

A close-up photograph of rice stalks with green leaves and yellowish-brown grain heads, serving as the background for the text.

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**5TH INTERNATIONAL CONFERENCE
ABOUT RICE AND ENGINEERING
SCIENCES IN BRĂILA**

31st JANUARY 2025
BRĂILA- ROMANIA



PROCEEDINGS OF “5TH INTERNATIONAL CONFERENCE ABOUT RICE AND
ENGINEERING SCIENCES IN BRAILA (ICRESB - 2025)”

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PROCEEDINGS OF “5TH INTERNATIONAL CONFERENCE ABOUT RICE AND ENGINEERING SCIENCES IN BRAILA (ICRESB - 2025)”



Ministerul Agriculturii și Dezvoltării Rurale
(M.A.D.R.)



Academia de Științe Agricole și Silvice
"Gheorghe Ionescu-Șișești"
(A.S.A.S.)



CERCETARE PENTRU BUNĂSTARE

ICRESB

FINAL PROGRAMME OF ICRESB 2025 CONFERENCE

31st JANUARY 2025, 10:00 AM, ROMANIA TIME

<https://us06web.zoom.us/j/85283640546?pwd=EpdU7nlyGbbd6bCuj6uong4Pv9HFb.1>

Meeting ID: 852 8364 0546

Passcode: 076127



SECTION 1:

10:00 – 10:05	INTRODUCTIVE PRESENTATION ABOUT ICRESB '25 CONFERENCE - Daniela TRIFAN
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10:35 – 10:50	1.3. STOP WASTING NITROGEN Author: <i>Alexandre MOUREAU</i> - ADVAGREEN Eastern Europe, Budapest Hungary
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SECTION 2:



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SECTION 1:



1.1. THE EFFECT OF RICE ON GUT MICROBIOTA AND BLOOD LIPIDS

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Abstract

Rice is a basic food source worldwide, significantly affecting gut microbiota and blood lipid profile. At the same time, rice can provide prebiotic properties that affect gut microbiota during digestion. Brown rice, especially, with its high fiber content, supports the proliferation of beneficial bacteria in the gut and helps reduce LDL cholesterol and triglyceride levels by increasing the production of short-chain fatty acids (SCFA). Rice can regulate gut microbiota and increase beneficial bacteria and reduce the negative effects related to obesity, inflammation, metabolic disorders. In addition, the soaking and germination processes of rice both improve glycemic control and have positive effects on gut microbiota. It is observed that less milled rice contains higher dietary fiber and phenolic compounds, which are fermented by gut microbiota and increase the production of SCFA. Rice types promote the growth of beneficial bacterial populations such as *Bifidobacterium* spp. and *Lactobacillus* spp. and positively affect the diversity of the intestinal microbiota. Some rice varieties, on the other hand, can create a different microbiota profile due to their low fiber content. In short, the effect of rice species on intestinal bacteria can play a significant role in metabolic processes and blood lipid levels. This study aimed to review the relationship between the consumption of different rice species and the composition of the intestinal microbiota, its effect on the blood lipid profile, its function, and its effects on metabolic health.

Keywords: Fermented Rice Products, Intestinal Microbiota, Brown Rice, Blood Lipids

INTRODUCTION

The interactions between the human gut microbiota and indigestible food ingredients significantly influence health and illness. This includes energy harvesting and storage, among other metabolic processes. Additionally, the host immune system and the gut microbiota interact by exchanging signals that support immune cell maturation and the proper development of immune functions. Diet, age, and mode of birth are factors that influence gut microbial populations (Pham et al., 2017). The gut microbiota creates short-chain fatty acids (SCFAs) as these indigestible carbohydrates ferment. Previous research has shown that the gut microbiota's production of SCFAs is linked to

human glucose metabolism and lipid metabolism. According to a different study, the gut microbiome composition of Japanese individuals revealed greater abundances of *Bifidobacterium* and *Blautia* than those of Western and other Asian individuals (Mano et al., 2018).

Rice is a dietary staple for more than half of the global population. Polished rice, or white rice, is the most frequently consumed rice variety due to its superior taste and texture. However, its rapid starch digestibility and the depletion of nutrients during the milling process have raised health-related concerns, particularly the increased risk of type 2 diabetes and insulin resistance associated with long-term consumption (Zhang et al., 2022). As a result, whole grains, including brown rice, have attracted significant public interest and are recognized for their numerous health-promoting benefits (Saleh et al., 2019). Nevertheless, the broader acceptance of brown rice remains constrained by its relatively higher cost, less favorable texture, and less desirable cooking characteristics. Recent research indicates that innovative processing techniques may effectively retain essential nutrients and enhance the rheological properties of whole grains (Liu et al., 2022).

The fermentation properties of moderately milled rice and its interaction with gut microbiota have been scarcely explored and require further investigation. Following digestion, the majority of white rice, primarily composed of starch, is absorbed in the gastrointestinal tract. In contrast, for brown rice and other whole grains, dietary fiber and nutrients bound to it, such as proteins and polyphenols, are less readily digested and absorbed. These components often reach the colon, where they interact with the gut microbiota. This interaction leads to the production of metabolites, including short-chain fatty acids (SCFAs) and branched-chain fatty acids (BCFAs), which serve as signaling regulators and influence gut health and host metabolism. Milling removes the bran layers of cereal grains, including the pericarp, testa, and aleurone layer. Different degrees of milling retain varying proportions of the bran layer, altering nutrient binding and, consequently, digestion properties. As a result, rice with different milling degrees (MDs) presents distinct compositions post-digestion and absorption, leaving varying fermentation substrates available for gut microbiota. This variation influences microbial fermentation, the gut microenvironment, and overall gut health. While the effects of whole grains on gut health have been extensively studied, the specific response of gut microbiota to rice with varying MDs remains largely unexplored (Zhang et al., 2024).

This study aimed to evaluate the effects of rice consumption of different types of processing methods on the diversity and composition of the gut microbiota and to reveal possible associations of these changes with blood lipid profile (e.g. LDL, HDL, total cholesterol, and triglyceride levels). In line with this aim, the effects of rice on metabolic health according to diet, especially findings that may be associated with the risks of cardiovascular diseases and metabolic syndrome can be evaluated. The study may highlight the important role of gut microbiota on health and the effects of nutritional interventions on this balance.

The Relationship Between Rice and Gut Microbiota

Rice consumption has been increasingly linked to health outcomes mediated by gut microbiota, the complex community of microorganisms residing in the gastrointestinal tract. The type and composition of rice, including polished white rice and whole grains such as brown rice, influence its digestion, fermentation, and interaction with gut microbiota (Mano et al., 2018).

White rice, predominantly composed of easily digestible starch, is rapidly absorbed in the small intestine, leaving minimal substrates for microbial fermentation in the colon. In contrast, whole grains like brown rice contain higher levels of dietary fiber, polyphenols, and bound nutrients, which resist digestion and reach the colon where they serve as fermentation substrates for gut microbiota. This interaction can lead to the production of bioactive metabolites, such as short-chain fatty acids (SCFAs), that play crucial roles in regulating gut health, inflammation, and metabolic processes.

While whole grains are recognized for their positive effects on gut microbiota and overall health, the degree of rice milling, which removes varying amounts of the bran layer, significantly alters its nutrient composition and fermentation properties. Understanding how different types of rice and their processing levels influence gut microbiota composition and function is critical for unraveling their role in gut health and related metabolic disorders. This intricate relationship between rice, gut microbiota, and health outcomes warrants further exploration to inform dietary recommendations and processing innovations (Han et al., 2018).

In a study it was researched to investigate the effects of whole grain-based cereal products on infants' gut microbiota because of the growing acceptance of whole grain cereals as an early weaning diet, their influence on gut microbiota, and the potential for disease development. They found an in vitro infant gut microbiota model system to examine the effects of four commercially available cereal products on infant gut microbiota and SCFAs: Bellamy's organic baby rice cereal, Weet-BixTM, gluten-free Weet-BixTM, and Real Good Food-Organic baby oat cereal. Compared to other treatments, including rice resulted in a considerably greater relative abundance of Bifidobacteriaceae ($P < 0.0001$). When rice was added, the relative abundance of the Lactobacillaceae family increased significantly ($P < 0.05$), and the Lactobacillus family was common in younger infants (age < 6 months) (Gamage et al., 2017).

A significant amount of the daily diet is made up of grains, which include wheat, rice, and plain oats. These foods are sometimes referred to as staple foods. In research, a different dietary staple was substituted (wheat in the first week, rice in the second, and oats in the third), and each person consumed the same quantity and kind of food each day. As a result, they found that the Weighted UniFrac distance between groups at various time points shows that when comparing the effects of the three staple foods on the gut flora, wheat had the most effect, followed by rice and oats (Li et al., 2017).

Recent research on whole grain eating and its impact on gut microbiota and satiety in healthy adults is compiled in a review. To ascertain whether brown rice and white rice, as well as whole grain barley and refined grain barley, have different effects on microbiota, more research is required. White and brown rice showed almost equal satisfaction scores, while whole grain items, such as whole grain wheat bread and pasta, scored higher than their refined grain counterparts. Overall self-reported satiety scores and ad libitum calorie or macronutrient intake at lunch did not differ amongst subjects in a study comparing satiety reactions to cooked cereals made of whole grain wheat, whole grain rye, or refined rice had at breakfast (Cooper et al., 2015).

In research, it was investigated the local and worldwide differences in Asian children's fecal bacterial communities and the relationship between these Asian microbiota characteristics and host factors, such as dietary practices. The different ethnic groups live in different parts of Asia and preserve their own traditions and dietary customs, there are significant differences both between and within these regions. We described the bacterial community in fecal samples taken from 303 school-age children who lived in urban or rural locations throughout five nations in temperate and tropical Asia to address the variety in their gut microbiota. The 303 participants' microbiota profiles were divided into two enterotype-like clusters, each of which was dominated by Bifidobacterium/Bacteroides (BB-type) or Prevotella (P-type). While individuals from Indonesia and Khon Kaen in Thailand primarily harbored P-type, the majority in China, Japan, and Taiwan harbored BB-type. A more conserved bacterial community that shares more type-specific phylotypes was the hallmark of the P-type microbiota. The frequency of rice consumption and P-type microbiota have a favorable correlation in the study. Several Japanese patients (13%) exhibited BB-type microbiota despite eating rice three times a day, indicating that the microbiota type is greatly influenced by other national variables. One explanation could be the variations in the rice cultivars consumed daily in each nation, which affect intestinal absorption and digestion and have different fine-structured starches (Nakayama et al., 2015).

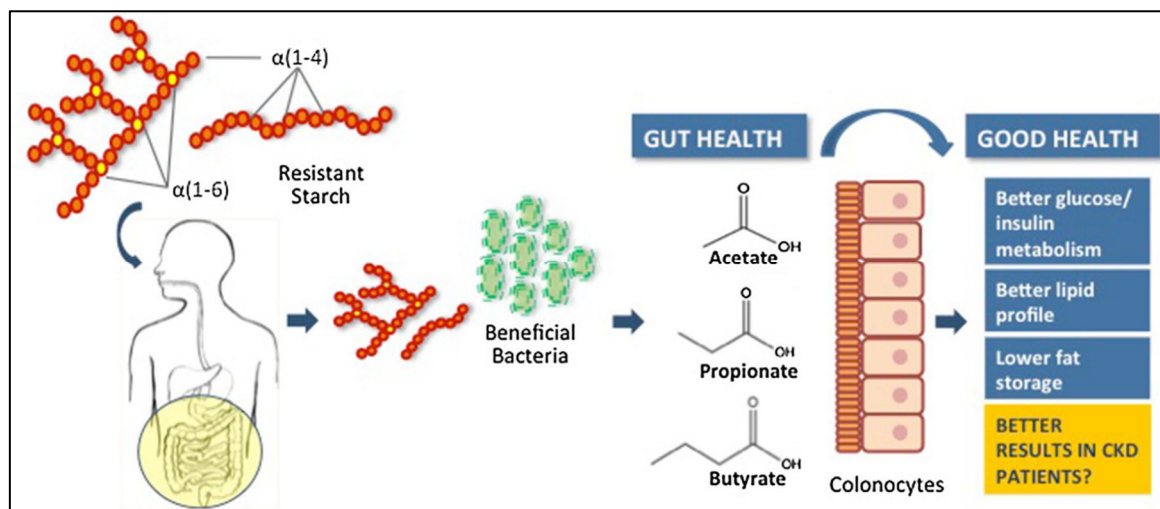


Fig. 1. Resistant starch and good health relation in the gut (it was taken from Moraes et al., 2016)

The connection between "gut health" and "good health" is becoming more and more clear (Fig. 1). It is important to note that prebiotic ingestion may also help chronic kidney disease (CKD) patients with other possible benefits like improved lipid profiles, glucose metabolism, and weight control (Moraes et al., 2016).

In another study, fermented sticky rice (FGR) was shown to reduce inflammation and oxidative stress by improving intestinal barrier function in a DSS (dextran sodium sulfate)-induced ulcerative colitis model. FGR increased the expression of tight junction proteins (ZO-1 and occludin) and improved intestinal permeability and colon damage. At the same time, FGR reduced the production of proinflammatory cytokines (IL-6, TNF- α , IL-1 β), supported antioxidant defense mechanisms (catalase and superoxide dismutase activities), and promoted the growth of beneficial bacteria (e.g. *Bifidobacterium*) in the gut microbiota. The study suggests that FGR may be a potential treatment strategy in inflammatory bowel diseases such as ulcerative colitis (Kim et al., 2023).

It was determined that brown rice enriched with resistant starch exhibited prebiotic properties and improved gut health in obese mice. The study found that resistant starch promoted the increase of beneficial bacteria (e.g., *Bifidobacterium* and *Akkermansia muciniphila*) in the gut microbiota, increased the production of short-chain fatty acids (SCFA), and improved intestinal barrier integrity. Furthermore, brown rice consumption reduced inflammation and contributed to the improvement of metabolic disorders associated with obesity. These findings suggest that resistant starch-enriched foods may be a potential nutritional strategy to alleviate obesity-related gut health problems (Park et al., 2024).

Complex Interactions Between Rice, Gut Microbiota, and Blood Lipids

Hyperlipidemia, a prevalent pathological condition, is characterized by abnormally elevated blood lipid levels. Modifiable lifestyle factors, including high-fat diets, physical inactivity, and smoking, have significantly contributed to its increasing global prevalence (Alloubani et al., 2021; He & Ye, 2020). As lipid disorders are primary drivers of cardiovascular diseases, their prevention and treatment are critical in clinical practice.

Dietary patterns play a vital role in the development and management of hyperlipidemia. Advances in functional foods have led to the identification of several crops, such as oats, tartary buckwheat, black rice, and giant embryo rice, that possess therapeutic potential against hyperlipidemia. Among these, brown rice, a whole grain retaining its bran layer and germ, has gained attention due to its

enhanced sensory and nutritional properties when germinated. Germinated brown rice (GBR) is rich in essential nutrients, including minerals, vitamins, dietary fibers, and bioactive compounds such as ferulic acid, γ -oryzanol, and γ -aminobutyric acid (GABA). As a promising functional food, GBR has demonstrated health benefits in managing various disorders, including hyperlipidemia, hypertension, diabetes, cardiovascular diseases, Alzheimer’s disease, and cancers. Specifically, GBR contributes to the alleviation of hyperlipidemia by improving lipid metabolism. However, while many studies have explored the hypolipidemic effects of GBR in animal models, there remains a limited understanding of its mechanisms and effects on hyperlipidemia in humans (Hu et al., 2022; X. Li et al., 2023).

The gut microbiota, a complex and diverse microbial ecosystem, is integral to human health. Dysbiosis of the gut microbiota has been implicated in a range of diseases, including metabolic, gastrointestinal, cardiovascular, and neurodegenerative disorders. Notably, the gut microbiota significantly influences lipid metabolism, and alterations in microbial composition are closely associated with hyperlipidemia. Cereal-based functional foods, such as oats, tartary buckwheat, black rice, red yeast rice, probiotics-fermented rice, and highland barley, have been shown to mitigate hyperlipidemia by restoring gut microbiota homeostasis (Ren et al., 2024). Germinated brown rice (GBR) has also been reported to enhance the abundance of beneficial microbes, such as *Lactobacillus gasseri*, contributing to improved glucose metabolism, reduced inflammation, and decreased insulin resistance in high-fat diet-induced mice (Chen et al., 2021; Zhao et al., 2022). However, the specific role of gut microbiota in mediating GBR's hypolipidemic effects in humans remains unclear, necessitating further investigation.

A study has shown that germinated brown rice is good for hyperlipidemia by correcting imbalances in the gut microbiota. Consumption of germinated brown rice was found to promote the growth of beneficial bacteria (e.g., *Lactobacillus* spp. and *Bifidobacterium* spp.), increase the production of short-chain fatty acids (SCFA), and improve intestinal barrier integrity. It was also found to reduce total cholesterol and LDL cholesterol levels and reduce inflammation by regulating lipid metabolism. The study suggests that germinated brown rice may both support intestinal health and reduce the risk of cardiovascular disease with prebiotic effects (Ren et al., 2024).

The research evaluated the effects of oat consumption on cholesterol levels, gut microbiota, and short-chain fatty acids (SCFA) in individuals with mild hypercholesterolemia compared with rice consumption. In the 45-day trial, daily consumption of 80 g oats significantly reduced total cholesterol (TC) and LDL-C levels (8.7% reduction) and increased beneficial bacteria such as *Akkermansia muciniphila* and *Roseburia* in the gut microbiota. Furthermore, oat consumption increased the levels of SCFA such as acetic acid and propionic acid, indicating that these compounds contribute to cholesterol metabolism. The study suggested that oats may reduce cardiovascular risk factors by supporting gut health with its prebiotic properties (Xu et al., 2021).

In conclusion, dietary intervention with AGBR reduced blood lipid levels in patients with hyperlipidemia. AGBR is rich in free amino acids, resistant starch, soluble dietary fibers, GABA, and flavonoids. Additionally, AGBR improved the gut microbiota in patients with hyperlipidemia, evidenced by reduced.

