al., 2021). It can also influence uniform spike maturation and enhance lodging resistance, which is important for the mechanized harvesting of triticale (Chang et al., 2023). Potassium helps synchronize developmental processes, such as flowering and maturation, ensuring uniform plant development (Hasanuzzaman et al., 2018).

This highlights the importance of the presence of both macronutrients and micronutrients in optimally recommended quantities for crops, as they decisively influence production elements (Saquee et al., 2023). Optimizing agricultural technology in triticale thus contributes to a sustainable, profitable agriculture adapted to modern requirements (Bielski et al., 2019; Stoyanov and Baychev, 2023).

The frequency of weeds is due to the lack of herbicide use in the area under study (Nath et al., 2024). Weeds can be detrimental to crop production due to their ability to outcompete cultivated crops for valuable resources such as nutrients, moisture, light and space (Ofosu et al., 2023). The potential of weeds to evolve, epigenetic capacity, hybridization, herbicide resistance, herbicides tolerance, cropping systems vulnerability, co-evolution of weeds with human management and the ability of weeds to ride the climate change storm anthropogenic activities have caused weeds to survive management strategies (Clements & Jones, 2021). Proper use of herbicides leads to higher crop productivity, but non-judicious use may lead to higher residues in crops (Sondhia, 2018).

Presently, herbicides are an integral part of weed management in developed countries (Nath et al., 2024). The adoption and use of herbicides has been slow in non-industrialized farming systems as compared to industrialized farming systems. However, in recent times, the use of herbicides is increasing in areas where traditional farming systems previously relied on mechanical weed control methods (Hossain, 2015). Yield losses due to weeds are of critical concern in cereal-producing areas (Flessner et al., 2021). Left uncontrolled, weeds can result in yield losses of even 100% (Chauhan, 2020). Weed harmfulness depends on several factors, including weed emergence time, weed density, the species composition of the weed community, and weed and crop species competitiveness (Feledyn-Szewczyk et al., 2020). In case of no doses of growth regulators in drier conditions, on better quality soils, high triticale yield can be obtained with low doses of herbicides (Wójcik-Gront & Studnicki, 2021).

Small grain forages are considered an alternative to maize, a globally important forage crop on dairy farms. Triticale is one of the most promising small grains to be cultivated as a source of forage. The inclusion of triticale in the crop rotation system can widen narrow maize rotation, increase biodiversity, and improve the humus balance (De Zutter et al., 2023).

In order to establish the influence of experimental factors on yield, fertilizers and the incidence of weeds, a poly-factorial experience was organized in Jugăstreni Village, Vima Mică Common (located in the Lăpuș

Depression, Maramureș County, Romania) taking into study a variant of winter triticale (Trismart variety). The aim of the research being first of all the quantification of yield, considering that in the studied area the registered productions are very low, and farmers do not use fertilizers or herbicides on their cultures. This study was conducted to observe if by improving technological elements, the production can be optimized. For the assessment of the yield of winter triticale variety, were considered climatic conditions, fertilizers and herbicides application.

MATERIALS AND METHODS

The experimental field was installed in Jugăstreni Village (coordinate 47°23'43.0"N 23°39'51.3"E), Vima Mică Common, Maramureș County which is part of the Lăpuș Depression, Romania. Climatic conditions are represented by temperate continental climate, where the average annual temperature in the area is about 9.3°C and average annual precipitation about 800 mm (Gabor, 2003; The Development Strategy of Vima Mica Commune, 2021-2027).

The experiment was placed according to the method of randomized blocks with four replication. The type of soil specific to the research area is a Typical Luvosol, with a clay-loam texture, characterized by a balanced content of sand, silt, and clay. This is the most widespread among luvisols and has the broadest distribution in hilly and plateau regions (SRTS, 2012). The pH is slightly to moderately acidic (5.5-6.0), good supply of mobile phosphorus, very good to excessive supply of potassium and average to low nitrogen content. The sowing was carried out on October 20 (at the same date in 2021 and 2022), 5 cm depth and 11.9 cm between rows, using Reform Semo 88 (Austria) sowing machine and International 383 (Germany) tractor. The variety sown is winter triticale Trismart, a rustic variety with great adaptability to the conditions of culture, good behavior to falling and to diseases, meeting the expectations of farmers (Antas et al., 2013). During the two years while the research was conducted, the preceding crop was triticale. Fertilizers were applied only on the harvestable plot and also the herbicides.

