PhD THESIS

Optimization of the cultivation technology of triticale under the conditions of Lăpuș Depression

(Summary of the Phd thesis)

PhD student **Iuliana Cionca**

Scientific coordinator **Prof. univ. dr. Teodor Rusu**

INTRODUCTION

Triticale, the first successfully developed cereal hybrid, was created in 1875 by Wilson through the crossbreeding of wheat (*Triticum*) and rye (*Secale*). Since its inception, the evolution of this crop has been of significant interest to scientists. According to researchers, triticale is expected to combine the best characteristics of its parent species: the baking quality and food production potential of wheat with the adaptability of rye to difficult soils—poorly drained, cold, disease-prone, and requiring minimal agricultural inputs. Over time, it has been observed that triticale yields are remarkably high, competing with the most common wheat varieties. Given its efficient utilization of nutrient-poor soils, this crop has the potential to contribute to alleviating poverty in underdeveloped regions. Nevertheless, ongoing research continues to investigate its adaptability, performance potential, and applications (Ammar et al., 2004).

Although triticale is not as widely recognized as wheat or maize and has had a relatively short history, it has come to occupy significant agricultural areas worldwide, covering approximately 4 million hectares, over 70% of which are in Europe. The newly developed triticale varieties outperform other crops in terms of forage quality and biomass production, making them valuable for both human and animal consumption (Nefir et al., 2011).

Triticale, also known as *Triticosecale*, is an essential component of modern agriculture, particularly in the exploitation of less productive lands that are unsuitable for wheat or maize cultivation. These include acidic soils, drought-prone areas, waterlogged fields, and nutrient-deficient lands. The necessity for this crop arises from the continuous growth of the global population and the increasing demand for food for both humans and livestock.

At present, triticale production competes with that of other cereals such as wheat and barley. One of the most significant advantages of this hybrid is its high nutritional content, particularly its protein concentration, resulting from the crossbreeding of wheat and rye. This crop holds particular importance both for direct human consumption and for use as animal fodder. Triticale varieties exhibit exceptional forage properties, making them particularly suitable for livestock feeding. It can be utilized in various forms, including fodder, green feed, or hay (Bielski, 2015).

However, global triticale and cereal production has not kept pace with the rapid population growth. Data indicate that in recent years, total global cereal production has fallen below average, which could contribute to food shortages at a global scale (Glamočlija et al., 2017). A viable solution to this issue is the expansion of triticale cultivation into marginal, arid, and nutrient-poor regions, which are increasing due to climate change. Recent triticale varieties have demonstrated significant improvements in their biological properties and overall quality, particularly with increased protein content, including a higher lysine concentration. This enhancement makes triticale more suitable for human consumption, as it can be used in flour blends with wheat for bread production, while still maintaining its role as a valuable livestock feed (Baier & Gustafson, 1996).

Objectives of the research project

In order to achieve the primary aim of the thesis, several specific objectives have been established. These objectives will guide the study and, upon their completion, will provide the necessary information to support the research findings.

- assessing the influence of the fertilization system on soil properties;
- evaluating the effects of chemical treatments on the quantitative and qualitative parameters of triticale yield;
- monitoring the weed spectrum following the application of chemical fertilizers;
- selecting appropriate herbicides based on the weed species present in the crop and developing a comprehensive weed control strategy;
- conducting a comparative analysis of the yields obtained for each fertilization and weed control variant;
- conducting an analysis of the economic efficiency of the agricultural production process.

Optimizing the cultivation technology for triticale in the Lăpuș Depression is a necessity for increasing the economic efficiency of farms, adapting to local climatic and pedological conditions, reducing costs, and enhancing the sustainability of agriculture in the area.

Experimental Factors

The research was conducted in the village of Jugăstreni, within Vima Mică commune, located in the southwestern part of Maramureș County, near the Lăpuș Depression. The experimental study was carried out from 2021 to 2023 and was designed as a bifactorial field experiment.