CONCLUSIONS

This review evaluated the literature on the effects of rice consumption on gut microbiota and blood lipids. The findings indicate that rice consumption may have significant effects on both microbiota diversity and blood lipids. However, these effects largely depend on the type of rice, degree of processing, and the amount consumed. Rice in its whole grain form may contribute to the balancing of gut microbiota due to the dietary fiber, vitamins, and minerals it contains. Literature suggests that whole-grain rice may increase the diversity of gut microorganisms and help suppress potentially harmful bacteria. In terms of blood lipids, the effects of rice consumption present different results in

the literature. Some studies suggest that the consumption of whole-grain rice may reduce serum cholesterol levels and have positive effects on LDL cholesterol. The fact that depending on the type of rice suggests that the type and amount of rice should be carefully evaluated in individual dietary arrangements.

In conclusion, rice consumption may have significant effects on intestinal microbiota and blood lipids, but these effects may vary depending on the type of rice consumed and individual metabolic characteristics. Data in the literature suggest that regular and balanced consumption of whole grain rice may have positive results on intestinal health and lipid profile. More controlled human studies are needed to further clarify the findings in this area and to evaluate the long-term effects of different rice types.

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1.2. EXPLORATION OF ADVANCED TECHNOLOGIES IN THE STUDY OF PLANT METABOLIC PROCESSES AND THE ASSESSMENT OF CROP RESILIENCE TO ABIOTIC STRESS

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Abstract:

Currently, the tolerance of various crop varieties to drought and high temperatures, as well as the mechanisms governing carbon and nitrogen allocation in symbiotic systems under stress conditions, remain incompletely elucidated. To optimize the breeding process, a deeper understanding of metabolic interactions is required. Alongside classical breeding approaches, emphasis should be done on the application of modern, non-invasive, and efficient technologies for investigating biological processes.

New devices have been employed to monitor plant growth and development processes, as well as their interactions with symbiotic microorganisms under abiotic stress conditions. The use of multispectral cameras and gas emission sensors has facilitated the retrieval of valuable biophysical and biochemical information in real time, allowing the assessment of plant physiological status. Physiologically significant quantitative parameters of certain soybean varieties, along with plant productivity elements (number of fertile and sterile pods, number of seeds per plant, TGW, total seed mass), have been studied in eight native Glycine max varieties. These parameters were correlated with the respiratory activity of nodules. Furthermore, optical imaging (RGB cameras, LiDAR, multispectral cameras), enables the determination of various physiological and morphological parameters, facilitating phenotypic analysis of crops. This approach can serve as an efficient method for agroecosystem monitoring. Thus, advanced remote sensing technologies have been proven to be effective in addressing agroecosystem challenges related to environmental protection and biodiversity conservation, serving as a decision-making tool for real-time plant management and future scenario development.

Key words: plants, respiration, non-invasive technologies, sensors, abiotic stress

INTRODUCTION

The effects of abiotic stress on soybean have been widely reported, including morphological changes in plants during the growing season, but also on seed quantity and quality. Under stress conditions, biological systems adapt their metabolism by engaging stress resistance/tolerance mechanisms /7,8,9/. Currently, the tolerance of different agricultural crops to drought and high temperatures, as well as the mechanisms governing carbon and nitrogen allocation in symbiotic systems under stress conditions, remain incompletely elucidated /8,9/. Numerous studies have reported methods for evaluating both quantitative and qualitative morphological parameters, but in order to optimize the breeding process, a deeper understanding of metabolic interactions and resistance mechanisms is necessary /3,6,11/. At the same time, along with classical breeding approaches /12/, emphasis should be placed on the application of modern, non-invasive and efficient technologies for investigating biological processes.

Currently, various modern systems and devices are used for monitoring agricultural crops /10/. The use of multispectral cameras and various sensors (temperature, brightness determination, gas emission sensors, etc.) facilitates the collection of valuable biophysical and biochemical information in real time, allowing the assessment of the physiological state of plants. The topicality of our research results from the need to identify intelligent and semi-intelligent devices that can be used to monitor the processes of plant growth and development and their interaction with the environment. Starting from the idea that identifying modern technologies that extract physiological information in real time, in a non-invasive or minimally invasive way would allow on-site monitoring of crop health, providing

key information for optimizing the crop growth environment and combating biotic and abiotic stress, the purpose of our research was to study the characteristics and capabilities of existing tools for phenotyping and investigating plant metabolic processes, as well as to identify individual resistance traits of some strain genotypes to abiotic stress.

MATERIALS AND METHODS

This study included eight indigenous soybean varieties, created by the Field Crops Research Institute "Selection". The research was conducted on the agricultural lands of the National Center for Seed Research and Production, in the city of Balti, in June-July 2024. The Aura variety, selected for cultivation based on the characteristics of plasticity, productivity and other technological characteristics, and requested in cultivation by soybean producers in Moldova, served as a control for the research.

Phenotyping of plants in field conditions was carried out using the multispectral camera, incorporated on Phantom4 drones and using the multispectral camera Areal Mapping Camera MOPIR Survey3. Respiratory activity was determined using PASCO Technologies for measuring the concentration of carbon dioxide and oxygen (in a gas mixture). Changes in gas levels in nodules were evaluated using wireless CO₂ sensors, and oxygen concentration profiles were determined using the sensitive O₂ gas sensor. Air and soil temperature was monitored using a wireless temperature sensor with a stainless steel probe. The sensors used allow the acquisition of experimental data in real time and in autonomous mode, with data storage in the sensor's own memory. The acquisition, processing, analysis and interpretation of experimental data was performed using SPARKvue SOFT. The sampling rate was chosen to be 1 Hz for different varieties investigated in the respiration process with graphical display of data for a duration of 10 min and 20 min.

The productivity elements were analyzed in a minimum of 3 repetitions, using 10 plants each, randomly collected from the experimental plots. The statistical processing of the morphobiological data was performed using the Wolfram Mathematica system [4,5].

RESULTS AND DISCUSSIONS

Unmanned Aerial Vehicles (UAVs) were used to monitor plant growth and development processes in agroecosystems (Fig 1.) [2,10]. The collected data allowed the development of elevation maps (Fig.1.a), orthomosaic maps (Fig.1.b) and the assessment of the physiological state of plants (Fig.1.c), based on the NDVI index (Fig.1.d).

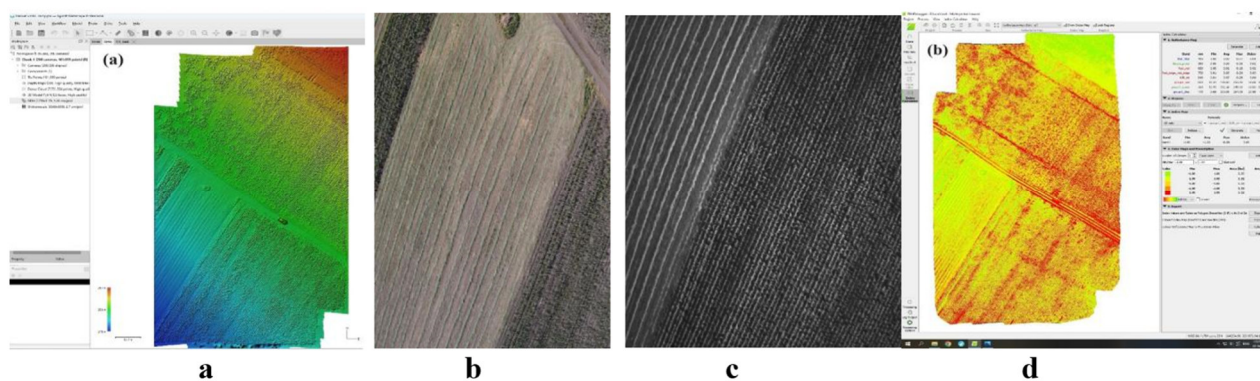


Fig. 1. Monitoring of plant growth and development processes in agroecosystems

In addition, optical imaging using sensors (RGB cameras, LiDAR, multispectral cameras) allowed the determination of physiological and morphological parameters, facilitating crop phenotyping. This

approach can serve as an effective method for monitoring agroecosystems. Combining this information with chlorophyll fluorescence and multispectral imaging technology allows for the differentiation of plant responses to stress by monitoring physiological data. To capture images of light reflectance and plant phenotyping, the Aerial Mapping MAPIR Survey3 multispectral camera was used. Further image processing with specialized software provides opportunities for identifying genotype-specific characteristics based on reflectance spectra.

Multispectral cameras allowed for image capture and the development of a solid database with reference to the reflectance spectra of different soybean varieties and highlighting damage caused by hyperthermal stress and water deficit (Fig. 2,3).



Fig.2



Fig. 3

Temperature and light sensors showed real data of a considerable increase in climatic indicators. Data collected with the help of temperature sensors, in the second decade of July, highlighted significantly higher air and soil temperatures during the period of monitoring the experimental field (Fig. 4). These data differ significantly from the data presented by hydro-meteorological stations which reported average temperatures of about 26° C in the northern part of the Republic of Moldova during this period.

Thus, in the experimental group, over several days, in July, air temperatures higher than 40°C (43.4°C) were recorded, and temperatures of 37.8°C - 41.9°C were recorded in the upper soil layer. We note that monitoring temperature variations at this stage is particularly important, given that the roots of leguminous plants form symbiotic systems (Fig. 5), located in the upper soil layers, and the increase in temperature in the rhizosphere region can substantially influence their interactions with symbiotic microorganisms under abiotic stress conditions, as well as the metabolic activity of nodules, with serious repercussions on the entire plant metabolism.



Fig.4



Fig. 5

The respiratory activity of the nodules, evaluated using CO₂ and O₂ sensors, revealed that the intensity of nodule respiration differs essentially in the varieties studied. During the first hour after the detachment of the nodules, CO₂ emissions showed higher values in the Enigma and Flamura varieties, followed by Deia and Viorela, with low values being attested in the Aura, Moldovița, Albiflora varieties. Exposure of the nodules to dehydration conditions, under high temperature conditions (32°C), for 30 hours demonstrated that the Viorela, Moldovița and Flamura varieties maintain their higher respiratory activity of the nodules even under severe dehydration conditions. It was established that the respiratory activity of the nodules is closely dependent on the water content of the nodules. Thus, at the full flowering stage, under dehydration conditions, the respiratory activity of rhizobacteria in nodules remains higher in varieties that have a higher amount of water in the cells /1/.

In order to establish the interdependencies between the researched parameters and plant productivity, at the end of the cultivation period, the agromorphobiological elements of the plants were determined. We emphasize that, under the climatic conditions of 2024, the analyzed varieties differed considerably in terms of the productivity elements formed (number of fertile and sterile pods, number of seeds per plant, MMB, total seed mass). Statistical analysis of the data using the Wolfram Mathematica system allowed highlighting the characteristic features of the analyzed varieties. A greater number of pods and grains was attested in the Deia, Igorina and Albiflora varieties, followed by Flamura, Viorela and Moldovița, and the Aura and Enigma varieties presented the lowest values (Fig. 6).

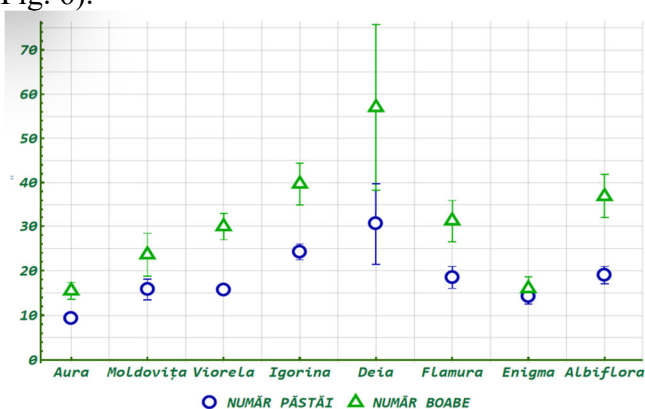


Fig. 6. Correlation between the number of pods and the number of grains

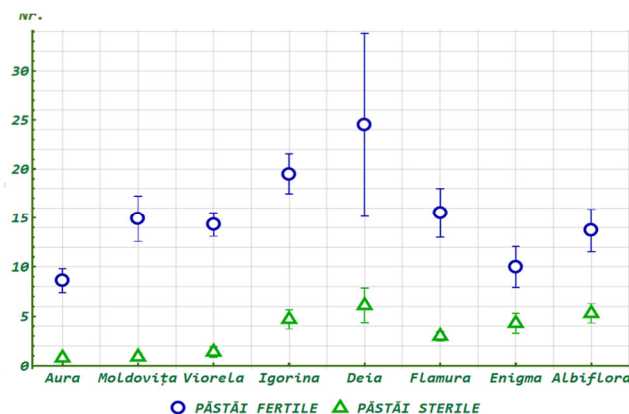


Fig. 7. Correlation between the number of fertile pods and the number of sterile pods

It is worth mentioning that the Deia, Igorina and Albiflora varieties that formed a large number of pods also had a large number of sterile pods per plant (Fig. 7). Compared to the total number of pods, a higher percentage of sterile pods was attested in the Enigma (30%) and Albiflora (27.9%) varieties, followed by the Deia (19.9%) and Igorina (19.4%), Flamura (16.2%). The Viorela (8.92%), Aura (8.51%) and Moldovița (5.7%) varieties presented low values. The same pattern was also shown by the ratio between the number of fertile pods to the number of sterile pods, which was higher in the Moldovița, Viorela and Aura varieties, which demonstrates that the mentioned varieties have a higher resistance to stress caused by high temperatures and insufficient humidity.

All varieties studied demonstrated higher productivity compared to the control variety (Aura). However, the Deia and Igorina varieties produce a greater number of pods and the highest number of grains and, respectively, their productivity was clearly superior to other varieties, exceeding the productivity of the control variety by 2-3 times, while the Moldovița and Viorela varieties exceed the control by only about 28% (Fig. 8, 9).

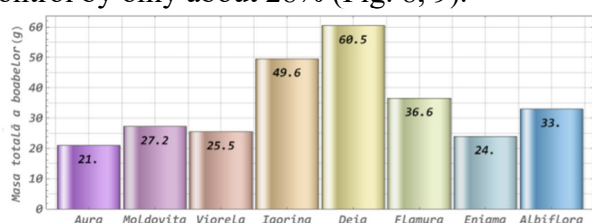


Fig. 8. Total mass of grains

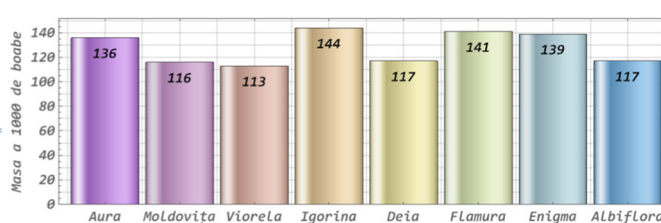


Fig. 9. Mass of 1000 grains

Table 1. Variation in the mass of 1000 grains

Parametri	$\bar{x}$ (g)	σ^2	σ	CV (%) *	IÎ**
Aura	136.0 ± 2.2	48.9	6.99	5.14	{131., 141.}
Moldovița	116.0 ± 2.7	71.1	8.43	7.27	{110., 122.}
Viorela	113.0 ± 2.1	45.6	6.75	5.97	{108., 118.}
Igorina	144. ± 4.	182.	13.5	9.37	{134., 154.}
Deia	117.0 ± 1.5	23.3	4.83	4.13	{114., 120.}
Flamura	141.0 ± 3.5	121.	11.	7.8	{133., 149.}
Enigma	139. ± 4.	166.	12.9	9.26	{130., 148.}
Albiflora	117.0 ± 2.6	67.8	8.23	7.04	{111., 123.}

Where: $\bar{x}(cm)$ - average mass; σ^2 -Standard deviation; σ -Variance;
CV(%)- "Coefficient of variation; IÎ**- Confidence interval.

These parameters were correlated with the respiratory activity of the nodules and with the physiologically significant quantitative parameters of the studied soybean varieties (number of nodules, fresh and dry biomass, water content) /1/. However, to elucidate the role of nodules in the resistance of legumes to drought, it is necessary to correlate the researched parameters with the productivity parameters of the varieties (Fig. 10).

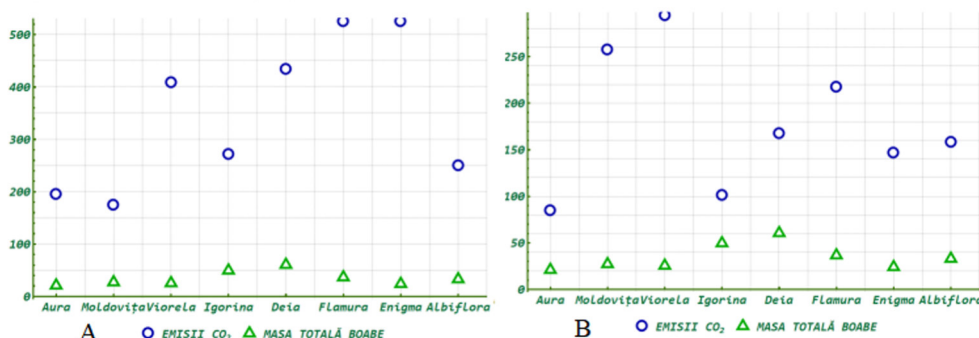


Fig. 10. Correlation of respiration intensity of soybean genotypes with the productivity of varieties
(A - 1 hour and B - 30 hours)

In our research, no close dependencies were attested between the respiratory activity of nodules and the productivity of varieties (Fig. 11). Carbon dioxide and oxygen emissions varied both in varieties that produced a higher number of grains and a higher grain mass, but also in varieties that under stress conditions had a lower productivity, which suggests the need for a more detailed analysis of the dynamics of biological processes related to plant resistance. However, based on the collected data, a mathematical model with a high level of reliability was developed.