Fertilization plays an important role when a high production is desired. Nutrient supply, especially that of nitrogen (N), is also a relevant factor in crop production. Generally, N fertilization increases crop yield, however, exceeding N fertilization does not substantially improve yields and has negative effects on the environment (Koppensteiner et al., 2022; Moitzi et al., 2020). Taking this into consideration, four variants of fertilization were established after soil analyses were conducted by the Office of Pedological and Agrochemical Studies from Cluj-Napoca. Soil samples were collected according to the diagonal method and were analyzed as the average sample of 16 partial samples.

The experiment was based on an Ax B - R: 4x 4 - 4 poly-factorial type, according to the method of subdivided plots. The surface of the harvestable plot had 36 m^2 (with 4 m width x 9 m length) and the experimental surface had 576 m^2. Experiment included factors, as follows:

Factors used in analysis

Factor Y - Year with two graduations:

- Year 2022;
- Year 2023.

Factor F - fertilization with four graduations:

- F_1 (Ct) = $N_{80}P_{70}K_0$ kg/ha active substance (a.s.) + 10 kg/ha NH_4NO_3 (ammonium nitrate) active substance (a.s.) applied in the spring (middle of April in both experimental years).
- F_2 = $N_{110}P_{90}K_0$ kg/ha active substance (a.s.) + 20 kg/ha NH_4NO_3 active substance (a.s.)
- F_3 = $N_{140}P_{110}K_0$ kg/ha active substance (a.s.) + 30 kg/ha NH_4NO_3 active substance (a.s.)
- F_4 = $N_{170}P_{130}K_0$ kg/ha active substance (a.s.) + 40 kg/ha NH_4NO_3 active substance (a.s.).

Fertilizer application was carried out manually after determining the required amounts of NPK 20-20-0 and ammonium nitrate (NH_4NO_3), by meeting the methodological rules of the experimental technique. This operation consisted in mixing the individual quantities of each nitrogen, phosphorus and ammonium nitrate in separate recipients, transported to the field and applied. The quantities applied on each harvestable plot are presented in Table 1.

Table 1. Fertilizer quantity on harvestable plot in kg (2022-2023)

Fertilizer / Graduation	Nitrogen (kg)	Phosphorus (kg)	Ammonium nitrate (kg)	Total kg fertilizer/plot
F_1	1.44	1.26	0.11	2.81
F_2	1.98	1.62	0.21	3.81
F_3	2.52	1.98	0.32	4.82
F_4	3.06	2.34	0.43	5.83

Factor B - herbicides with four graduations:

- B_1 = Untreated/Control (Ct)
- B_2 = Comod Superstar 50 SG (dicotyledonous weeds), produced on the basis of tribenuron - methyl 50%, 30 g/ha; Foxtrot 69 EW (monocotyledonous weeds), produced on the basis of cloquintocet-mexyl 34.5 g/l + fenoxaprop-p-ethyl 69 g/l, 0.9-1.1 l/ha. These two were combined and applied on the culture when triticale plants were in phase of 2-3 internodes (BBCH 31-32) and weed plants had 2-3 leaves (BBCH 12-15).
- B_3 = Hudson (annual dicotyledonous, perennial dicotyledonous), based on fluroxypyr 200 g/l, 0.75-1.25 l/ha, applied when plants where in the phase of 2-3 internodes (BBCH 31-32) and weed plants had 3 leaves.
- B_4 = Granstar Super 50 SG (Annual and perennial dicotyledonous weeds), produced on the basis of 25% thifensulfuron-methyl + 25% tribenuron-methyl, 40 g/ha, applied when plants were in the phase of 3-4 internodes (BBCH 32-36) and weeds had 4-5 leaves.

Combating weeds represents an important aspect in order to obtain a high yield. Considering the economic aspect and the spectrum of weeds predominantly encountered in cereal crops over time, a selection of four herbicides was made, of which two were combined for a better effect. Regarding weed control, one variant was left untreated as a control, applying herbicides only to the following three.

These variants of herbicides were applied in both experimental years, 2022 and 2023, on approximately the same dates with a difference of 3-4 days considering the weather conditions. The method was using a garden sprayer, back sprayer with hand pump having a capacity of 16 liters.