The experimental factors were:

Factor A – Fertilization System with Four Levels

- A1: 80 kg/ha a.i. N + 70 kg/ha a.i. P from N-P-K 20-20-0 (N_80 P_70) a.i. + 10 kg/ha a.i. ammonium nitrate
- A2: 110 kg/ha a.i. N + 90 kg/ha a.i. P from N-P-K 20-20-0 (N_110 P_90) a.i. + 20 kg/ha a.i. ammonium nitrate
- A3: 140 kg/ha a.i. N + 110 kg/ha a.i. P from N-P-K 20-20-0 (N_140 P_110) a.i. + 30 kg/ha a.i. ammonium nitrate

• A4: 170 kg/ha a.i. N + 130 kg/ha a.i. P from N-P-K 20-20-0 (N_170 P_130) a.i. + 40 kg/ha a.i. ammonium nitrate

Factor B – Weed Control System with Four Levels

• B1: Unweeded/control

• B2: Mixture: COMOD SUPERSTAR 50 SG – 30 g/ha (tribenuron-methyl 50%) post-emergence – applied at the three-leaf stage of the crop until the flag leaf ligule becomes visible. FOXTROT 69 EW – 0.9–1.1 L/ha (fenoxaprop-P-ethyl 69 g/L + cloquintocet mexyl 34.5 g/L) post-emergence – applied when weeds are in the 1–2 leaf stage up to the 3–4 leaf stage.

• B3: HUDSON – 1 L/ha if weeds are small or 2 L/ha if weeds are larger (fluroxypyr 200 g/L) post-emergence – applied between the three-leaf stage and the visible second internode stage of the crop.

• B4: GRANSTAR SUPER 50 SG – 40 g/ha, 2 g/10 L water (500 m^2), (25% thifensulfuron-methyl + 25% tribenuron-methyl) post-emergence – applied from the tillering stage until the emergence of the flag leaf. For weeds, applied from the cotyledon stage up to a maximum of six true leaves.

The field experiment followed an A × B – R: 4 × 4 – 4 factorial design, resulting in 16 experimental variants with four replications, as follows:

V1 – a1b1
V2 – a1b2
V3 – a1b3
V4 – a1b4
V5 – a2b1
V6 – a2b2
V7 – a2b3
V8 – a2b4
V9 – a3b1
V10 – a3b2
V11 – a3b3
V12 – a3b4
V13 – a4b1
V14 – a4b2
V15 – a4b3
V16 – a4b4

The experiment was conducted on a winter triticale crop of the Trismart variety (Fig. 5.1.). This variety is considered rustic, highly adaptable to various cultivation conditions, and exhibits good resistance to lodging and diseases. The plant has a medium-to-tall height, semi-early to early heading, and semi-late maturity. It is classified as a well-balanced variety, featuring high protein content and strong production potential, with a thousand kernel weight (TKW) of 52 g.

Under optimal sowing conditions, a seeding rate of 180 kg/ha is recommended. This variety is suitable for all triticale-growing regions (www.dinagris.ro).

Fig. 5.1. Trismart Variety
Source: Original

The experimental research aimed to monitor the influence of differentiated fertilization and applied treatments on the productive and agrochemical parameters of triticale cultivation. The experimental field was established on May 5, 2021, adhering to the technological requirements specific to the region.

The bifactorial experiment, implemented in four replications, was designed using the split-plot method, which allows for precise control of variability and interaction between experimental factors (Fig. 5.2). This methodological approach is essential given the variable soil and climate conditions, enabling an accurate evaluation of plant responses to different fertilization and treatment regimes.