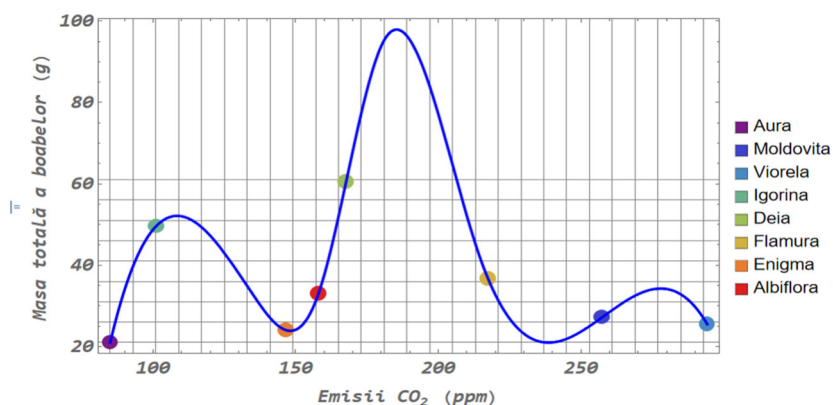


Fig. 11. Correlation of respiratory activity of nodules with total grain mass

Thus, in order to analyze the relationship between CO₂ emissions after 30 hours from nodule detachment and the total mass of the grains in different soybean varieties, a regression model was developed (Fig. 10), the main purpose of which was to evaluate through a mathematical function the existence of a significant correlation between: $x = \text{CO}_2$ emission level (ppm) and $y = \text{total mass of the grains (g)}$. The Spline curve draws a smooth trend between the points, modeling the relationship between CO₂ and yield.

Thus, it is observed:

- A strong local maximum around 180 ppm (highest productivity).
- Areas of minimum around 140 ppm and 240 ppm.
- A nonlinear relationship between CO₂ emissions and grain mass was attested.

CONCLUSIONS

- Advanced remote sensing technologies have proven to be essential tools in addressing the increasingly complex challenges in agroecosystems, especially in the context of climate change and pressures on natural resources. They allow real-time monitoring of the physiological state of plants, early identification of abiotic and biotic stress, as well as the

optimization of agronomic interventions with reduced environmental impact. By integrating them with information systems and predictive models, they become a true decision-making support tool, contributing to sustainable crop management and the development of future adaptation and resilience scenarios for agriculture.

- In the same context, CO₂ and O₂ sensors have proven to be extremely efficient in quantifying gaseous emissions and the intensity of metabolic processes at the level of different plant organs, providing detailed information about the health status, metabolic activity of plants. This approach allows a deeper understanding of the physiological responses of plants to environmental conditions, constituting a functional indicator of agronomic performance.
- In addition, mathematical models developed based on these data provide solid analytical support for the integration of desired agronomic traits (such as productivity, stress tolerance, resource efficiency) with the metabolic peculiarities specific to soybean plants. These models can be used in iterative processes of crossing and assisted selection, allowing the creation of genotypes better adapted to unfavorable conditions (drought, extreme temperatures, poor soils), without compromising production potential.

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1.3. THE STRATEGY FOR THE EXPANSION OF RICE CULTIVATION IN ROMANIA

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Abstract

The Agricultural Research and Development Station of Braila is the only research station in Romania that has dealt with rice improvement and has managed to obtain productive rice varieties with increased resistance to the Nordic limit of rice cultivation. By hybridizing local varieties with Turkish, Korean and Italian varieties, six new rice varieties have been obtained in the last 5 years. However, the rice fields that were created in the past have been occupied by other agricultural crops, which is why we have formulated this strategy to resume rice cultivation in Romania, in order to no longer import rice in the future.

Key words: rice, production, strategy, global warming

INTRODUCTION

The importance of rice cultivation in Romania

For Romania, rice cultivation has a double importance:

- On the one hand, rice is the only crop that can economically exploit saline or poorly productive soils that it introduces into the agricultural circuit;
- On the other hand, the production obtained could largely satisfy domestic consumption from its own production;
- Currently, Romania only ensures 20% of its rice consumption from its own production and annually pays approximately 50-60 million euros to cover its import needs.
- A Romanian consumes 4 kg of rice annually, and thus the population's consumption exceeds 75,000 tons.

Global warming also affects Romania

Graph of average annual temperatures recorded during the period 1900 – 2024, compared to the multi-annual average of 11°C is presented in figure 1. An increase in air temperature of 3.6 °C is observed in

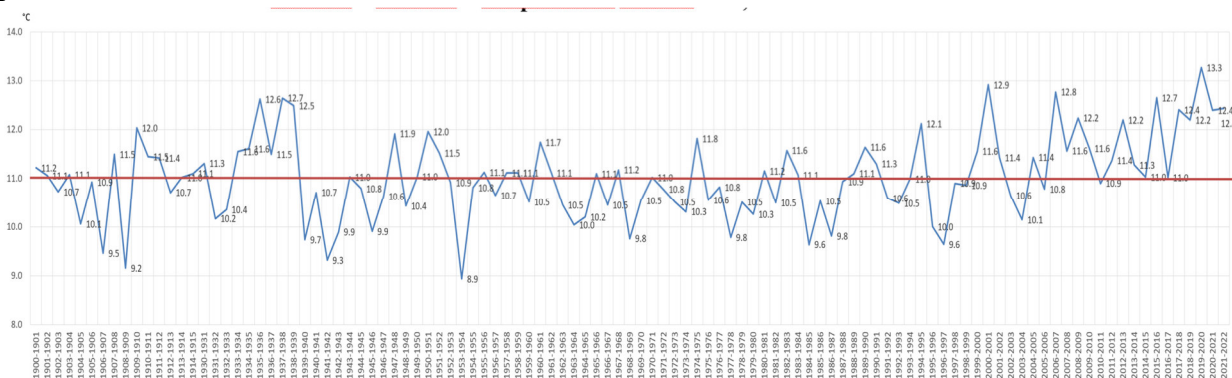


Fig. 1. The increase of air temperature in Braila county (ARDS Braila)

Factors that constitute the ecological environment for rice

- ✓ Rice is cultivated worldwide from the equator to the northern latitude of 47° and 40° southern latitude from sea level to an altitude of about 1500m.
- ✓ The factors that constitute the ecological environment of rice cultivation are: climatic factors, edaphic factors and water factors.
- ✓ Among all climatic factors, the temperature factor is the most important;

- ✓ In our country, the rice growing season lasts for 5 months, achieving during this period a sum of temperature degrees (thermal constant) that varies between 2400 and 3200 °C;
- ✓ Light influences the growth and development of rice through photoperiodism (light-dark alternation), the length of the day, the duration of sunlight, the intensity and quality of light.
- ✓ The duration of sunlight must be at least 1000 hours (I.Badea)

Rice temperature requirements during the growing season are presented in table 1, and the climatic elements from the period 2023-2024 according to the Braila weather station are presented in table 2.

Table 1. The requirements of rice during the vegetation season

Vegetation stage	Temperature (°C)		
	Minimum	Optimum	Maximum
Germination	10-12	25-30	35
Siblings	16	20	32-34
Panicle emergence, flowering and fertilization	20-22	28	38-40
Maturity	15	19	-

The average temperature of the agricultural year 2023-2024 exceeded the multiannual average temperature by 3.6°C. The agricultural year 2023-2024 is a favorable year for rice cultivation in Romania. During the vegetation phases, it can be observed that the average monthly temperature tends towards optimum.

Table 2. The climatic elements in Braila county, in agricultural year 2023 - 2024

Climatic elements			X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX	Total/ Average
Precipitation (mm)	2023-2024	Average month	4.5	3.4	124.0	23.0	16.0	0.3	40.4	26.1	35.0	47.3	33.2	17.2	370 / 57.0
		Multiannual average month	32.0	30.0	33.0	36.0	28.0	27.0	26.0	35.0	48.0	62.0	46.0	39.0	442 / 68.0
		Deviation ±	-27.5	-26.6	91.0	-13.0	-12.0	-26.7	14.4	-8.9	-13.0	-14.7	-12.8	-21.8	-71/ -11
Temperature (°C)	2023-2024	Average month	20.9	15.9	8.1	3.6	0.4	7.4	8.2	16.8	16.6	24.3	26.5	25.2	14.5
		Multiannual average month	17.3	11.5	5.6	0.6	-2.1	-0.2	4.7	11.2	16.7	20.9	22.9	22.1	10.9
		Deviation ±	3.6	4.4	2.5	3.0	2.5	7.6	3.5	5.6	-0.1	3.4	3.6	3.1	3.6 °C

Rice soil requirements (fig. 2):

- To have a loamy-sandy or clay-loamy texture;
- The permeability should be good in the arable layer and reduced in the sub-arable layer;
- To have a stable structure;
- The soil reaction should be weakly acidic - nutritious, pH = 7;
- The soil content in harmful salts should be low, namely: less than 0.1% sodium carbonate, less than 0.2% sodium chloride and under 0.75% sodium sulfate;
- The supply of nutrients should be as good as possible.

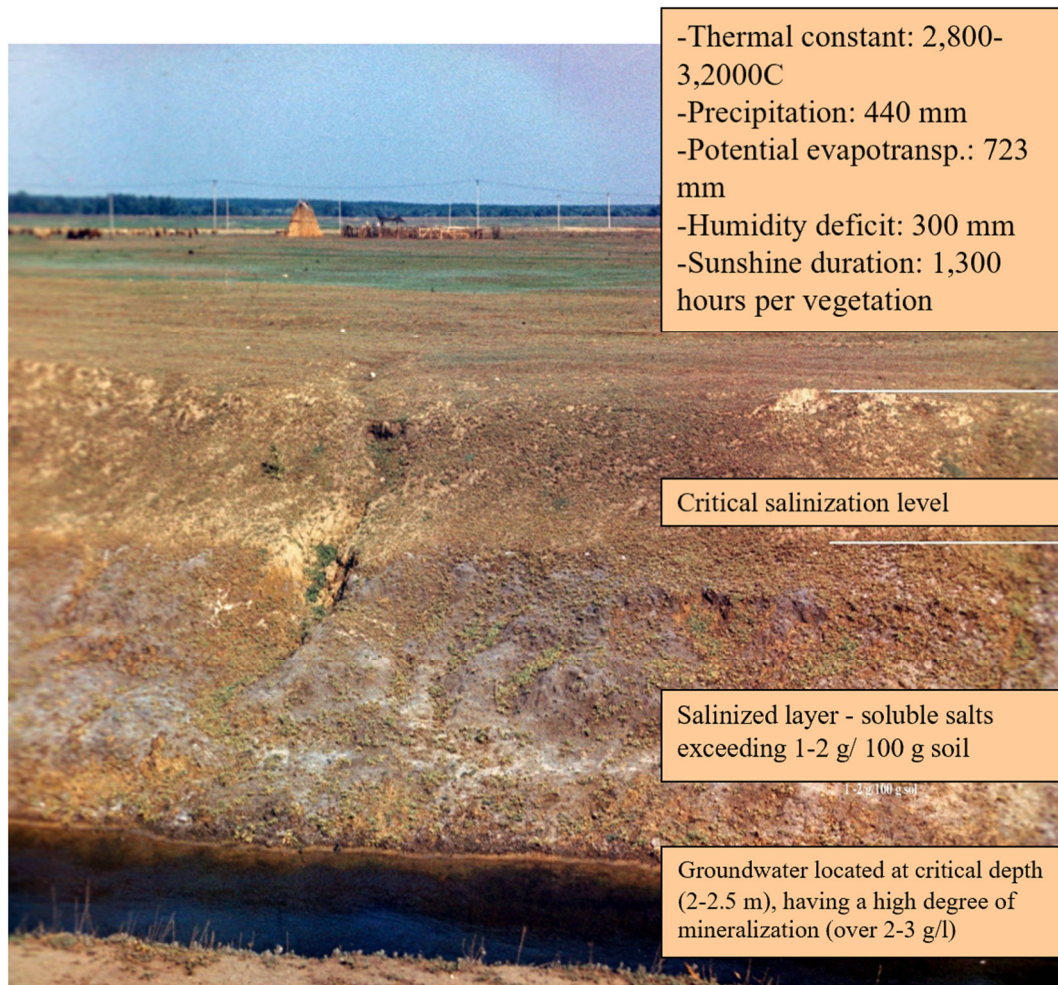


Fig. 2. Climatic factors in the Calmatui-Gropeni dam area

Favorable areas for rice cultivation

The figure 3 shows the favorable zones for rice in Romania:

- Zone I of favorability, is a 20 km wide strip, along the Danube from Clafat to Brăila, in the area of influence of the 22°C isotherm, where, in addition to other factors, the water and light source (Boțzan M) are simultaneously provided at an optimal level. The sum of the temperature degrees $\geq 15^{\circ}\text{C}$ is between 3000 – 3400°C. The annual multiannual average is over 11°C.
- Zone II of favorability, is found north of the 23°C isotherm for July, a 30-40 km wide strip along the Danube, the 21°C isotherm. The sum of temperature degrees $\geq 15^{\circ}\text{C}$ is between 3000-3200°C. The multiannual annual average is 10.5 – 11.0°C.
- The climatic zones favorable for rice cultivation overlap with the most arid areas. In these areas there are 100 thousand ha with saline soils (I.C.P.A. Bucharest).

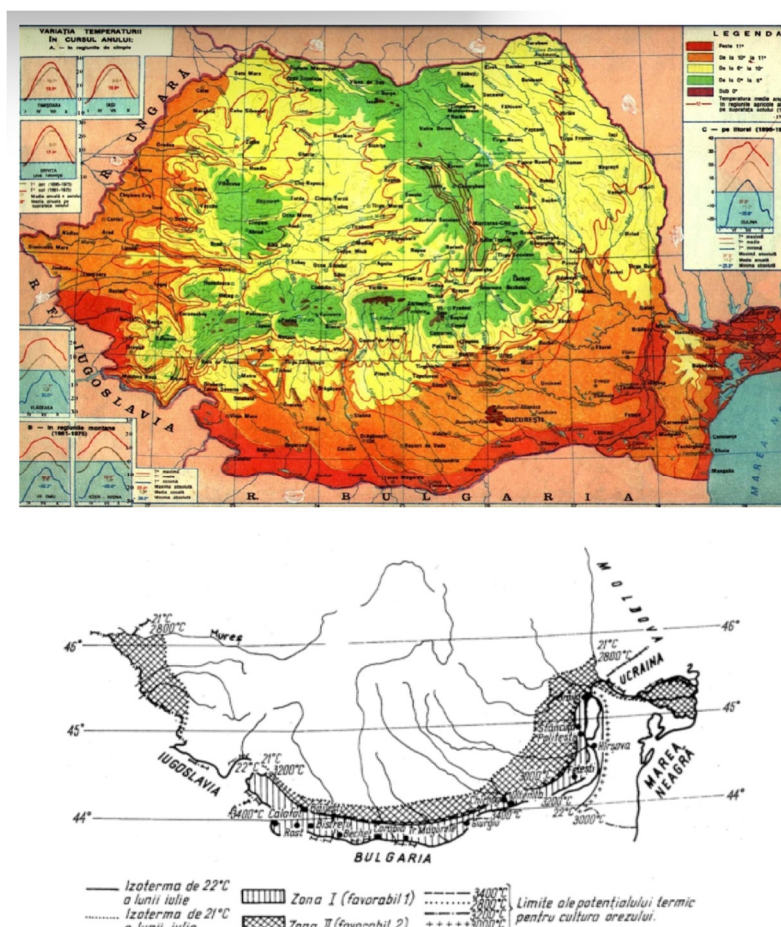


Fig. 3. Favorable area for rice cultivation in Romania

S.W.O.T. analysis

The SWOT analysis for rice cultivation in Romania is presented in table 3.

Table 3. SWOT Analysis for rice cultivation in Romania

Strengths:	Weaknesses:
Rice cultivation on 59,500 ha and are scientifically substantiated by research conducted by ICPA Bucharest and SCDA Braila. The water source is the Danube River and adjacent rivers. The water supply to the rice fields is free at the first pumping stage; The rice fields are equipped with specific, modern equipment (levelers guided by a laser device), tractors and high-power equipment, etc.	Lack of pesticides specific to the rice crop approved in Romania; The small number of rice processors.
Opportunities:	Risks:
Rice is the only crop that can make superior and economic use of the land in rice-growing areas; Due to global warming, rice cultivation can expand to 100 thousand ha in the Danube Plain, in favorable areas, and from an importer of rice, Romania can become an exporter.	In conditions of prolonged drought, the water supply from the II stage, the pump station, may be interrupted; The lands in the rice-growing areas, not cultivated with rice, in the conditions of global warming may become salinized; Most of the rice-growing areas belong to the A.D.S., and the companies that exploit these lands, may abandon them.

The rice cultivation program provided for the expansion of the cultivated area to 75,000 ha, of which 33,300 ha were on salt flats (table 4).

Table 4. Situation of rice plains organized in Romania in the last 40 years

County	Rice plains organized in Romania				
	Being in 1988	Proposed 1989 – 1990	Total provided 1990	Of which on salted soils	
				Carried out until 1985	Estimated Total 1990
Braila	16160	800	16960	11450	12300
Calarasi	13100	3800	16900	3500	3800
Constanta	1000	3900	4900	560	1550
Dolj	7200	-	7200	2500	4400
Giurgiu	40	-	40	40	40
Ialomita	11000	3900	14900	6100	7800
Olt	2800	-	2800	1800	1800
Teleorman	3700	-	3700	460	460
Timis	1200	-	1200	350	450
Tulcea	3200	-	3200	240	700
Unidentified surfaces	-	3100	3100	-	-
TOTAL	59500	15500	75000	27000	33300

- The largest rice area was cultivated in 1989, 49,300 ha, and the smallest area was recorded in 2001, 1,200 ha, with a production of 1,263 kg/ha.
- After this decline, with the appearance of foreign investors, the crop revived.
- Thus, in 2009 it increased to 13,300 ha with a production of 5,426 kg/ha.
- Due to the lack of herbicides specific to the crop and the infestation of rice fields with wild rice (*Oryza sativa* var. *silvatica*), the areas began to decrease dramatically, reaching in 2023 an area of 2,432 ha with an average production of 5,031 kg/ha.