In order to determine the level of weed infestation, the metric frame method was used (the quadrat used had 0.25 m^2 but all data will be reported in m^2 by multiplying the results by four). The determinations were made before post-emergence weed control and before harvesting, in two repetitions on the diagonal of the plot, being expressed in the number of weeds m^2.

Considering that production is generally influenced by meteorological conditions as well as the inputs applied to the crop, a meteorological station was installed in the experimental area. The specific model used was HOBO-MAN-H21-002, and it recorded data on soil temperature at depths of 15 and 30 cm, as well as water content at the same depths during the two years. Climatic conditions from January 2022 to September 2023 at the experimental field are presented in the Results and Disscusions section. The harvest of the triticale experiment was gathered manually by meeting the methodological rules of the experimental technique. This operation consisted in collecting the protective strips around the samples and also the road access between the harvestable plots. For yield determination, methodology for field yield evaluation (DCS no 77/1986) was applied (Rusu, 2020). In the absence of specialized equipment for harvesting the experimental plots, measurements were conducted using a metric frame (the same used for determining the level of weed infestation) according to the following procedure: the metric frame was randomly placed on each experimental plot. All spikes within the frame were harvested and counted and the medium number of spikes per m^2 was established. Ten spikes were then selected, and the grains were counted. The total of the grains was divided into ten, resulting in the medium number of grains in spike. Using the number of spikes per square meter (Nr. spikes/m^2) and the number of grains per spike (Nr. grains/spike), along with the Thousand Kernel Weight (TKW), the yield per hectare was calculated using the appropriate formula (Rusu, 2020):

$$Q\left(\frac{kg}{ha}\right) = \frac{\text{Nr.}\frac{spikes}{m2} \times \text{Nr.}\frac{\text{grains}}{\text{spike}} \times \text{TKW (g)}}{1000}$$

Statistical methods

Assessment of data normality distribution was done using descriptive statistics and quantile-quantile (Q-Q) plot. The variables were summarized by mean. Statistical interpretation of experimental data was made by Student T test for the 1st factor (year), Analysis of variance (One-way ANOVA test followed by Duncan post-hoc test for multiple comparisons) for the 2nd and 3rd factors (fertilization and herbicides) and correlations (Pearson correlation). The p-values $p<0.05$, $p<0.01$, and $p<0.001$ denote levels of significance determined. Polyfact (PolyFact, 2020) and Excel 365 software was used for statistical analysis.

RESULTS AND DISCUSSIONS

Agriculture is the sector which is mostly influenced by climatic conditions. The meteorological conditions of the year are of primary importance for the correct growth and development of agricultural crops (Georgieva & Kirchev, 2020).

The temperature regime of the area has an important role in the growth and development of crops, as well as in terms of yield and resistance. Climatic conditions from December 2021 to September 2023 at the experimental field are presented in Figure 1, after Hobo Meteorological Station was installed in Jugăstreni, Maramureș (December 2021).

There were installed two sensors at two different depths (15 cm and 30 cm) for each precipitations and temperature. During the studied period of 22 months (December 2021 - September 2023), rainfall and temperature had more or less significant limits. The highest amount of precipitations was recorded in March 2023 (0.386 mm) at a soil depth of 15 cm, and in September 2023 (0.390 mm) at a soil depth of 30 cm. At the same time, the lowest amount of precipitations was registered in January 2022 (0.182 mm) at a soil depth of 15 cm, and in January 2022 also the lowest (0.048 mm) at a soil depth of 30 cm.

The temperature registered the highest value in May 2022 (22.942°C) at 15 cm soil depth, and in May 2022 (22.700°C) also at 30 cm soil depth. The lowest values were registered in March 2023 (1.546°C) at 15 cm soil depth and also in March 2023 (1.964°C) at 30 cm soil depth. There were not registered negative temperatures during the studied period.

The optimum temperature of triticale growth is considered between 10-24°C, the optimum for germination 20°C, the minimum temperature of survival until -10°C and the maximum temperature of survival 33°C or more.