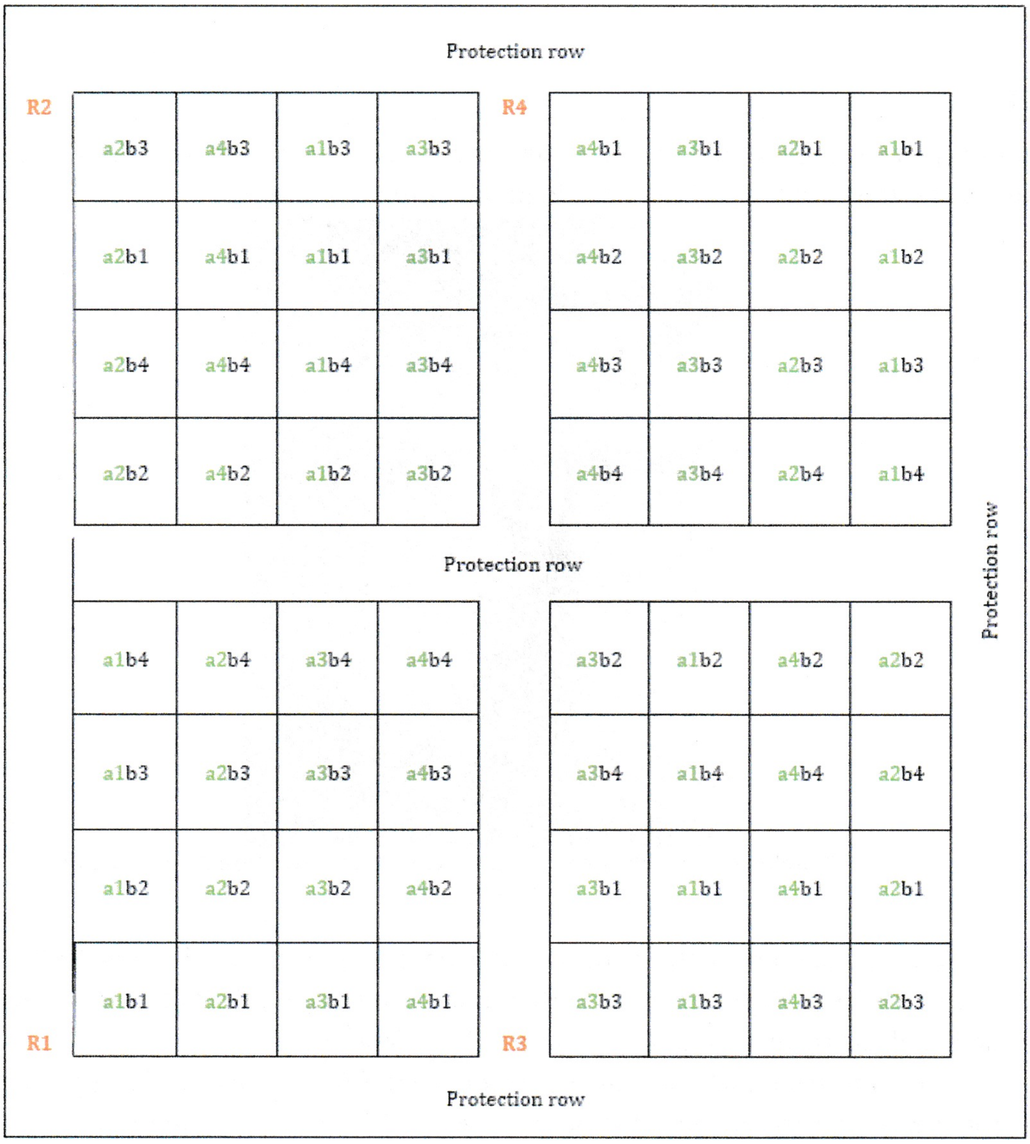

Fig. 5.2. Triticale Experimental Field Layout
Source: Original

Each experimental variant was allocated individual plots of 36 m^2, with plots measuring 4 m in width and 9 m in length. Access roads and buffer strips were set at 2 m wide to prevent cross-contamination between variants. The regional crop technology, adapted to the specific pedoclimatic conditions and triticale requirements, was applied in the observation plots.

Sowing was performed annually on October 20 using the Reform Semo 88 seeder, ensuring uniform seed distribution. The row spacing was set at 11.9 cm, and the sowing depth was 5 cm, which is optimal for germination and early plant development, as supported by specialized literature. The sowing process was carried out in conjunction with an International 383 tractor (Fig. 5.3). The preceding crop was winter triticale, maintained to ensure uniform evaluation conditions and to analyze the effects of differentiated technologies in monoculture conditions.