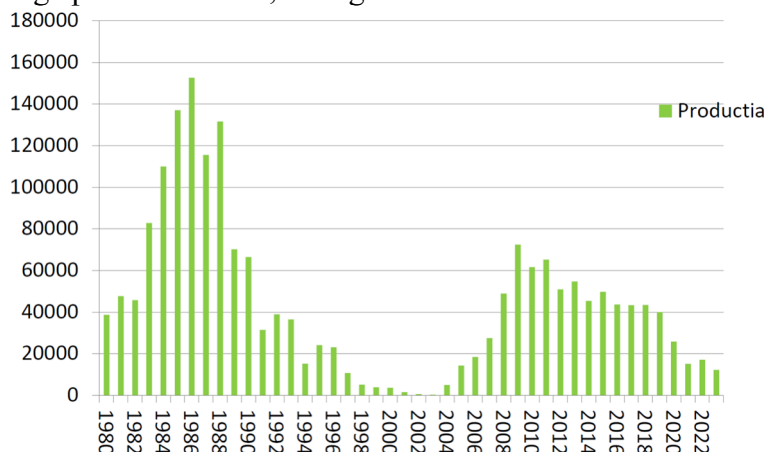


Fig. 4. Evolution of rice production in Romania

The causes that led to the reduction of rice cultivated areas:

- Rice monoculture.
- Use of seeds infested with rice crop-specific weed seeds for sowing;
- Infestation of land with wild rice *Oryza sativa* var. *silvatica*;
- Use of seeds infested with the rice nematode *Aphelenchoides bessey*,
- Lack of effective herbicides specific to rice crop.

MATERIAL AND METHODS

Through the "Program for the improvement and valorization of saline lands" in Romania SCDA Braila has conducted fundamental and demonstrative research on rice cultivation.

Research began in 1958 with the establishment of the Polizesti Experimental Center.

The first research was carried out in vegetation pots, microplots and lysimeters, and the results were taken over by applied research that was completed through development and demonstration research in large plots of the experimental field and the pilot farm of the Stăncuța IAS).

Two climatic zones for rice and 4 classes of land suitability were established - from very good to unsuitable (I.Albescu, A.Maniu et al.);

The following indicators influencing rice production were established: groundwater depth, soil texture, sum of temperatures in the range with averages $\geq 15^{\circ}\text{C}$, groundwater depth, soil texture, type of salinization, alkalization, pH, calcium carbonate content, humus, phosphorus and soluble potassium content and permeability (Florea N, Albescu I, Curelariu Gh., Piciu I., A. Maniu);

Irrigation water quality (temperature $\geq 15^{\circ}\text{C}$, mineralization below 1 g/l, during the peak period to ensure 4-5 l/s/ha), relief conditions and natural drainage (Mania A., Albescu I. et al.).

RESULTS OBTAINED IN THE FIELD OF IMPROVING SECONDARY SALINE SOILS

The natural and anthropogenic causes of secondary soil salinization were established either as a result of damming or as a result of the irrational location and exploitation of irrigation systems, with special reference to the arrangements arranged in steps (G. Obrejanu, AL.Maianu et al.);

Following the research carried out on the rice cultivation arrangement, it was finalized with the development of an indigenous type of arrangement "Stăncuța type" with ameliorative functionality (Albescu I. and V.Ionescu - 1983);

The improvement method through agropedoameliorative works was established, which includes: two measures necessary to create the framework for the development of the improvement-exploitation process (leveling and deep soil mobilization) and three basic improvement measures (drainage, washing and amendment) in close interdependence (I.Albescu, A.Măianu et al.);

It was established that the improvement of solonchaks and salinized soils (excess soluble salts in the soil solution) is achieved by washing under drainage conditions, and solonets and alkalized soils (exchangeable sodium in the colloidal complex) by amendment followed by washing under drainage conditions (I.Albescu, Antoaneta Maniu et al.);

The salinity tolerance of rice was established depending on the sowing method (Albescu I., Irina Axenova, Măianu A.);

Rice tolerance to salinity and factors leading to its increase (Maniu A. Albescu I, Ivan I.);

Salinity tolerance of the main agricultural plants on phreatic-humid soils with chemical salinization (Maianu A., Irina Axenova, Albescu I);

Choosing the assortment of crops on saline lands depending on the tolerance of plants to solonetization (A. Maniu, I. Albescu);

Rice tolerance to alkalization and factors influencing it (A.Maniu, Albescu I., Ivan I-1988)

Staging of the technology of improvement and cultivation of a saline soil in a submerged regime with rice (I.Albescu, A.Maniu, Ivan Ionel.);

All rice fields located on salinized lands were scientifically substantiated by research conducted by I.C.P.A.Bucuresti in collaboration with S.D.A.Braila.

We have made the necessary changes to the rice cultivation technology to allow for the development of improvement works while taking into account the specific characteristics of the soil included in the evolving desalination process;

- The experiences referred to: land preparation works, fertilization, irrigation regime, optimal sowing method, the assortment of field plants that enter into rotation with rice and specific cultivation technology.

- Based on this research, we have developed the rice cultivation technology for each improvement stage which led to the achievement, under research conditions, of a production of 10 tons/ha of rice. The research results were disseminated by publishing them in specialized brochures, scientific papers presented in symposia. Rice growing companies benefited from the scientific results. • It is worth mentioning that S.C PADOVA AGRICULTURA SRL from Brăila County, in 2009 on an area of 4189 ha achieved an average production of 8545 Kg/ha.

Through the direct hybridization method, we created new rice varieties. S.C.D.A Brăila had three projects:

- ADER PS 1.1.4 -, "Creation of rice lines with increased adaptability to climate change" (2015-2018) and

- ADER 1.1.2 -, "Creation of new rice lines with superior productivity characteristics and adaptability to the specific conditions of the northern crop limit" (2019-2022) and

- External contract - collaboration with South Korea, during the period 2014-2022.

- During the period 2019 – 2023, 6 rice varieties with superior morpho-productive properties were approved: Polizești 19, Roko 20, Roko 21, Roko 22 and Roko 23 and Polizești 23 and we have 75 lines in study (Fig. 5, and Table 5).



Fig. 5. Images from experimental center Polizești, SCDA Braila, Romania

Table 5. Morpho-physiological and productive characteristics of approved varieties

No	Variety /Line	Earing Date	Plant height cm	Length panicle cm	Processing yield %		Production KG/HA		DIF +/- Control White rice	Mass of a thousand grains gr	Protein content (%SU)	Resistance		
					Cargo rice	White rice	Paddy	OREZ ALBIT				Falling	Diseases	Shaking
1	POLIZEȘTI 28	10.08	93	13,1	80,04	61,15	8156	4987,4	MT	30,0	7,49	1	3	6
2	ROKO 20	12.08	90	16,8	80,71	63,64	12070	7681,0	+2694	30,0	7,54	1	2	2
3	ROKO 21	11.08	88	12,8	81,35	64,19	9017	5788,0	+801	30,0	8,32	1	1	5
4	ROKO 22	14.08	92	13,6	80,1	63,9	8146	5205,3	+218	33,0	8,19	1	1	3
5	ROKO 23	12.08	83	12,8	81,15	69,34	9629	6676,7	+1689	31,0	7,59	1	1	5
6	POLIZEȘTI 19	09.08	88	19,6	80,33	61,88	9161	5668,8	+681	31,0	7,75	1	2	3
7	POLIZEȘTI 23	13.08	85	19,5	79,43	66,56	9221	6137	+1150	31,0	8,22	1	1	

Comparative competition crops with rice varieties and lines, harvest 2024, biometric observations and measurements (Table 6):

The earliest variety proved to be the Polizesti 19 variety which ripened 3 days earlier than the Polizesti 28 (Mt) variety.

The latest proved to be the Roko 22 variety which ripened 9 days later than the Mt variety.

Regarding the height, we note that all the varieties created at C.E. Polizesti have a small-medium height ranging between 75-91 cm.

Regarding the number of grains in the panicle, we note that the Polizesti 23, Roko 20 and Linia 94/11 varieties register over 100 grains in the panicle.

Table 6. Morpho-physiological and productive characteristics of rice varieties in 2024

No	Variety /Line	Panicle density m ²	Earing Date	Plant height cm	Length panicle cm	Total grains	Empty grains No	Empty grains %	Mass of thousand grains gr
1	POLIZESTI 28	426	06.08	87	16.6	88	10	11.36	30.0
2	POLIZESTI 19	532	03.08	84	14.4	78	6	7.69	29.5
3	POLIZESTI 23	444	13.08	75	18.2	101	20	19.80	32.5
4	ROKO 20	460	11.08	87	15.1	108	17	15.74	32.2
5	ROKO 21	524	09.08	86	12.1	83	10	12.04	28.3
6	ROKO 22	436	15.08	87	17.2	98	20	20.40	32.6
7	ROKO 23	432	10.08	90	19.0	81	8	9.87	29.7
8	LINIA 124	436	14.08	85	16.4	90	10	11.11	26.9
9	IMPULS	424	12.08	110	19.1	97	15	15.46	27.3
10	MAGIC	440	11.08	97	15.0	87	17	14.79	31.5
11	LINIA 94/11- CC2023	444	14.08	91	19.8	105	15	14.28	29.8

Comparative competition crops with rice varieties and lines year 2024 quality characteristics processing yield of cargo rice and milled rice are presented in Table 7.

Table 7. Quality characteristics of rice production in 2024, at EC Polizesti Romania

No	Variety /Line	Processing yield %		Rice paddy production kg/ha	White rice production		Diff. + / -	Significance
		Cargo rice	White rice		Kg/ha	%		
1	Polizesti 28	81,00	50,42	10150	5118	100	Control	-
2	Polizesti 19	80,37	55,99	11200	6271	122,5	+ 1153	XXX
3	Polizesti 23	79,43	66,56	11557	7692	150,2	+ 2584	XXX
4	Roko 20	78,77	61,74	13290	8205	160,3	+ 3088	XXX
5	Roko 21	83,84	66,06	10946	7231	141,1	+ 2113	XXX
6	Roko 22	80,36	60,17	11020	7731	151,0	+ 1513	XXX
7	Roko 23	79,90	66,88	9440	6313	123,3	+ 1195	XXX
8	Linia 124	80,21	68,71	9370	6438	125,7	+ 1320	XXX
9	Impuls	82,11	61,57	9530	5868	114,6	+ 750	XX
10	Magic	80,21	60,80	9690	5892	115,1	+ 774	XX
11	Linia 94/11	82,67	71,13	12487	8880	173,5	+ 3764	XXX

P 5% = 2,09 409

P1% = 2,84 556

P0,1% = 3,85 755



The maximum production of 8880 kg/ha was recorded at Linia 94/11.



In third place was the Roko 20 variety, which recorded a production of 8205 kg/ha



In third place was the Polizesti 23 variety with a production of 7692 kg/ha.

The results of comparative competition crops with rice varieties and lines year 2024 production results – paddy rice are presented in table 8.

Table 8. Comparative production results of paddy rice in 2024, at EC Polizesti Romania

No	Variety /Line	Production KG/HA			
		PADDY	%	DIF + / - Control	Significance
1	POLIZESTI 28	10150	100	Control	-
2	POLIZESTI 19	11200	110,3	+ 1050	xxx
3	POLIZESTI 23	11557	113,8	+ 1407	xxx
4	ROKO 20	13290	139,0	+ 3140	xxx
5	ROKO 21	10946	107,8	+ 796	xx
6	ROKO 22	11020	108,5	+ 870	xx
7	ROKO 23	9440	93,00	- 710	0
8	LINIA 124	9370	92,31	- 780	00
9	IMPULS	9530	93,89	- 620	0
10	MAGIC	9690	95,46	- 460	-
11	LINIA 94/11	12487	123,02	+2337	xxx

P 5 % = 2,0 566

P 1% = 2,84 769

P 0,1% = 3,85 1043



The maximum production was recorded for the Roko 20 variety of 13290 kg/ha, exceeding the Polizesti 28 variety by 139%.



Linia 94/11 was in second place, exceeding the control variety by 123%.



Polizesti 23 was in third place, exceeding the control variety Polizesti 28 by 113.8%.

The Braila Agricultural Development Research Station is the only one in Romania that conducts research in the field of rice cultivation.

Rice cultivation is extremely important, as it feeds 66% of the world's population and has the ability to adapt to thermal stress conditions;

Modern solutions, such as the expansion of rice cultivation, include the ecological restoration of degraded areas through rehabilitation and even the inclusion of crops in protected areas for the growth and conservation of biodiversity.

In the future, Romania could become the third largest rice producer in Europe, after Italy and Spain, if its lands were rehabilitated for rice cultivation. (Vijulie Iuliana et al., 2016).

Considering the experience in rice cultivation, global warming that inevitably affects Romania, I propose as a strategy the expansion of rice cultivation on as large an area as possible.

In figure 6 are presented the values of production in paddy rice, milled rice and processing white rice in 2024, at EC Polizesti, SCDA Braila, Romania.

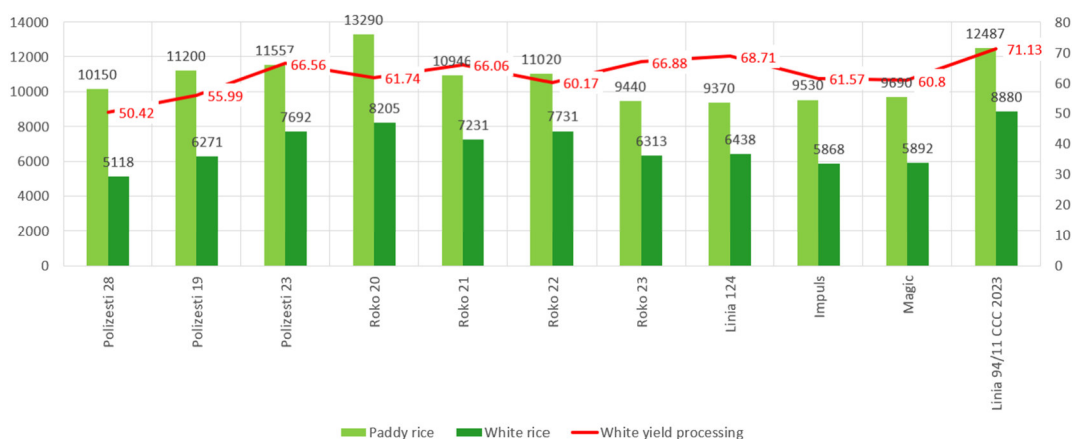


Fig. 6 The graph on paddy rice production, milled rice and processing yield

S.C.D.A Brăila strategy regarding the expansion of rice cultivation are presented in table 9.

Table 9. The strategy in rice at SCDA Braila, Romania

Variant	What we obtain
I. 3-year rotation of which: 1 year rice and 2 years field plants, 33% of the area arranged for rice results in an area of 19635 ha (59,500 haX 33%).	An area of 19.635 thousand ha cultivated with rice; A production of 75 thousand tons (19.6 thousand X 6 tons/ha X 0.65) which ensures Romania's rice needs from its own production;
II. 3-year rotation: with a load of 50% with rice, where it is cultivated: 50% of the area with rice and 50% with field plants, spring annuals.	Increasing the share of rice to 50% (which would be ideal), from the rotation, results in an area of approximately (29,750 thousand ha X 6 to/ha X 65% = 116,025 to food rice. We obtain 41,000 tons of food rice that we can export.

Perspectives on the expansion of rice culture in romania in the context of climate change

Farmers should consider more sustainable agricultural techniques and practices, such as: capital leveling with laser-guided levelers, merging small plots and creating large plots (25-30 ha), where the land allows, efficient water management with "monk" type tillers, the use of rice varieties created in Romania, which are adapted to climatic conditions.

Implementation of advanced agricultural technologies: sowing methods appropriate to the soil type, the use of selective herbicides to be applied with high-precision equipment, guided by GPS, etc.

Research activity should also be continued to develop rice varieties adapted to changing climatic conditions and to find innovative solutions to face the increasing challenges of climate change on rice production.



Fig. 7 Collection of rice varieties in 2024, at EC Polizesti – SCDA Braila, Romania



Fig. 8 Rice breeding field in 2024, at EC Polizesti – SCDA Braila, Romania

CONCLUSIONS

Farmers should consider more sustainable agricultural techniques and practices, such as: capital leveling with laser-guided levelers, merging small plots and creating large plots (25-30 ha), where the land allows, efficient water management with "monk" type tillers, the use of rice varieties created in Romania, which are adapted to climatic conditions.

Implementation of advanced agricultural technologies: sowing methods appropriate to the soil type, the use of selective herbicides to be applied with high-precision equipment, guided by GPS, etc.

Research activity should also be continued to develop rice varieties adapted to changing climatic conditions and to find innovative solutions to face the increasing challenges of climate change on rice production.



Fig. 9 Rice breeding field, comparative and competition crops, in 2024, at EC Polizesti, SCDA Braila, Romania



Fig. 10 Seeds production in selection rice field in 2024 at EC Polizesti, SCDA Braila, Romania

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1.4. MINI-TILL SYSTEM WITH MULCH FOR SOIL TILLAGE THROUGH THE PRISM OF THE CONCEPT OF PEDOREGENERATIVE AGRICULTURE

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Abstract:

The pedoregenerative imperative involves the synchronized management of bioenergetic resources by managing the organic carbon cycle in soils and their physical state by reducing tillage (Mini-till) or even completely excluding it (No-till). Despite the insistent promotion of the No-till procedure at the current stage of development and implementation of the pedoregenerative concept of chernozem pedogenesis, preference must be given to the Mini-till system with mulch because it meets some basic requirements for the regeneration of the chernozem process under agrogenesis conditions - the permanent presence in the soil profile of humus detritus, root residues and the preservation of up to 35% of plant residues and more than 60-65% of stubble on the surface. In this way, the Mini-till system with mulch to a greater extent corresponds to the natural model of chernozem pedogenesis, which involves the storage and transformation-humification of organic residues in the soil profile with the formation of humic substances and the regeneration of the chernozem system of organic substances. The development, over time, of the mulch layer ensures the regeneration of the humiferous detritus layer in the upper segment of the profile responsible for the regeneration of the basic functions of the soil, which contributes to the restoration of chernozem circuits of substances, and the regeneration of the chernozem process under agrogenesis conditions.

Key words: No-till, Mini-till with mulch, pedoregenerative agriculture.