The year and fertilization influence on yield and productivity elements of the experimental factors were evaluated (Table 2). The number of grains per ear was higher in 2023 (46.25) and lower in 2022 (30.38). Also, the yield from 2023 was higher compared to the yield from 2022. This fact was due to temperatures closer to the optimal value for the triticale crop development during the vegetation period from 2023. Following increased fertilization rates, all three studied characteristics the number of ears per square meter, the number of grains per ear and the yield, presented an increase compared to the unfertilized variant (control group, F1).

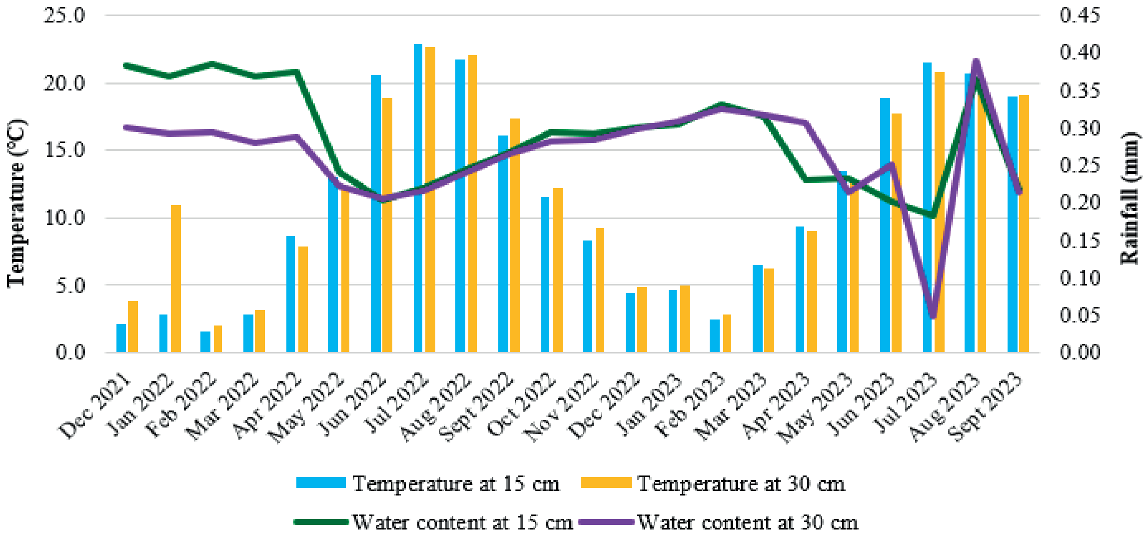

Figure 1. Climatic conditions of the experimental area, Jugăstreni 2021-2023, Hobo Meteorological Station

Table 2. Experimental factors influence on yield and productivity elements

Variables	*Year*				
	1st year (2022)		2nd year (2023)		p-value
No of ears/m2	529.63		491.88		0.055
No of grains/ear	30.38		46.25		< 0.001
Yield (kg/ha)	850.99		1179.04		< 0.001
	Fertilization				
	F1–ct.	F2	F3	F4	p-value
No of ears/m2	473.00[a]	500.50[ab]	520.75[ab]	548.75[b]	0.041
No of grains/ear	31.25[a]	38.38[ab]	45.00[b]	38.63[ab]	0.049
Yield (kg/ha)	785.23[a]	982.49[ab]	1208.92[b]	1083.43[b]	0.006

Note: p - values denote levels of significance from student T test and ANOVA test; a, b - Duncan test.

Analyzing soil chemical characteristics (Table 3), it was observed that increasing fertilization rates resulted in negative changes in both soil pH (5.49) and nitrogen content (0.17 - higher fertilization rates increase soil acidity and nitrogen forms inaccessible to plants can be formed) for the 3rd and 4th fertilization variant compared to the control. Conversely, with the increase in fertilizer quantity, there was a positive change in phosphorus and potassium content for all the fertilization variants compared to the control which was unfertilized.

Table 3. Experimental factors influence on soil chemical composition

Variables	*Year*				
	1st year (2022)		2nd year (2023)		p-value
pH	5.66		5.76		0.214
Nitrogen (%)	0.17		0.18		< 0.001
Mobile Phosphorus (ppm)	36.06		13.75		< 0.001
Mobile Potassium (ppm)	458.56		502.50		0.033
	Fertilization				
	F1–ct.	F2	F3	F4	p-value
pH	5.82[b]	5.79[b]	5.74[b]	5.49[a]	0.003
Nitrogen (%)	0.16[a]	0.18[b]	0.17[b]	0.18[b]	0.002
Mobile Phosphorus (ppm)	15.50[a]	16.88[a]	28.25[ab]	39.00[b]	0.016
Mobile Potassium (ppm)	459.38[a]	492.50[ab]	523.25[b]	447.00[a]	0.036

Note: p - values denote levels of significance from Student T test and ANOVA test; a, b - Duncan test.