Fig. 5.3. Reform Semo 88 Seeder Aggregated with International 383 Tractor
Source: Original

Soil fertilization in the experimental field was performed using NPK 20-20-0 complex fertilizers, supplemented with ammonium nitrate (33.5%), selected based on the soil analysis results conducted at OSPA Cluj (Table 6.1).

The analyses indicated that the experimental field consists of a typical Luvisol, characterized by variable nutrient supply levels, with a slightly to moderately acidic pH (5.5–6). This soil type is rich in potassium but significantly deficient in nitrogen and phosphorus, which may limit optimal triticale development in the absence of adequate nutrient supplementation.

- mobile phosphorus was generally well represented;
- nitrogen, a crucial element for growth and vegetative development, was found at medium to low levels;
- potassium was highly abundant, ranging from very good to excessive availability.

Due to these findings, potassium doses were reduced, focusing fertilization efforts on nitrogen and phosphorus supplementation.

To correct nutrient deficiencies and optimize crop productivity, the following fertilization approach was implemented:

- NPK 20-20-0 was applied during seedbed preparation;
- ammonium nitrate was applied simultaneously with NPK, in a mixed formulation.

The exact doses of nitrogen and phosphorus were determined based on initial soil chemical analyses, ensuring a steady nutrient supply throughout the crop cycle. The application of NPK 20-20-0 and ammonium nitrate was targeted at the crop base, supporting early root development and tillering stimulation.

Fertilization was strictly applied to plots designated for experimental harvests, preventing overapplication to minimize nutrient leaching and volatilization losses. Weed control was performed through a single application of chemical treatments at different vegetation stages (Factor B). These treatments included both herbicide mixtures and standalone herbicide applications, targeting monocotyledonous and dicotyledonous weed species predominant in the triticale crop.

The optimal timing for herbicide application was determined by monitoring weed and crop growth stages, ensuring maximum treatment efficacy while minimizing negative effects on the primary crop.

Results and conclusions

The research conducted in the Lăpuș Depression aimed to optimize triticale cultivation technology through the application of efficient fertilization and weed control strategies, taking into account the specific pedoclimatic conditions of the region. The study highlighted the significant influence of experimental factors on soil properties, crop growth, and yield, providing practical solutions for improving agricultural productivity.

Impact of Fertilization on Productivity Elements

Fertilizer application had a positive influence on spike density, the number of grains per spike, and total yield.

The F3 fertilization variant (NPK 20-20-0 + ammonium nitrate 33.5%) yielded the best results, with an average production of 3192 kg/ha, compared to the control variant (2516 kg/ha) in 2022.

Fertilization stimulated spike formation and root system development, increasing nutrient use efficiency.

The favorable climatic conditions of 2023, compared to 2022, supported better plant growth and optimal nutrient absorption.

Influence of Fertilization on Soil Chemical Parameters

Fertilization significantly altered soil composition, particularly affecting pH, nitrogen content, and phosphorus availability.

The application of nitrogen fertilizers resulted in slight soil acidification, with pH decreasing in some variants from 6.04 to 5.72.

Mobile phosphorus improved significantly in certain variants, increasing from 8–22 ppm to 34–81 ppm, confirming the effectiveness of phosphate fertilizers.

Mobile potassium fluctuated, indicating possible leaching in some plots.

Correlations Between Experimental Factors and Yield

The study identified significant correlations between yield, spike density, nitrogen content, and mobile phosphorus.

Spike density (spikes/m^2) showed a positive correlation with yield ($r = 0.799$), confirming the impact of fertilization on plant density.

Soil nitrogen content correlated significantly with the number of grains per spike and total yield, highlighting its essential role in plant metabolism.

A higher level of mobile phosphorus was associated with better root system development and more efficient nutrient uptake.

Weed Control Efficiency

The weed analysis in the triticale crop identified a prevalence of Galeopsis tetrahit, Trifolium spp., Atriplex patula, and Poa spp.