INTRODUCTION

The challenges faced by contemporary agriculture have involved the need to review the paradigm of the agricultural systems practiced. In this sense, it is known that any agricultural system must necessarily meet one of the basic requirements - maintaining and increasing the fertility, health and ecosystem functions of the soil materialized in the expanded reproduction of the pedogenetic process. The current state of the soils and its trend allows us to conclude that none of the agricultural systems practiced in the past and even now has met and does not meet this basic requirement. In our opinion, the specified situation is caused by the fact that measures to improve the agricultural systems practiced started from economic aspects, which directly determined the agrotechnical procedures applied in order to ensure the continuous increase in crops and incomes, the emphasis being placed on soil cultivation and mineral fertilization. Throughout the entire history of agricultural civilization, one of the basic goals, along with the creation of favorable conditions for plants.

With reference to soil works in historical aspect, these were applied from the start in the supposed intensification of the processes of mobilization of nutrients in the soil through the mineralization of humus. As a result, the intensification of agriculture by "improving them" led to the accelerated dehumification of soils manifested in the degradation of the soil structure and, respectively, of the physical, hydrophysical, physical-mechanical (technological) properties but also of the pedogenetic (hydric, thermal, aeration) and pedofunctional (hydrothermal, aérohydric, oxidation-reduction, biological) regimes. This led to noticeable changes in the intensity and meaning of the chernozem typogenetic processes, especially the formation-accumulation of humus and the aggregation-structuring of the soil mass manifested in the disruption of the interdependent and interdetermined

functioning of the pedofunctional system [bioenergetic system]↔[aggregative system], materialized in the unidirectional degradation of natural fertility and basic eco/agroecosystemic functions. In the trend of mitigating the consequences induced by these, the emphasis has been shifted to the "optimization" of structural-aggregate and settlement parameters (apparent density, total and differential porosity).

This led to the deepening of physical degradation processes and the establishment of the overcultivation process in soils, which with different degrees of quantitative-functional expression, affected all arable chernozems (Jigău, 2009).

The challenges in regional agriculture induced by this phenomenon brought to the attention of researchers the conservative soil cultivation system including direct sowing (No-till) and reduced tillage (Mini-till).

Evaluated through the principles of sustainable development, the conservative tillage system, as well as other types of soil cultivation, is an integrated part of the agricultural system in which the main value is the means of production - the soil. The agricultural system cannot be considered unrelated to natural landscapes and must make the connection between the processes of increasing and maintaining soil fertility, the biological characteristics of the growth and development of agricultural crops depending on bioclimatic conditions and economic needs.

By its essence, it represents a balanced agricultural system that takes into account both environmental factors and the growing conditions of certain crops. In this context, modern balanced agricultural systems must necessarily take into account the positive biological factors that contribute to increasing the productivity of arable land. At the current stage of development of agricultural science, it is necessary to take into account all the factors of biolization of agriculture, which include techniques that promote the accumulation of nitrogen in the soil by fixing it, the use of organic fertilizers (manure, plant residues, green manure biomass, cultivation of new varieties and hybrids, the use of biofertilizers and biologically active substances). An element of major importance is the optimal minimization of soil tillage, which is the main subject of the present research.

MATERIALS AND METHODS

From the perspective of the theory of the chernozem process of solidification, the primary factor of reproduction/regeneration of the chernozem process of solidification is the expanded unidirectional reproduction of soil fertility materialized in the self-reproduction capacity of the soil ecosystem and its functions (Jigău, 2019).

The conceptual-methodological framework of technological systems for sustainable management of soil fertility and regeneration of the chernozem process of solidification is provided by the new concept of the terrestrial ecosystem as a symbiotic unit of biocenoses specialized in types of nutrition (phytocenosis, zoocenosis and pedocenosis/pedomicrobiota) integrated into a common closed metabolic cycle (Керженцева, 2020).

Through this prism of ideas, the basic principle of rational pedoregenerative agriculture involves the expanded reproduction of bioenergetic resources in the soil and the sustainability of the activity of the soil biota, this being the main condition for providing the ecological system "soil-plant" with the basic factors (physical, chemical, physico-chemical, biological) for the unidirectional functioning in the pedoregenerative sense. In this sense, the soil is a stable self-regulating system: the greater amount of synthesized organic matter implies more intensive decomposition processes and more intensive metabolism, materialized in the increased productivity of phytocenoses. Therefore, the development of modern agriculture involves ensuring the continuous optimal functioning of the system "soil-phytocenosis-zoocenosis-pedocenosis-plant-soil", taking into account the specific situation prevailing in agriculture and the peculiarities of the agricultural production process. This implies the

need to identify the characteristic differences of the pedogenesis process in natural ecosystems and agroecosystems.

Under natural conditions, the restoration of soil fertility is ensured by the undisturbed functioning of the production block "soil-plant-environment". The pedofunctional expression of the specified processes is the Law of the primacy of soil fertility in the expanded reproduction of quantitative and qualitative pedogenesis realized in the "Law of the unity of soil and plant" and the "Law of return", the latter being a particular manifestation of the "Universal Law of conservation of matter and energy".

The law of the unity of soil and plant and the Law of return under natural ecosystem conditions materialize in the closed circuit of carbon and nutrients (matter and energy).

Under agroecosis conditions, the natural production system "soil-plant-environment" is substituted by the bioeconomic system "anthropic factor-soil-production process-plant-soil", i.e. the restoration of fertility follows the same laws (mentioned above) but with sustainability adjustments through technoanthropic inputs adapted to landscape conditions.

From the perspective of the biophysical concept of pedogenesis and soil fertility, this is a special emergent natural system whose formation is ensured by the development over time, at the pedological time scale, of the interactions between the substances and energy of living and routine matter, resulting in the formation and accumulation-stabilization of humus - an indicator of the meaning and intensity of the pedogenetic process but also a qualitative and quantitative parameter of soil fertility. Like any natural process, the exchange of substances and energy takes place in accordance with the laws of physics, chemistry and biology.

The unidirectional realization of the processes of integration of biotic and abiotic matter, at the pedological time scale, led to its establishment as a self-regulating system that ensures the natural reproduction of soil fertility in certain value ranges corresponding to the cyclicity of environmental factors, in particular the climatic one.

The main factor that in the natural regime ensures the expanded reproduction of the pedogenetic process and soil fertility is the closed nature of the carbon cycle and biophilic chemical elements determined by the organic matter cycle.

The inclusion of soils in the agricultural cycle inevitably leads to the disruption of the carbon and nutrient cycle in the "soil-plant" system, materialized in the unidirectional reduction of bioenergetic resources in the soil and their transfer to a lower energy level of functioning. The regeneration of the pedogenetic process involves complex systematic measures to restore and maintain bioenergetic resources in the soil through the sustainable management of the carbon and biophilic elements cycle. In this context, it must be taken into account that in the agricultural regime, the soil, as a basic means of production, maintains its capacity to preserve or increase bioenergetic resources and fertility only under conditions when only part of the organic matter produced is alienated.

Quantitatively, this must correspond to the amounts of organic matter necessary to compensate for the bioenergetic reserves consumed in the production of biomass in specific conditions of the landscape and structure of agrophytocenoses (Жирэу, 2018).

If the amount of organic matter consumed is greater than the amount returned to the soil, a stable tendency of devegetation and dehumusification materialized in the overcultivation of soils is established. The latter involves physical and biophysical states that quantitatively and qualitatively limit the meaning and intensity of typogenetic processes and, respectively, the reproduction of the pedogenetic process and soil fertility. In this context, more recent research has shown that more than 80% of the arable land of the space between the Prut and the Dniester is affected by overcultivation, and moderate and strong forms are predominant (Zhigêu, 2020).

With reference to this subject, in the specialized literature several authors consider that the regeneration of the humus formation-accumulation-stabilization process in overcultivated soils involves only partial realization of the soil potential and requires a long period of time.

In this sense, Andrews believes that crop rotation maintains the organic matter content in the soil up to a certain level and cannot be restored to the potential level corresponding to landscape conditions by applying organic fertilizers, including green fertilizers, when these are applied for economic purposes (Andrews, 1959), and Debruck and Kerschens believe that analogous effects are also observed in the case of using straw as fertilizers even when they are administered to the soil in quantities that exceed the needs of the soil (Kerschen, 1992).

Recent generalization of research in the field has shown that under agricultural regime, chernozems can recover only up to 10% of the total amount of carbon lost as a result of agricultural use (Sharkov, 1987; Sharkov, 1997; Sharkov & Antipina, 2022). This implied the conclusion that the process of carbon sequestration-stabilization in chernozems is characteristic only of cultivated soils. Therefore, the transfer of chernozems to fallow regime leads to the unidirectional regeneration of the process of sequestration-stabilization of organic carbon in the soil. According to calculations, in fallow regime the addition of humus content in chernozems is about 0.039%/year (Mamontov et al., 2020).

At the same time, however, the practice of this procedure under market economic conditions is unfeasible. Therefore, it can be used only on limited areas where it is not appropriate to cultivate agricultural crops.

At the same time, our research has shown that the promoted alternative pedoconservative technological systems (FAO) only partially provide the pedofunctional framework necessary for the expanded regeneration of the chernozem process within the framework of anthropized chernozem pedogenesis. This implies the need to optimize the practiced pedoconservative technological systems (No-till, Mini-till) by biologizing them and the staggered optimization of the physical properties and regimes of the agrogenic layer and the subsequent sustainability of the pedogenetic process by optimizing the structure of agrophytocenoses, respecting crop rotations, cultivating intercropped (under-seeded) and successive crops, practicing sidual arable farming, bioorganic fertilization, taking into account the state of the soils under conditions of unidirectional intercropped impact of agrogenesis and climate change. In this context, the generalization of our research conducted in the period 2007-2023 highlighted several conceptual-methodological conclusions (Jigău et al., 2022):

1. From the perspective of the concept of anthropo-natural pedogenesis, the inclusion and intensive use of soils in the agricultural circuit inevitably leads to genetic-functional changes at all hierarchical levels of its structural-functional organization: ionic-molecular↔elementary particle↔microaggregate↔aggregate→horizon↔profile, which are reflected in the pedogenetic, pedofunctional regimes and typogenetic processes responsible for soil health and fertility and the reproduction of the pedogenetic process.

2. The specified changes have induced a series of challenges that agriculture faces under conditions of intercalated impact of agrogenesis and climate change:

- a) soils no longer correspond to current climatic conditions and the degree of non-compliance is in unidirectional development (phenomenon unknown to the theory of pedogenesis).

- b) as a result of the reduction of the adaptation capacity, soils no longer cope with the current trend of climatic conditions.

- c) the technologies practiced no longer correspond to the state of the soils.

- d) in conditions of reduced natural soil fertility, the bioproductivity of agroecosystems is "forced" to increase through various agrotechnological processes and is materialized in soil depletion.

3. None of the currently practiced technologies ensures the reproduction of the adaptation capacity of soils and agroecosystems to the current trend of climatic conditions.

4. A complex of agrobiocenotic pedoregenerative measures adapted to landscape conditions ensures the restoration of the ecological balance of agrolandscapes, the reproduction of soil fertility and health in the system of the production block "soil-plant-environment" and the functional framework capable of eliminating contradictions in the system "anthropic factor-soil production process-plant-environment-soil".

Based on the specified conclusions, we consider that the following agrophytocenotic principles should be taken as the basis for the sustainable management of the regeneration process of chernozem pedogenesis and the ecosystem and agroecosystemic functions of chernozems within the framework of pedoregenerative technologies:

1. Systematic control of organic matter reserves and the ratio between their components (non-humified organic matter; humiferous detritus; mobile humic substances; stable humic substances) formed on the basis of root rotation and edaphic, epiphytic and biogeochemical processes of transformation into various mineral, organic and organo-mineral compounds.
2. Maintaining in soils the reserves and structure of organic substances at an optimal level corresponding to the specific landscape conditions.
3. Management of mineralization-humification processes and the ratio between them by ensuring optimal bioaerohydric, biohydrothermal conditions and the C:N ratio.
4. Expanded reproduction and preservation of soil fertility (as a factor with a primary role in achieving pedogenesis), through the permanent renewal of the system of organic substances to ensure the processes of mineralization, humification, accumulation and stabilization of organic carbon and support of edaphic processes.
5. Managing soil fertility and reproducing the soil organic matter system by intensifying the flows of substances and energy in the "soil-plant-environment" ecological system by biologizing all components of agroecosystems and practices, including plant protection.

Based on the conceptual-methodological aspects presented and the multilateral analysis of various models of "conservative technologies" practiced in the Republic of Moldova in about 130 agricultural holdings, a pedoregenerative agrophytocenotic model conforming to the current state of the soils and their evolutionary trend was developed within the framework of the present research:

1. Adaptation of all components of the agricultural system (soil cultivation, structure of agrophytocenoses, fertilization system) to the specific landscape conditions.
2. Rational management of stubble and plant residues as organic fertilizers and mulch.
3. Soil cultivation at depths that will not exceed the seed incorporation depth or their exclusion.
4. Preservation of 60-65% of stubble and not less than 30-35% of plant residues on the soil surface.
5. Practice of sidereal farming (as appropriate).
6. Cultivation of phytoameliorative cover crops or intercrops.
7. Restoration of the soil organic matter system and its functionality; ensuring a positive trend in the humus balance.
8. Monitoring the soil nutrition regime at the end of the growing season, adapting the amounts of organic fertilizers to the needs of the soil and their differentiated administration.
9. Ensuring the biological nitrogen sources necessary for the functioning of the soil microbiome and the achievement of the humification process by using bioorgano-mineral products of humic origin and administering algal preparations.
10. Root rotation and promoting biological soil loosening processes. Practicing mechanical loosening only in exceptional cases. Sustaining the root and coprolitic mechanisms of self-loosening and structural aggregation of the soil mass.
11. Cultivating varieties and hybrids adaptable to the practiced tillage system:
 - a) the minimum tillage system with mulch imitating the natural soil formation process.

b) the minimum tillage system only in rows with mulch without tilling the space between rows (Strip-till).

c) the minimum mulch system and loosening with a chisel plow at a depth of 30 cm.

12. Performing all agrotechnical operations in optimal terms.

In terms of the specified components, the most suitable for achieving the pedoregenerative objective are the direct sowing (No-till) and Minimal tillage systems with mulch (Mini-till). In this regard, the present research involves evaluating the Mini-till system with mulch in terms of quality from the perspective of the pedoregenerative concept by comparing it with the No-till system.

RESULTS AND DISCUSSIONS

In the context of the agrophytobiocenotic technology model within the current conditions of soil resource management, self-reproductive systems with the use of non-traditional sources of plant mineral nutrition, especially plant residues and stubble of predecessor crops and crops (interspersed between rows or rows of basic crops; under-sown crops) grown as green fertilizers that contribute to the reproduction and restoration of typogenetic processes, soil health and fertility.

Their efficient management depends on the uniformity of the distribution of plant residues on the soil surface and in their superficial layer, which, in turn, is determined primarily by the tillage system. In this regard, it is unanimously recognized that the traditional process of incorporating them under the furrow is not justified both from an economic and agroecological point of view. As a result, in the last 30-40 years, in chernozem areas, interest in minimal soil cultivation systems has significantly increased, the foundations of which were formulated in the last decade of the 19th century (ОВСИНСКИЙ, 1899).

Although the work cited in the foreground evaluates the aspects related to the reduction of soil work in order to reduce soil vulnerability, from areas with moisture deficit to severe climate conditions (drought) to the present, minimal soil work is more often appreciated from an economic aspect. In this regard, more recent evaluations have shown that compared to traditional systems, minimal work contributes to the reduction of technological costs by about 20% and those related to labor by 25%. At the same time, income increases by about 25% (Ареев, 2021).

In the area between the Prut and the Dniester, the reduced mulch tillage system was successfully used as early as the 1980s, but with the use of equipment with a low conservation effect, which did not ensure the expected results. In this context, in our opinion, one of the main causes of the failure of shallow haymaking at that stage was the irrational management of secondary production (vegetable residues and stubble), which was either evacuated from the field or burned. It should be noted, however, that already at that stage it was found that this procedure ensured better results, compared to other tillage systems, in years with unfavorable climatic conditions.

In our opinion, the specified effect was due to the fact that at that stage the practice of superficial loosening carried elements of adaptation to landscape conditions, especially to soil conditions (granulometric composition, settlement state) this procedure being used mainly for clay soils prone to settlement and consolidation/slitting. At the same time, a more recent analysis of this tillage system from the perspective of soil resilience to drought highlighted a series of beneficial effects and pedofunctional advantages provided by the Mini-till with mulch system (Jigău, 2018). In this context, our research has shown that the minimum tillage system with mulch ensures:

- unidirectional improvement and optimization of the physical properties of soils with the creation of favorable conditions for the development of biophysical, physicochemical and physical processes materialized in increasing the health and fertility of the soil and the reproduction of the chernozem process of soil formation;

- incorporation of plant residues, green manure stubble at optimal depths creates favorable conditions for the implementation of mineralization-humification processes with intensification of the humus formation process and stabilization of organic carbon in structural aggregates;
- creation of a homogeneous seedbed with biohydrothermal and bioaerohydric conditions for seed germination, plant development and the functioning of the "soil-plant" ecological system.

At the same time, minimal soil tillage systems with mulch contribute to:

- accumulation of organic matter in the upper layers of the soil profile;
- development of biodiversity;
- establishing and maintaining a dynamic balance between beneficial and pathogenic microorganisms in the soil, thus ultimately revitalizing and healing the soil;
- contributing to reducing the risk of soil dehumusification, intensifying the humification process and accumulating-stabilizing humus in chernozem structural aggregates (3-1 mm) which are characterized by maximum humus content and increased hydrostability.

Tillage at a depth of 8-10/14-16 cm ensures the continuity of the pore space and the ratio between pores with various functions. This contributes to an optimal ratio between the volume of solid, liquid, gaseous phases and the free circulation of water and air in the soil. The bioaerohydric and biohydrothermal conditions created in the soil favor the processes of decomposition-humification of fresh organic matter with the formation of qualitative humus and organo-mineral phytonutrients with phosphorus, nitrogen, potassium, etc.