Following fertilization, a difference in the number of ears per square meter was observed in all fertilized variants from 2022 compared to the control variant (Figure 2).

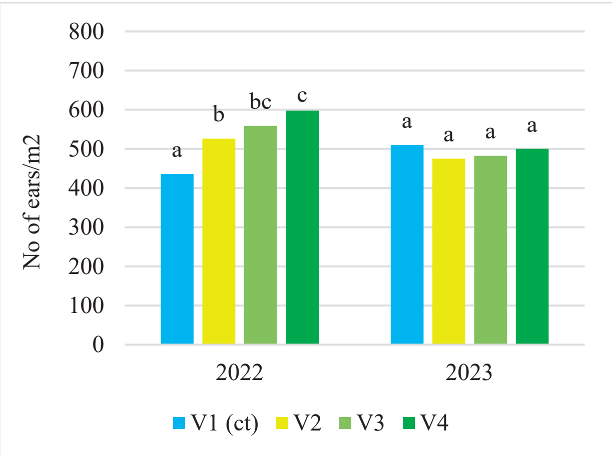

Figure 2. Number of ears/m^2 according to F (fertilizer) in 2022 and 2023. Note: a, b, c - Duncan test

Fertilizers application led to an increase in the number of ears. Even though the second and third variants were higher, still the 4th variant showed higher values than the control (Ct - 436 and V4 - 597.5 ears/m^2). For the year 2023, no differences in the number of ears per square meter were observed compared to the unfertilized variant (V1 - control).

Among the studied interactions, is also the one between fertilizers and yield. In the first year of the study (2022), a positive difference in yield was observed for all the three fertilized variants compared to the unfertilized control variant (Ct) (Figure 3), with the highest yield, recorded for variant 3 (1192.46 kg/ha), while the lowest was for control variant (516.15 kg/ha). For the year 2023, an increase in yield was observed for all fertilized variants compared to the unfertilized variant (V1 - control).

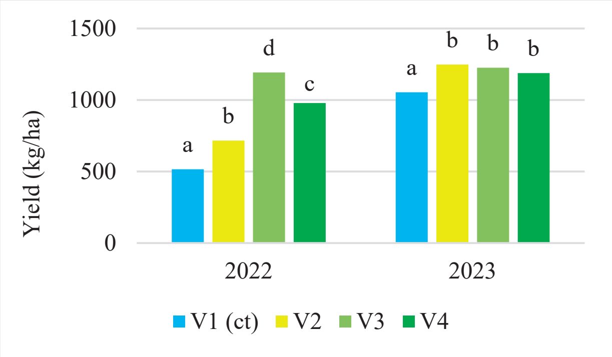

Figure 3. Triticale yield according to F (fertilizer) in 2022 and 2023. Note: a, b, c, d - Duncan test

In addition to the number of spikes per square meter and the yield, a change in nitrogen content was observed after fertilizers application (Figure 4). As a result of fertilization in the first experimental year (2022), the nitrogen content shows a higher value compared to the control for all three fertilized variants. In 2023, following fertilization, all three variants recorded also a higher nitrogen content compared to the control.

Production elements such as the number of grains per ear and the number of ears per square meter, and also yield, pH and soil chemical components, were tested for interaction (Table 4). In 2022, yield was positively influenced by both the number of ears per square meter and the number of grains per ear.