The B3 and B4 treatments were the most effective against dicotyledonous weeds, while B4 had the highest efficiency against monocotyledonous weeds.

Herbicide application significantly reduced weed density, contributing to an increase in crop yield.

Integrated weed control strategies, including crop rotation and annual monitoring, are essential for maintaining long-term treatment effectiveness.

Optimization of Triticale Cultivation Technology

Until now, fertilization and weed control have been carried out without a clear scientific foundation, leading to inefficient and inconsistent applications.

The study demonstrated that rational application of fertilizers and herbicides improves yield and reduces nutrient losses.

The optimal recommendation includes:

Single-phase fertilizer application in spring

Use of herbicides adapted to the weed spectrum

Optimizing cultivation technology must also consider economic efficiency, as farms in the Lăpuș Depression are small-scale operations.

Adopting sustainable practices can enhance farm profitability and provide viable solutions for maintaining local agriculture.

The results confirm the importance of balanced fertilization and effective weed control in optimizing triticale cultivation technology. By applying scientifically based strategies, farmers can:

Increase yields

Reduce costs

Maintain soil fertility over the long term

This study provides a sustainable model for agricultural resource management, adaptable to the specific pedoclimatic conditions of the region.

Recommendations regarding the economic efficiency of agricultural production: It is recommended to adopt fertilization strategies adapted to the variability of climatic conditions in the Lăpuș Depression:

- **In years with sufficient rainfall:** It is recommended to apply an intensive fertilization regime (variant A3), which maximizes production and profitability by taking advantage of optimal moisture conditions for efficient nutrient uptake.
- **In years with reduced rainfall:** It is recommended to opt for a moderate fertilization regime (variant A1), which minimizes additional costs and prevents nutrient losses, while ensuring superior economic efficiency.

These recommendations underscore the importance of flexible management of agronomic inputs, adapted to local soil and climate conditions, to ensure the long-term sustainability and profitability of triticale cultivation.

Originality

The research conducted in this study provides significant original contributions to the field of triticale cultivation technologies by integrating multidimensional experimental approaches specifically adapted to the variable pedoclimatic conditions of the studied region. A key element of originality lies in extending the analysis beyond total grain yield, incorporating an assessment of quality-related characteristics such as the number of grains per spike, nitrogen and phosphorus content in the soil, and interactions among these factors. Unlike existing studies, which often focus on a single agricultural season or isolated factors, this research employed a multi-annual experiment and a complex statistical evaluation, allowing for the identification of significant correlations between fertilization, soil parameters, and yield performance.

The methodology used to analyze correlations between agrochemical soil parameters (pH, nitrogen, phosphorus, potassium) and grain yield represents another innovative aspect of this research. It highlights relationships that have been insufficiently explored in previous studies. For instance, the negative relationship between pH and phosphorus availability demonstrated the necessity of soil amendments and fertilization adjustments to maintain soil fertility and optimize nutrient uptake. Another original aspect of this study is the differentiated analysis of weed control efficiency for monocotyledonous and dicotyledonous species over two consecutive experimental seasons, emphasizing the influence of climatic conditions on weed sensitivity and herbicide effectiveness.

Additionally, this study offers a major practical contribution by providing recommendations for farmers in regions characterized by acidic soils or pronounced pedoclimatic variability. These recommendations include adjusting fertilization rates based on soil pH and specific seasonal conditions, implementing integrated weed control strategies, and adopting sustainable practices to support agroecosystem resilience. By correlating experimental results with existing research, this study provides a robust foundation for optimizing triticale production systems across diverse ecological conditions.

Furthermore, the results open new research avenues, suggesting the necessity of long-term studies to fully evaluate grain quality, straw yield, and the nutritional value of the crop. The accumulated data can support further research on bread-making potential, forage digestibility, and the use of triticale straw for bioenergy production, thus highlighting the versatility of this species and its agronomic and economic value.

The originality of this research derives from both its multidisciplinary approach and the practical applicability of its findings, advancing knowledge in agricultural technologies and supporting informed decision-making in the efficient management of triticale crops, particularly in the studied region.