Water vapor, permanently present in the soil air, concentrates at the boundary surface between the loosened and uncultivated segment. This contributes to the formation of "internal dew" (internal irrigation) and ensures satisfactory aerohydric and biohydrothermal conditions for the implementation of biological and biochemical processes with the provision of organo-mineral nutrients even in conditions of moisture deficit.

In addition, under these conditions, the need for mineral fertilizers is reduced, the administration of which in conditions of moisture deficit has a negative impact on soil and plant biota (Jigău, 2018).

Another important advantage of Mini-till with mulch technologies is the possibility of their implementation without a transition period (5-7 years) required for the implementation of No-till.

At the same time, they are suitable for all soils with medium, medium fine granulometric composition and those with finer granulometric composition (clay-loam and clay). Mini-till with mulch technology based on loosening with a chisel and a side plough are more suitable for sloping lands with a risk of erosion and the combined Mini-till technology based on loosening (0-30 cm) without turning the furrow and forming a mulch layer by incorporating organic residues with a disc harrow 8-10/14-16 cm (depending on the granulometric composition) is more suitable for eroded lands for the purpose of regenerating the chernozem pedogenetic process and their ecological rehabilitation.

The applicative-pedoregenerative framework for implementing and practicing Mini-till technologies with soil tillage mulches is confirmed by the evolution laws of the basic physical parameters of chernozems (structural-aggregate composition; settlement indices; apparent density, total and differential porosity) which are determined by the physical processes of self-organization (manifested in the structural-aggregate composition) and self-loosening (manifested in the settlement state indices).

In this sense, the present research has shown that both in the case of direct sowing (No-till) and in the case of mini-till soil tillage with mulches, there is a clear tendency for regeneration of the structural-aggregate composition and its homogenization in the active humiferous layer (0-60 cm), but with different quantitative expression.

Table 1. Structural-aggregate composition of arable chernozems under No-till system conditions

Soil	Depth, cm	Aggregate diameter, mm. Aggregate content, %					
		>10	0,25-10	5-1	2-1	<0,25	Ks
Typical moderately humiferous chernozem*	0-20	11,4	85,7	50,2	18,9	2,9	6,0
	20-40	13,0	85,7	49,3	19,3	1,3	6,0
	40-60	29,4	69,5	38,8	19,5	2,1	2,3
Typical weakly humiferous chernozem**	0-20	6,0	89,8	51,1	21,2	4,2	8,8
	20-40	11,2	86,4	57,0	21,9	2,4	6,4
	40-60	8,3	90,4	59,0	23,1	1,3	9,4
Typical weakly humiferous chernozem**	0-20	9,2	88,8	49,3	19,6	2,2	7,9
	20-40	12,2	86,2	54,1	22,3	1,6	5,5
	40-60	13,6	85,0	55,2	25,2	1,4	5,7
Carbonate chernozem**	0-20	8,3	88,8	55,3	22,4	2,9	7,9
	20-40	13,6	84,7	57,1	20,5	1,7	5,5
	40-60	14,9	83,7	55,3	20,0	2,4	5,1

*No-till since 2007 without transition period

**No-till 3 years with transition period Minitill with mulch 5 years

The data presented in Table 1 show that in the case of No-till the regeneration of chernozem processes of soil mass aggregation and the effects induced by them depend on the way in which the technology was implemented. In this sense, from the data presented, we find that in the case when the No-till technology was implemented without a transition period for optimizing physical tillage, despite the long period (17 years) of its practice, the active humus layer (0-60 cm) by its structural-aggregate composition is clearly divided into two substrates.

The upper substrate (0-40 cm) is characterized by an aggregate content > 10 mm below the critical level of 20%. The content of agronomically valuable aggregates (0.25-10 mm) in the 0-40 cm substrate is excellent and the content of agronomically valuable chernozem aggregates (5-1 mm) falls within the range of "good" values. The content of the fraction < 0.25 mm presents values < 3% which indicate the increased mechanical stability of the structural-aggregate composition. The structuring coefficient (Ks) presents excellent values (Ks = 6.0) corresponding to soils with excellent structural-aggregate composition.

The underlying substrate (40-60 cm) is substantially detached from the overlying one by the parameters of the structural-aggregate state.

The content of aggregates > 10 mm in it exceeds by about 2.3-2.6 times their content in the overlying layer and the content of agronomically valuable aggregates (0.25-10 mm) is about 1.2 times lower than in the overlying layer (0-40 cm). The content of agronomically valuable aggregates (5-1 mm) is about 1.3 times lower. At the same time, the content of the 2-1 mm fraction, which practically does not react to changes in land use, has relatively identical values throughout the entire thickness of the active humus layer (0-60 cm) (Kholodov et al., 2019).

Based on the above, we consider that in the case of No-till technological implementation without a transition period (5-7 years) in chernozems, soil mass reaggregation processes occur that are determined by physical processes without renewal of the aggregate mass. In our opinion, the specified structural-aggregate state is determined by the achievement of the coagulation-structuring process only in the 0-40 cm layer where the root residues are concentrated, the decomposition-humification of which provides an insufficient amount of humic substances for the regeneration of the chernozem aggregation-structuring process. The humic substances that are formed as a result of the decomposition of vegetable mulch at the soil surface participate in aggregation-structuring only in the superficial segment of the active humiferous layer.

At the same time, from the data of the same Table 1, we find that when the implementation of No-Till technology is followed by a 5-year Mini-till transition period with mulch in chernozems, a stable tendency for the regeneration of the chernozem aggregation-structuring process is established throughout the entire thickness of the active humus layer (Table 2).

Table 2. Structural-aggregate composition of arable chernozems under conditions of Mini-till tillage system with mulch

Soil	Depth, cm	Aggregate diameter, mm. Aggregate content, %					
		>10	0,25-10	5-1	2-1	<0,25	Ks
Typical moderately humiferous chernozem	0-20	9,0	88,7	56,3	28,3	2,3	7,8
	20-40	12,3	85,5	56,9	21,3	1,9	6,2
	40-60	16,0	82,6	50,5	19,8	1,4	4,7
Typical moderately humiferous chernozem	0-20	12,3	84,8	53,2	19,3	2,9	5,6
	20-40	18,5	89,6	53,1	19,5	1,9	8,6
	40-60	13,8	84,1	59,3	24,0	2,1	5,3
Typical moderately humiferous chernozem	0-20	9,2	86,9	51,3	21,5	3,9	6,6
	20-40	12,0	84,2	55,2	21,2	3,8	5,3
	40-60	14,3	84,3	52,2	20,0	1,4	5,4
Typical weakly humiferous chernozem	0-20	6,8	89,2	54,6	29,3	4,0	8,3
	20-40	9,3	88,2	55,7	27,1	2,5	7,5
	40-60	8,5	90,1	59,6	27,2	1,4	9,1
Typical weakly humiferous chernozem	0-20	9,2	86,2	61,1	28,2	4,6	6,2
	20-40	10,8	86,0	54,0	21,0	3,2	6,1
	40-60	9,9	88,0	59,4	29,8	2,1	7,3

The data presented in Table 2 confirm that the pedogenetic environment established under Mini-till conditions with mulch contributes to the interdependent and interdetermined regeneration of the humus formation-accumulation process and the aggregation-structuring process with its stabilization in chernozem structural aggregates (5-1 mm).

The quantitatively and qualitatively interdependent and interdetermined realization of chernozem typogenetic processes contributed to the formation of a homogeneous active humiferous layer with excellent aggregate composition throughout its thickness (0-60 cm).

Within it, the content of agronomically valuable aggregates (0.25-10 mm) varies in the range of values 84-90% and in the composition of the agronomically valuable structure about 61-71% belong to agronomically valuable aggregates (5-1 mm). The content of aggregates > 10 mm presents values below 20% and allows us to conclude that during the vegetation period in the soils no processes of structural degradation occur. On the contrary, the content and distribution of aggregates in agronomically valuable (0.25-10 mm) and agronomically valuable (5-1 mm) indicate the establishment in it of a process of renewal of the aggregate structure determined by the simultaneous interaction of the coagulation, root and coprolitic mechanisms of aggregation-structuring of the soil mass. The driving force of these processes are the humification-accumulation processes of humus that are carried out in the active humiferous layer supported by the regeneration of the functionality of the organic substance system of arable chernozems.

The content of 2-1 mm aggregates in most cases makes up > 20% and its increase indicates the regeneration of the entire structural-functional organization chain:

ultramicroaggregate→microaggregate→fine aggregates→mesoaggregate-macroaggregate with ensuring the degree of physical protection of organic carbon in the 5-0.25 mm aggregates.

The content of aggregates < 0.25 mm and their distribution within the active humiferous layer indicate a high degree of mechanical stability of the aggregate structure formed under Mini-till with mulch conditions.

The indices of the settlement state (apparent density, total and differential porosity) are indispensable functions of the structural-aggregate composition and vary depending on its variability (Table 3, 4). This allows us to conclude that both under No-till conditions and under Mini-till with mulch conditions in soils, processes of restoring the volume, composition and continuity of the porous space are carried out, manifested in the ratio between the physical phases (solid, liquid, gaseous of the soil) whose quantitative expression is the apparent density.

Tabelul 3. Indici de așezare a cernoziomurilor în condiții de No-till

Soil	Depth, cm	Apparent density g/cm ³	Porosity, %			
			micropores	mesopores	macropores	total
Typical moderately humiferous chernozem*	0-20	1,13	15	25	10	50
	20-40	1,28	18	25	8	51
	40-60	1,39	25	15	5	45
Typical weakly humiferous chernozem**	0-20	1,00	8	25	12	45
	20-40	1,19	10	25	9	44
	40-60	1,28	10	20	6	36
Typical weakly humiferous chernozem**	0-20	1,08	10	26	8	44
	20-40	1,15	12	28	8	48
	40-60	1,24	14	25	6	45
Carbonate chernozem**	0-20	1,08	10	30	15	55
	20-40	1,16	13	27	11	51
	40-60	1,25	13	29	8	50

*No-till since 2007 without transition period

**No-till 3 years with transition period Minitill with mulch 5 years

Table 4. Chernozem settlement indices under Mini-till with mulch tillage system conditions

Soil	Depth, cm	Apparent density g/cm ³	Porosity, %			
			micropores	mezopori	macropori	totală
Typical moderately humiferous chernozem	0-20	1,05	9	28	11	48
	20-40	1,12	13	29	8	50
	40-60	1,23	13	26	8	47
Typical moderately humiferous chernozem	0-20	1,03	8	29	12	49
	20-40	1,14	12	26	10	48
	40-60	1,21	16	22	9	47
Typical moderately humiferous chernozem	0-20	1,05	9	28	11	48
	20-40	1,12	13	29	8	50
	40-60	1,23	13	25	7	45
Typical weakly humiferous chernozem	0-20	1,06	8	30	15	53
	20-40	1,16	7	30	15	52
	40-60	1,23	7	30	11	48
Typical weakly humiferous chernozem	0-20	1,06	5	35	12	52
	20-40	1,19	7	35	10	52
	40-60	1,27	9	30	10	49

Comparative analysis of the data presented in Tables 3 and 4 shows that with greater efficiency the structural-functional reorganization proceeds under conditions of Mini-till with mulch in which the active humiferous layer is characterized by "excellent" values of apparent density and "good" and "relatively good" volume of the volume and the ratio between pores with various functions.

Controlled incorporation of plant residues and annual storage of root residues in it led to the start of the development and restoration of the humiferous detritus layer in the upper segment of the profile

responsible for the regeneration of bioenergetic, physical, phytosanitary and hydrological functions of the organic substance system of arable chernozems under conditions of the Mini-till system with soil tillage mulch (Table 5).

Table 5. Physical soil regenerative functions of the organic matter system of chernozems under conditions of Mini-till
System with soil tillage mulches

Functions	Functions Pedoregenerative Effects
Biological	
Substrate for the microbiome	Source of carbon and energy
Reservoir of biophilic elements	Source of biophilic elements for phytocenosis and soil biota (zoocenosis; pedocenosis).
Supply of biologically active substances	Continuous production of native enzymes and physiologically active substances for soil biota.
Supplier of organo-mineral phytonutrients	Production of mobile humic substances as a source of nutrition for plants and biota.
Supporting the active carbon and nutrient cycle in the ecological system "soil-agrophytocenosis"	Reintegration of carbon, biophilic micro- and macroelements into the biogeochemical cycle.
Catalyzing the chernozem pedogenetic process in the "B" transition horizon	Formation of humic substances carrying the "chernozem genetic code", and their migration from the "Am" horizon to the B horizon.
Expanded reproduction of the chernozem organic matter system	Reestablishment, over time, of the "humification-productive zone" in the Am horizon, the unidirectional development of the "transformational-accumulative zone" in the "B" horizon.
Physics	
Aggregation-structuring of the soil mass	Supply of humic substances with coagulation-aggregative action
Organo-mineral reactions and stabilization of organic carbon	Formation of organomineral products and hydrostable aggregates with stabilization of organic carbon.
Ensuring structural and functional stability	Optimization of hydrophysical properties, water permeability and hydraulic conductivity.
Self-loosening and self-organization of the soil mass	Reduction of volumetric mass and ensuring its stability to drought and moisture deficit; development of meso- and macropores.
Regulator of the thermal regime of soils	Determination of the thermal properties of the soil.
Chemistry	
Cation exchange	Factor of exchange of cations and molecules with the adsorptive complex of the soil [CAS].
Stabilization of soil reaction	Inducer of the buffering capacity of the soil and stabilization of its reaction.
Formation of complex compounds	Supply of substances forming complex compounds.
Immobilizer of pollutants	Sorbent-detoxifier of toxic substances for soil biota and plants.
Ecology	
Stabilizer of terrestrial ecosystems	Factor of stability, flexibility and resilience of the "soil-plant" system.
Biotope for geobionts	Vital space for soil biota and determining factor of its biodiversity.
Source and accumulator of greenhouse gases	Producer and acceptor/sequestrator of greenhouse gases.
Phytosanitary	
Anti-pathogenic activity	Nutrient substrate for antagonistic organisms with antipathogenic effect
Self-accumulation capacity	With substrate for organisms that break down organic pollutants.
Hydrological	
Supporting chernozem pedogenetic processes in the transition horizon "B"	Formation of hydro-accumulative capillary barriers that ensure interception of capillary-ascending water currents and block unnecessary water losses during evaporation. Reduction of capillary-adsorption potential in the mulch layer as a

	result of reducing the volume of capillary pores and formation of a capillary-suspended water layer in the underlying segment.
Restoring the water regime	Restoration of the balance of dynamics and water circulation in the soil and substitution of the pronounced non-percolative exudative-transirative agrogenic water regime with the periodic deep percolative desorption-transpiratory water regime. Reduction of the period of deficient water supply ($W < 0.35CC$).

CONCLUSIONS

The current state of arable chernozems in the area between the Prut and the Dniester rivers, the pedoregenerative objective involves practicing agricultural technologies capable of ensuring in soils conditions maximally corresponding to the natural model of reproduction of the basic typogenetic processes manifested in the structural-aggregate state and the indices of the settlement state.

The comparative analysis of the No-till and Mini-till tillage systems with mulch has shown that at this evolutionary stage of the natural-anthropogenic chernozem pedogenesis, preference should be given to the Mini-till system with mulch, which to a greater extent corresponds to some basic requirements of the concept of regeneration of typogenetic processes: the permanent presence in the soil profile of humiferous detritus represented by organic residues in various phases of transformation-humification, root residues, preservation of about 30-35% of plant residues and about 60-65% of stubble on the soil surface.

Typogenetic regeneration processes under Mini-till conditions with structural-aggregate state and settlement state parameters.

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SECTION 2:



2.1. CAPITALIZING ON THE POTENTIAL OF WINE BY PRODUCTS IN ORDER TO IMPROVE DEGRADED SOILS

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Abstract

Soil is a living ecosystem, dynamic through the multitude of useful macro and microorganisms (viruses, organic degradation bacteria, fungi, insects, etc.), which multiply dependent on abiotic and biotic factors to create a functional balance. It is an essential component of terrestrial ecosystems and not only that, being essential to all terrestrial life. Soil degradation represents the decline in the capacity to support and develop its ecosystems following the phenomena of accelerated erosion, salinization, mineral and organic imbalances, acidification and depletion of soil organic carbon (SOC). Currently, the aim is to minimize the impact of human activities on the environment without reducing economic yield through techniques that properly manipulate, eliminate or recycle by-products and waste. As a result of the winemaking process, a variety of secondary products are generated, considered without economic utility and currently have limited secondary applicability. Implementing strategies aimed at utilizing these by-products can become a life-saving solution for degraded soils. The present study aims to identify methods for applying circular models for capitalizing on the phenolic and mineral potential of pomace.

Key words: vinification by products, degraded soils, composting

INTRODUCTION

Soil is a defined body of four dimensions (length, width, depth and time). It provides contact between atmosphere and lithosphere and is essential for all terrestrial life. From a functional point of view, soil is also the earth's geomembrane, a protective filter, a buffer and energy, water and biogeochemical compounds mediator, a germinal reservoir and an archive of planetary history. (Research & 2012, 2012)

Soil health has effects on human well-being in a broad sense, as soil is the main source from which most food comes. It also intervenes in the performance of complex ecological functions, which ensure the balance of the planetary ecosystem (Pimentel et al., 1995). Sanchez and Swaminathan have been reporting since 2005 that the main cause of malnutrition on the African continent as well as subsequent social problems is the "soil health crisis" (Sanchez et al., 2005)

Soil degradation is a global problem caused by many factors; intensive agricultural techniques, inadequate crop rotations, overgrazing, deforestation, mining, construction, urban sprawl and, last but

not least, climate change. The pressure exerted by the needs of an expanding global population requires the adoption of sustainable agricultural and land management practices that maintain and improve soil health. These strategies represent the best solution for mitigating and reversing current soil degradation trends.(Nadal-Romero et al., 2016.).

Soil degradation is not a new problem for humanity. Greek and Roman philosophers were aware of soil health importance for prosperity and demonstrated this understanding by the treatises on farm management more than 2,500 years ago (Hillel, 1992).