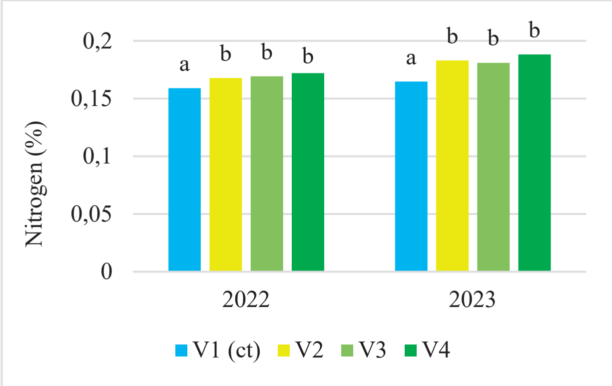

Figure 4. Nitrogen quantity according to F (fertilizer) in 2022 and 2023. Note: a, b - Duncan test

As the number of ears per square meter and the number of grains per ear increases, an increase in yield per hectare is expected. Regarding pH, as its value increases, the number of ears per square meter decreases. Phosphorus content in the soil also presented a positive influence on yield and productivity elements.

Besides, as the amount of nitrogen and phosphorus increases, the pH value decreases. Also, potassium content in the soil negatively influenced the phosphorus content.

Table 4. Correlations between characteristics from 2022

	No of ears/m^2	No of grains/ear	Yield (kg/ha)	pH	Nitrogen (%)	Mobile Phosphorus (ppm)	Mobile Potassium (ppm)
No of ears/m2	1						
No of grains/ear	0.614**	1					
Yield (kg/ha)	0.799***	0.964***	1				
pH	-0.500*	-0.229	-0.339	1			
Nitrogen%	0.452	0.354	0.411	-0.687**	1		
Mobile Phosphorus (ppm)	0.795***	0.473	0.631**	-0.734**	0.478	1	
Mobile Potassium (ppm)	-0.236	0.445	0.254	0.497*	-0.142	-0.563*	1
LSD 5% = 0.497; 1% = 0.623; 0.1% = 0.742.							

Note: p<0.05 (*), p<0.01 (**), and p<0.001 (***) denote levels of significance.

To determine the relationship between analyzed variables for 2022 and 2023 (for both years), the same Pearson correlation was used (Table 5). Consequently, it was observed that in the case of triticale (Trismart variety), yield was influenced by the number of grains per ear (the larger number of grains, the higher the yield). Nitrogen has also shown a positive influence on the number of grains per ear and yield. Important relationships were also determined between soil phosphorus content and productivity elements. As phosphorus levels increase, the number of ears also increases, but an increase level of phosphorus affects the pH value. As pH value increases, the phosphorus content decreases, and the potassium content in the soil increases. Phosphorus negatively influences pH values, while potassium has a positive influence on it.

Table 5. Correlations between characteristics from 2022 and 2023

	No of ears/m^2	No of grains/ear	Yield (kg/ha)	pH	Nitrogen (%)	Mobile Phosphorus (ppm)	Mobile Potassium (ppm)
No of ears/m2	1						
No of grains/ear	-0.089	1					
Yield (kg/ha)	0.293	0.922***	1				
pH	-0.513*	0.075	-0.116	1			
Nitrogen%	-0.083	0.694***	0.618***	-0.233	1		
Mobile Phosphorus (ppm)	0.713***	-0.331	-0.061	-0.600***	-0.184	1	
Mobile Potassium (ppm)	-0.321	0.556***	0.444*	0.379*	0.361*	-0.611***	1
LSD 5% = 0.349; 1% = 0.449; 0.1% = 0.554.							

Note: $p<0.05$ (*), $p<0.01$ (**), and $p<0.001$ (***) denote levels of significance.

Regarding weed control, after implementing the control scheme, the frequency and type of weeds encountered in the triticale crop were determined.

When examining the number of monocotyledonous and dicotyledonous weeds (from both years), a decrease in their numbers was observed (Figure 5) following the three herbicide applications compared to the untreated sample (control). The most effective treatment for monocotyledonous weeds was treatment B4 followed by B2 and B3, while for dicotyledonous weeds, treatments B3 and B4 showed the best results.

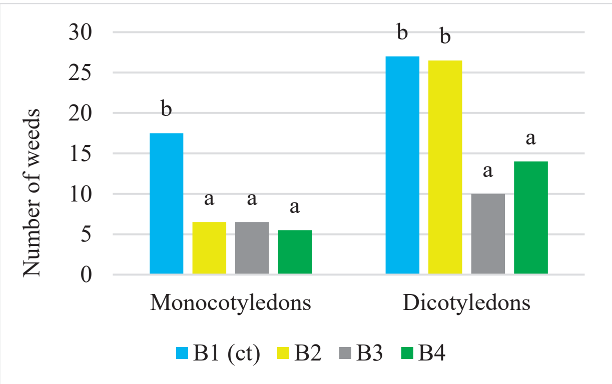

Figure 5. Number of Monocotyledons and Dicotyledons from the experimental field. Note: a, b-Duncan test

Focusing on the number of monocotyledonous weeds (Figure 6), a decrease was observed following the three herbicide applications in both experimental years compared to the untreated sample (control). The most effective treatments in 2022 were treatments B3 and B4, while in 2023, the best results were achieved with treatments B2 and B4.

As for the quantity of dicotyledonous weeds, a decrease was observed (Figure 7) following the three herbicide applications in both experimental years compared to the untreated sample (control). The most effective treatments for dicotyledonous weeds in both 2022 and 2023 were treatments B3 and B4.

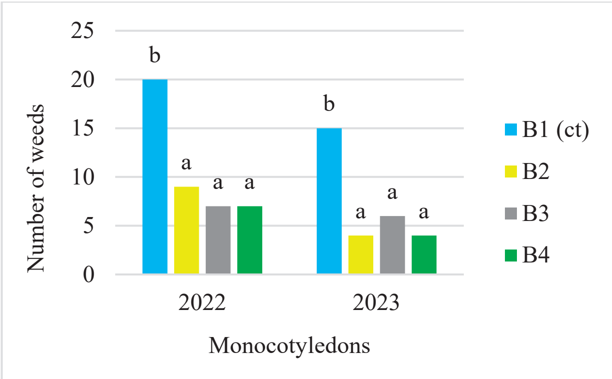

Figure 6. Number of monocotyledons from 2022 and 2023. Note: a, b - Duncan test

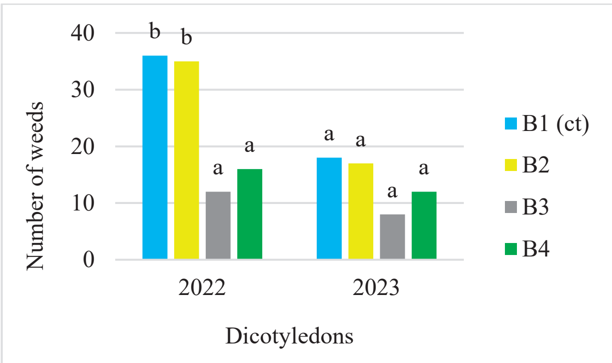

Figure 7. Number of dicotyledons from 2022 and 2023. Note: a, b - Duncan test

CONCLUSIONS

The highest yield was recorded for variant 3 (1192.46 kg/ha), in 2022 while the lowest was for control variant (516.15 kg/ha). It is not recommended application excessively high amounts of fertilizer (see variant 4) because, due to weather conditions (high precipitation and strong winds), it has been shown that plant lodging resistance was affected, which leads to a potential reduction in yield (depending on the growth stage of the plants at the time of lodging) and complicates the harvesting process.

Based on the obtained results it could be concluded that the grain yield capacity of the studied winter triticale variety Trismart is around 1100-1200 kg/ha, depending on fertilizer quantity. In the Lăpuș Depression, regardless of the climatic conditions, fertilization with $N_{110}P_{90}K_0$ kg/ha active substance (a.s.) + 20 kg/ha NH_4NO_3 active substance (a.s.) and $N_{140}P_{110}K_0$ kg/ha active substance (a.s.) + 30 kg/ha NH_4NO_3 active substance (a.s.) applied in the spring seems to be most indicated because high grain yields per hectare were obtained.

The explosive weeding of the triticale crop, the infestation and the variability of the ratio between weed species impose a specific differentiated strategy of integrated control of weeds, in order to reduce their number below the economic threshold of damage. The best results in terms of control were obtained with variants B3 (Hudson) and B4 (Granstar). From an economic perspective (herbicide effect and price), it is recommended variant B4.

To obtain more in-depth results (such as grain quality, baking capacity, feed efficiency, and straw production) regarding the cultivation of the variety in the studied area, it is recommended a study over a longer period

ACKNOWLEDGEMENTS

This work was supported by the project "Collaborative Framework for Smart Agriculture" - COSA that received funding from Romania's National Recovery and Resilience Plan PNRR-III-C9-2022-I8, under grant agreement 760070.

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