Conventional agricultural techniques tend to deplete natural resource and thus produce imbalances in soil microbiome with adverse consequences both on crops health and along the entire food chain.(Dini-Andreote & Van Elsas, 2019).

Soil health is defined by their microbiome. Imbalances in the microbiome lead to a decrease in nitrogen (N), phosphorus (P) concentrations and other essential plant nutrients. These imbalances cannot be remedied or substituted, even by the synthesis of genetically improved clones. Deficiency of these elements has repercussions on production yields, causing a cascade of negative effects throughout the socio-economic chain (Management & 2019). Soil health appraisal is still dominated by chemical indicators, despite discoveries related to soil biodiversity importance, due to limited functionality knowledge on soil ecosystems (Lehmann et al., 2020).

In addition to intensive agricultural techniques, climate change, through an increase in frequency and intensity of extreme events that has serious repercussions at a global level, accelerating the growth of degraded land areas (Tully et al., 2015)

Both the scientific community and policy makers consider that approaching a "Circular Economy (CE)" concept represents the only alternative that can ensure economic prosperity and social well-being, conserving natural resources and biodiversity and thus ensuring the future generations (Völker et al., n.d.)

Winemaking processes involve a complex series of operations, from growing grapes, harvesting, fermentation and wine aging to managing specific categories of waste generated in all technological stages. The main residue in winemaking is grape pomace, also called pomace. It results from grape pressing process. This by-product is composed from stems, skins, pulp and seeds. Each component having variable percent representation in total pomace mass: 30% grape stems, 30% seeds and 40% grape skins and pulp. This gives to this winemaking by-product a series of qualities that were previously not exploited(Contreras et al., 2022). As current management of winemaking residues is in the early stages of development, the focus is on its use as an organic soil improver (Sayara et al., n.d.).

The present study aims at identifying methods for applying circular models that capitalize on phenolic and mineral potential of pomace resulted from winemaking processes, using composting methods.

MATERIALS AND METHODS

Consultation of relevant international databases: Elsevier (Science Direct), MDPI, PubMed, Frontiers, Springer and Wiley Online. Bibliographic sources were used to retrieve articles, book chapters and international articles.

In order to consult the European legislation in force and to select directives or reports related to relevant keywords, international databases for the European Commission were used.

Keywords relevant to the topics of interest were taken into account: "grape marc", "winemaking by-products", "circular economy", "composting methods", "grape marc recovery"were selected.

The selected publication period included articles until 2024, published in English.

Based on the data reported in literature, an experimental protocol for composting grape marc, with regular determination of pH in the composting platform, was initiated.

RESULTS AND DISCUSSIONS

Grape pomace is an appreciable by-product (representing solid organic waste that results after pressing procedures), representing maximum 25% of total grape weight used in the winemaking process (Rodrigues et al., 2022).

Pomace quantity tends to variate and is dependent on vine variety and technological processes used. Moisture percentage after pressing is usually situated around 20–30%, while resulting organic material characterized by a C:N ratio situated between 40 to 45:1 and a pH between 3 and 6, low electrical conductivity and high content of organic and inorganic matter. Micro and macronutrients complexes are mineralized over time (Troncozo et al., 2019).

Products generated by composting grape pomace can have a positive impact by changing the amount of available soil organic carbon. This practice is in accordance with latest circular economy principles regarding waste management (Kokkinomagoulos & Kandyli, 2023).

Attention is currently focused on the possibility of efficient use of grape pomace for the production of organic fertilizer through the composting process. Composting is a biotechnological process that degrades polymeric substances naturally present in pomace via hydrolytic enzyme activity released by mesophilic and thermophilic microorganisms during mineralization under aerobic conditions (Azim et al., 2018). Composting products are CO₂ and stable forms of carbon, so organic matter decomposition and mineralization lead to humic substances production (Wang et al., 2020)

Composting consists of the following phases:

1. mesophilic phase is characterized by the rapid growth of fungi and bacteria due to absorption of soluble sugars and starch;
2. thermophilic phase is characterized by microbial enzymes protease, hemicellulase, and cellulase degradation
3. cooling phase (second mesophilic phase) occurs when microorganisms thermophilic activity ceases due to nutritive substrate depletion;
4. maturation phase is characterized by substrate quality decrease and formation of lignin-humic complexes (Salgado et al., 2019)

Compost quality is dictated by raw materials capacity to produce a stabilized final product during aerobic biological transformation of organic matter up to its humidification process that can be evaluated in the maturity phase. (Bazrafshan et al., 2016)

Two characteristics define compost: stability and maturity. Stability is related to the transformations of the initially unstable products into stable organic matter at the end of composting (Salgado et al., 2019-b). Maturity refers to safe use due to the absence of phytotoxic substances (Isobaev et al., 2019). Compost stability and maturity are evaluated through various physical, chemical and biochemical indicators such as temperature, C, CO₂, Ha/Fa ratio, NH₄ N/NO₃ N, C/N, pH, microbial biomass, enzymatic activities, seed germination and heavy metal concentration. (Yu et al., 2019)

However, no single method or parameters can be universally applied for evaluation due to variation in feedstock and composting method. (Lin et al., 2018). Specifically, pomace composting can be performed using only materials resulting from fermentation processes or in mixtures with other materials to lower the C/N ratio to improve compost quality (Fincheira-Robles et al., 2016)

However, there are limited studies that use a variety of raw materials provided by the wine industry involving chemical, biochemical and microbiological parameters assessing the quality of compost. In this context, this study proposes recycling wine industry by-products through composting in order to produce organic amendment in vine plantations. In this sense, composting appears to be a viable strategy to enrich soil low organic matter content determining higher grape production yields. Therefore, evolution of chemical, microbiological, phytotoxic and biochemical stability parameters during composting processes for different wine industry raw materials in order to determine compost maturity.

Circular economy case studies

1. A study was conducted at Empresas Bauzá located in Ovalle (Coquimbo Region, Chile). Climate is classified as steppe according to the Köppen Climate Classification System, with inceptisol soils characterized by low organic matter concentration (<1%). Area was characterized by a thermal amplitude of 20°C with an average annual temperature of 16°C and total 150mm/year with 85% probability of rainfall in winter.

Method used:

- derivatives of horse manure, goat manure;
- grape pomace (fresh and aged);
- cutting residues, oat straw;
- yeast fermentation residues;

Composting methods in Romania

Grape pomace as fertilizer

1. Experimental protocol was implemented at the University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" of Banat - Timișoara, Faculty of Horticulture and Forestry;

2Szent István University, Institute of Genetics and Biotechnology, Páter K.u.1., Gödöllő, Hungary; University of Agricultural Sciences and Veterinary Medicine "King Michael I of Romania" Banat - Timișoara, Faculty of Agriculture- Nistor Eleonora^{1*}, Dobrei A.1, Dobrei Alina¹, Kiss Erzsebet², Ciolac Valeria, as follows:

pomace as control (P1);

grape pomace with 20% chicken manure pile (P2);

grape pomace with 30% chicken manure pile (P3).

Chicken manure was added as an activator for the bioconversion (composting) process. Temperature and humidity were measured periodically in each pile and monitored during the 6-month compost preparation period. Humidity was monitored at a max depth of 0.50 m starting at the top of the pile with a weekly frequency. Temperature measurements were also taken weekly in the center of the compost platform, at a depth of 0.50 m from the top via the use of a soil thermometer. Chicken manure was added to the pomace to increase the pH value which allows for greater microbial activity in the composting mass. Low pH in fresh pomace (3.7 – 4.5 pH) and must be adjusted to activate microorganisms and ensure microbiological conversion. Composted material was turned over every 2 weeks to facilitate fungi and bacteria aerobic activity during humification process, otherwise oxygen limitations within the material are problematic. Reduced oxygen circulation can limit decomposition. Composting can be a process that takes six to ten months, depending on turning frequency, humidity and temperature of the piles.

Grape marc compost is a very good fertilizer in viticulture because it gradually releases nutrients from the soil needed by the vine, especially nitrogen and potassium, the latter being considered a quality factor in wines. The gradual release of nitrogen into the soil is suitable for vineyards, which generally have high nitrogen levels. Grape marc compost is recommended for vineyard application because high water content present in organic matter facilitates its incorporation and improves soil water-holding capacity, and gradually release of nitrogen and potassium.

Temperature is a very important parameter in composting processes because it is directly correlated with the composting bioprocess. For efficient composting, an optimal humidity between 45-60% (water concentration in the pile) and a temperature (45 – 60°C) are required.

Temperatures exceeding 70°C can lead to combustion, destroying valuable organisms and microbes (fungi, bacteria).

Composting methods for grape pomace carried out at SCDVV Bujoru



Fig.1 Grape pomace composting platform 2023



Fig.2 Grape pomace compost whit Calcium hydroxide conglomerates

2.1

- 30cm layer of pomace;
- addition of quicklime-Calcium Oxide 2%, for neutralization;
- addition of a 20cm layer of soil, to create a conducive binder for fungi and bacteria development in humification process;
- moistening with water;
- rhythmic control of temperature, humidity and pH, to be adjusted.

2.2

- 30cm layer of pomace;
- addition of slaked lime-Calcium Hydroxide 2%, for neutralization;
- addition of a 20cm layer of soil mixed with sawdust, to create a binder conducive to the growth of fungi and bacteria in the humification process;
- moistening with neutralized yeast;
- rhythmic control of temperature, humidity and pH, to be adjusted

Data obtain during initiation of composting processes regarding temperature and pH is synthesized in table 1.

Table 1. pH temperature variations during composting

Compost platform	pH/ temp	Observations	Ambient temperature °C
1	7/11		0
2	7/16		0
3	7/14		0
4	7/18		0
Raw grape pomace			
Thin layer	7/14		0
Thick layer	5/47°C	intensely fermenting; insect + white	0
Thick layer	5/33°C	fungal mycelium coating is observed	0
Initial compost formation		intensely fermenting	0

South platform	5/9; 7/8; 5/5; 5/5; 5/5	3
North platform	5/20; 5/16; 5/20; 5/19; 5/19	3
29.02.2024 -Composting platform turn over	platform was mixed for fermentation	
N-V	5/23,5; 5/23	
CENTER	5/30; 5/22	
S	5/22	
V	5/32	

In 2024, composting platform was expanded in order to optimize grape pomace composting processes (Fig.3).



Fig.3 Grape pomace extended composting platform 2024

Grape pomace compost was distributed evenly across Fetească neagră vineyard experimental field situated at experimental base 2 (F-2). Compost spreading aimed at obtaining a 10 cm uniform layer across the entire surface of the experimental field. pH and temperature variations were monitored using variable locations whit multiple measurements form each location.

Data collected from field experiment during spring and summer months, detailed in tab.2.

Table 2. pH temperature variations during field experiments

Field experiment	pH/ temp	Observations	Ambient temperature °C
<i>F-2 Fetească neagră</i>	7/10	18.04.2024-eperimental initiation	15
<i>Jos spre sediu</i>	7/30		15
	5/30	Soil pH predominantly acidic	15
	5/30		15
<i>F-2 Fet. neagra</i>			22
<i>mijloc spre sediu</i>			23
	5/18	Soil pH predominantly acidic	22
<i>F-2 Fet. neagra</i>			22
<i>Jos spre sediu</i>			30
	5/25	Soil pH predominantly acidic	29
			30

F-2 Fet. neagra
mijloc spre sediu

		30
		33
5/28	Soil pH predominantly acidic	33
7/28		33
5/29		34
5/28		33
5/30		34

After compost treatment during April 2024, rhythmic soil pH measurements were carried out until the time of grape harvest (September 2024)

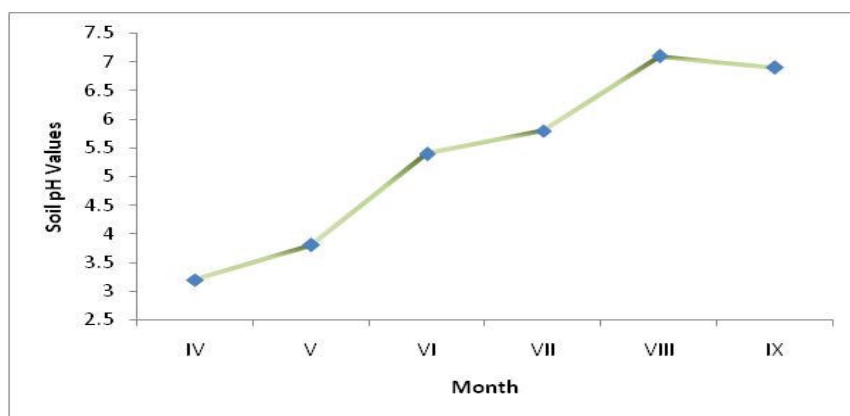


Fig. 4 Soil pH Variation in the experimental field

Experimental field was characterized by natural acidic pH values, present throughout Bujoru viticultural area. When applying the pomace compost, an increase was observed from values of 5.2 towards neutral, with maximum values of 7.1. Initial temperature values were close to those measured in composting platform. Monthly observations saw a decrease in initial temperatures whit values close to ambient.

CONCLUSIONS

- Wine yeast can be used as such, by mild neutralization and as an adjuvant in wetting the composted pomace platform in order to accelerate biochemical processes.
- Pomace compost produced an improvement in the native pH of the soil with possible positive effects on the supply of organic carbon in the soil and macronutrients in the soil.
- The composting method currently being implemented in the experimental field of the SCDVV Bujoru area may be a possible solution to slow down the processes of soil degradation in SE Romania

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2.2. WINTER WHEAT GENOTYPES RESPONSE TO PLANT GROWTH REGULATORS AND NITROGEN FERTILIZATION APPLICATION

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Abstract

Even though wheat breeding programs have improved wheat over the years in terms of yield, quality traits and resistance of the new cultivars, environmental factors still have an impact on wheat growth and development. Extreme climate events like heavy rain and wind can cause lodging, which can affect winter wheat grain yield. PGR applied from the beginning of stem elongation can effectively control lodging. One of the goals of the winter wheat Breeding Laboratory at the ARDS Turda, is the improvement of their cultivation technology. This was the main reason for the beginning of a study to see the effect of PGR treatment and different nitrogen fertilization rates on some morpho-physiological traits and yield capacity of seven winter wheat genotypes. PGR treatment reduced the plant height of the genotypes from this study. In the plots where the highest dose of nitrogen was administered, genotypes with tall plant heights showed a higher manifestation of lodging; however, PGR treatment reduced the lodging risk of these genotypes. Using PGR is an important and cheap way to reduce lodging and to prevent yield losses.

Key words: cereal lodging, plant height, PGR, yield, winter wheat.

INTRODUCTION

Despite all of the progress made over the years in wheat breeding programs to improve wheat new cultivars in terms of resistance, yield, and quality traits, environmental factors continue to have an impact on wheat growth and development, particularly on wheat yield and quality. Local natural factors are represented by diverse climate conditions in each place, which are highly different from one place to another and cannot be controlled by humans (Leonte, 2011). In recent years, we are witnessing extreme climatic phenomena (Mustățea et al. 2008) and one of the phenomena we encounter especially in the rainy years which causes decreased yield is lodging. There are many factors that contribute to lodging, mostly: wind, heavy rain, hail (Rajkumara, 2008) and high amount of nitrogen fertilizer applied (Mykhalska et al., 2020; Leonte, 2011; Berry et al., 2004). Along with good agricultural practices lodging can be efficiently controlled through the use of plant growth retardants applied of the beginning of stem elongation. Using these chemical compounds to prevent lodging is absolutely necessary especially in areas with high amount of rainfall or when high doses of nitrogen fertilizers are applied (Muntean et al., 2014).

Plant growth retardants (PGR) like chlormequat chloride and trinexapac-ethyl are synthetic substances that have been used in agriculture for a long time for reducing plant height, because they produce thicker and shorter stalks, thus facilitating the mechanical harvesting of cereals. In order to prevent lodging in winter wheat, many of the available plant growth regulators (PGRs) are applied prior to and/or during stem elongation with the aim to produce lower internodes with shorter lengths, thicker stems and stem cell walls (Qin et al., 2020).

Retardants are artificial chemical substances that allow humans to control and even regulate the growth, development, and ripening processes of plants. They affect different plant organs and tissues in a complex and specific way. Retardants temporarily slow the growth of vegetative organs, particularly stems and shoots, but they usually promote flowering and fruiting, which results in significant increases in both quantitative and qualitative production. In subapical meristem tissues,

the intensity of cell division and elongation is decreased, which inhibits the formation of stems and shoots. Retardants "do not irreversibly block the vital metabolic processes of plants, do not cause malformations in various vegetative or reproductive organs, and do not reduce the viability of the whole plant." (Neamțu et al., 1991; Gâdea, 2009). In agronomic crops, plant growth retardants are used to minimize unwanted longitudinal shoot growth without reducing plant productivity (Matyasiak, 2006).

One of the goals of the winter wheat Breeding Laboratory at the Agricultural Research and Development Station Turda, in addition to the creation of new varieties of winter wheat, is the improvement of their cultivation technology, and using plant growth retardant is an important and cheap way to reduce lodging and to prevent yield losses caused by lodging. This was the main reason for the beginning of a study to see the effect of PGR treatment and different nitrogen fertilization rates on some morpho-physiological characters, yield capacity of winter wheat, cultivated in Transilvania Plain conditions. The purpose of this research was to collect as many information regarding PGR influence, how to they act on winter wheat, to see if their application is justified, for introducing this treatment in the cultivation technology of the new varieties created at Agricultural Research and Development Station Turda.

The purposes of this research were:

- The evaluation of PGR influence on winter wheat morpho-physiological characters such as plant height and the length of the internodes;
- The assessment of PGR influence in reducing or preventing lodging risk;
- The evaluation of PGR influence on yield.

MATERIALS AND METHODS

The field experiment was conducted at the Agricultural Research and Development Station Turda and the experimental design consists in subdivided plots in a three factorial experimental system.

The experimental factors were:

1. PGR treatment:
 - Ct.- Untreated (Control);
 - OT- Treated with Optimus 175 EC (trinexapac-ethyl);
 - ST- Treated with Stablan (chlormequat chloride).
2. Nitrogen fertilization:
 - F1- base nitrogen rate applied in autumn before sowing N₅₀P₅₀;
 - F2- base nitrogen rate + on crop fertilization with N₁₅₀;
3. Winter wheat genotypes:
 - Arieșan, Apullum, Andrada, Codru, Bezostaia, Cezara, T 109-12.

The PGR foliar treatment was applied with the Solo Backpack Sprayer:

- In 28.03.2019 and 18.03.2020 Stablan (2l/ha) was sprayed over the foliage at the beginning of stem elongation stage; and Optimus was applied in 03.05.2019 and 28.04.2020 when winter wheat was in the stem elongation stage with 4 internodes formed.

Nitrogen fertilizer used in this experience was Nitrocalcar and was applied like so:

Base nitrogen (F1) rate was applied before sowing in autumn.

On crop fertilization (F2) rates was divided in two, first rate was applied when wheat winter wheat was in the stem elongation stage (10.04.2019; 27.04.2020) and the other half at boot stage (17.05.2019; 14.05.2020).

Observation and determinations made:

- At final stage of maturity, the plant height was measured and grades were given for lodging resistance to every genotype.

- Plants treated with PGR and untreated with PGR from every experimental plot were taken before harvest and after that in the laboratory length of the internodes were measured at 30 stalks.
- The quantity of seed harvested from each plot was weighed and the production per hectare was calculated for each experimental plot.

The data were statistically processed through Polifact and Microsoft Office 2010.

Regarding the temperatures (figure 1), the two experimental years were warm due to both the hot summer months and the occurrence of winter temperatures above the multiannual average, which has become more frequent in recent years.

Monthly rainfall averages (figure 2), have fluctuated from drought to excessively rainy, in 2019, the months of April and May were rainy, followed by 2 dry months, while in 2020 the stem elongation stage, that is, the months of April and May, were dry, and at the end the vegetation period of the wheat in June and July recorded large amounts of rainfall.

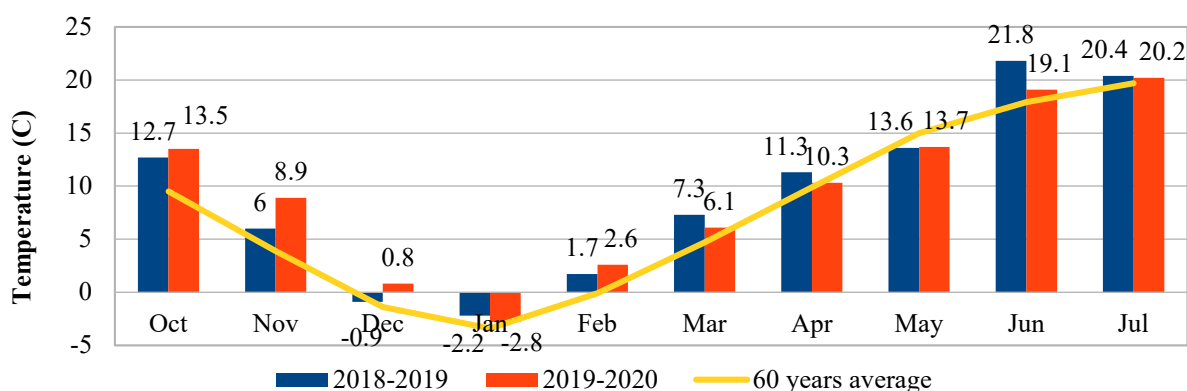


Figure 1. Temperatures (°C) during winter wheat vegetation period, in Turda Romania.

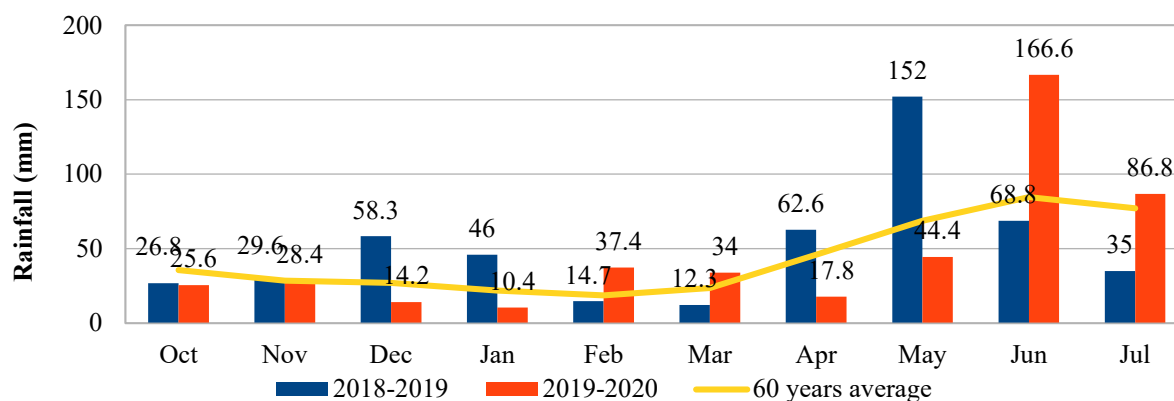


Figure 2. Rainfall (mm) during winter wheat vegetation period, in Turda Romania.

RESULTS AND DISCUSSIONS

The climatic differences of the 2 years in which this study was conducted had an impact on wheat growth and development, which is evidenced by the Duncan test (table 1). Plant height differences are evident; in 2019, the height of the plants was significantly higher than in 2020; nevertheless, lodging was greater in 2020 than in 2019, and the yield was significantly higher in 2020 than in 2019. When compared to Stabilan treatment, Optimus treatment caused a more significant decrease in plant

height and reduced the occurrence of the lodging phenomena. Additionally, the yields obtained from the retard-treated variants were superior to those from the untreated variant.

Table 1. The influence of the experimental factors on studied traits according to Duncan Test

Experimental factors		Plant height (cm)	Lodging resistance	Yield (kg/ha)
Year	2019	102.04 a	1.82 b	5901 b
	2020	92.12 b	3.65 a	7633 a
		SX= 0,76	SX= 0.07	SX= 132
PGR Treatment	Ct.	100.38 c	3.10 a	6677 b
	OT	94.39 a	2.42 b	6856 a
	ST	96.46 b	2.69 a	6767 ab
		SX= 0,44	SX= 0.10	SX= 33
Nitrogen fertilization	F1	96.25 b	2.32 b	6318 b
	F2	97.91 a	3.15 a	7215 a
		SX= 0,51	SX= 0.08	SX= 49

As we can see in figure 3 and figure 4, in average, the Optimus-treated variants had greater plant height differences than the Stablan-treated variants as compared to the untreated variant. The biggest differences were recorded in F1 in 2019. In both experimental years, the differences observed in F2, where it was additionally nitrogen fertilized on crop, were less than those observed in F1. In both experimental years, the genotypes that recorded significant differences from the untreated control variant were those with tall plant height (Ariesan, Apullum, and Bezostaia).

According to other studies by Swoish and Steinke (2017), Nunes et al. (2016), Rajala and Peltonen-Sainio (2001), using trinexapac-ethyl-based retardants leads to a significant decrease in winter wheat plant height.

Although plant height is mostly genetically determined (Gale and Yossefian, 1985), environmental and cultural factors have a significant impact on this trait. Treharne et al. (1985) discovered that nitrogen promotes the growth of plants by increasing gibberellin synthesis. According to Zhang et al. (2001), nitrogen promotes plant development when applied in the stem extension stage, whereas retardants limit plant height by inhibiting gibberellin synthesis. Nitrogen fertilization also has an effect on plant height, as demonstrated by previous researchers who found that increasing the nitrogen dose caused an increase in plant height (Iqtidar et al., 2006; Ali et al., 2011). Figures 3 and 4 shows the effect of nitrogen fertilization on plant height; the highest values were obtained in F2 in both experimental years. The plant height of all the genotypes were lower in 2020 than in 2019, because of a lack of rain during the period of internode elongation in April and May, plant height being a character strongly influenced by vegetation conditions (Voziyan et al., 2014; Shelepov et al., 2009).

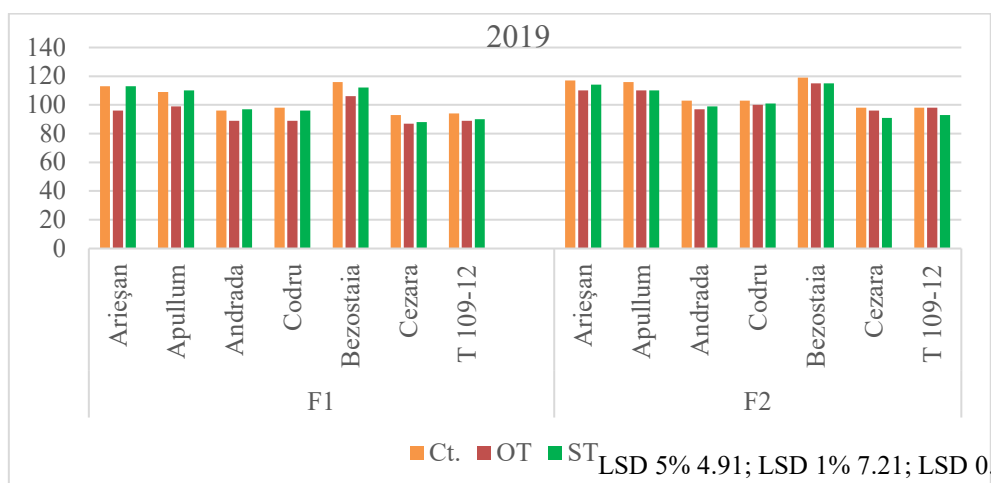


Figure 3. The influence of PGR treatment on plant height in 2019

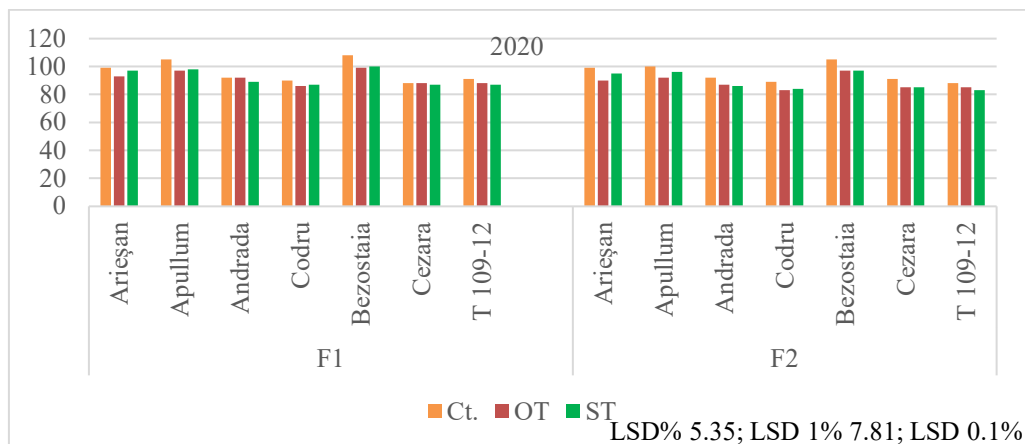


Figure 4. The influence of PGR treatment on plant height in 2020

Graphically in figure 5 and figure 6, the internode lengths are represented in the control variant compared to the variants treated with the two retardants used. Treatment with the two retardants influenced the reduction of the length of internodes, so in 2019 Stablan predominantly caused the shortening of the lower internodes, while Optimus led to the reduction in length of the superior internodes. In 2020, the effect on the length of internodes contrary to 2019 was totally different. Optimus has also influenced the reduction of the lower internodes not only of the superior ones as it happened in 2019, and after Stablan treatment in addition to the influence on the lower internodes, the last internode was significantly reduced.

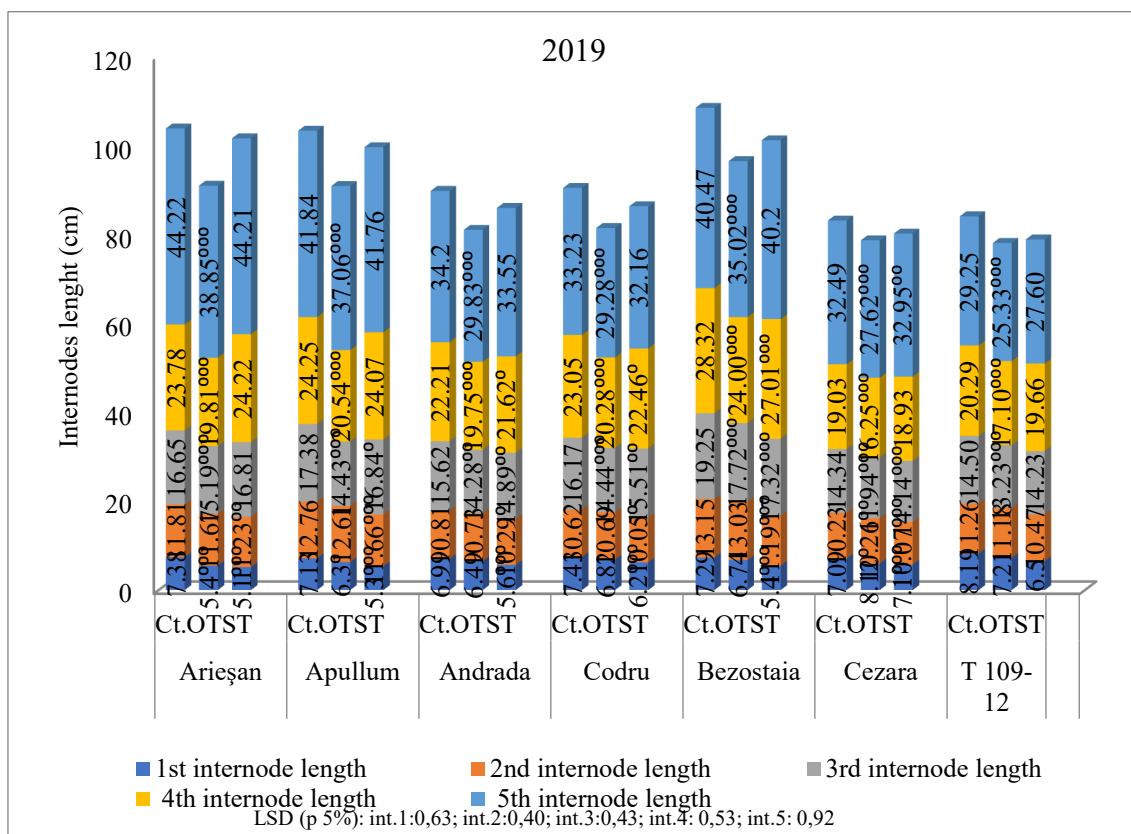


Figure 5. The PGR treatment influence on internodes length in 2019

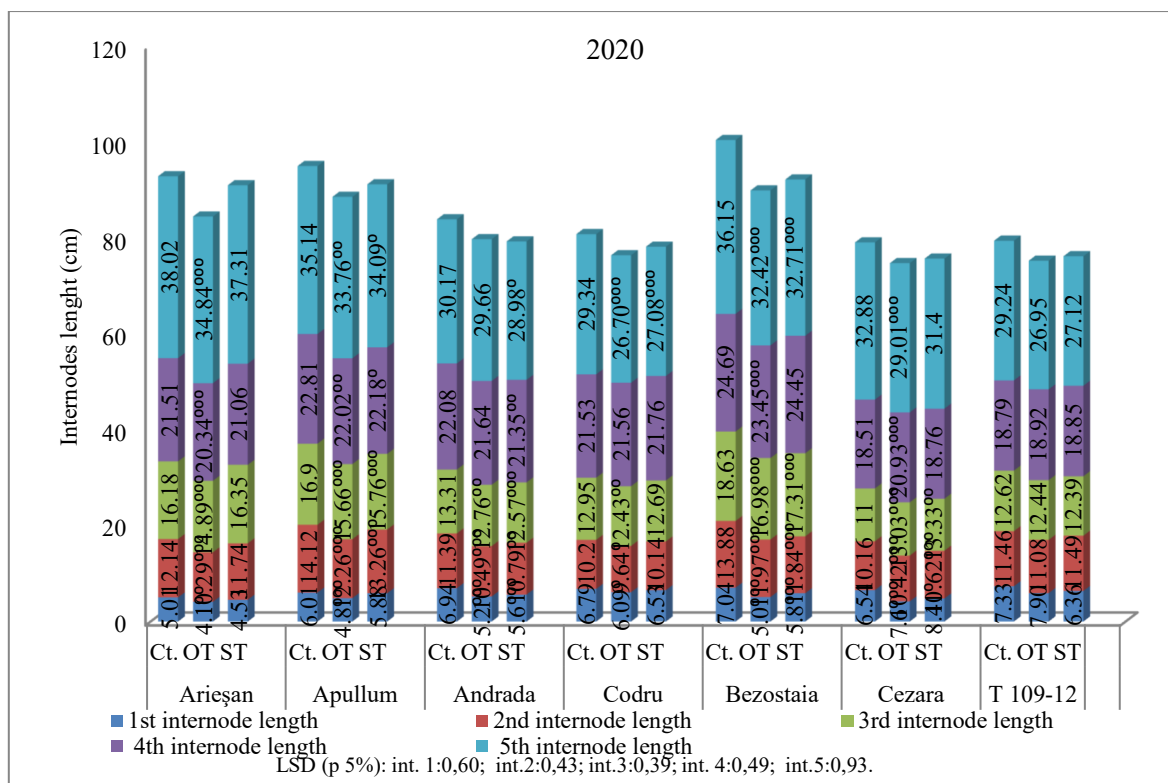


Figure 6. The PGR treatment influence on internodes length in 2020

Due to the lack of rainfall in June and July, lodging was not observed in 2019. Only the varieties with tall plant height from experience, such as Ariesan, Apullum, and Bezostaia, displayed some lodging tendencies. The occurrence of this phenomena was more pronounced in 2020, when at the end of the growing season due to heavy rainfall and strong winds, lodging occurred especially in F2 where additional nitrogen fertilization was applied, to varieties with tall plant height. The lodging manifestation has decreased in case of the variants treated with retardants. Again, the varieties with tall plant height, prone to lodge: Bezostaia, Ariesan, Apullum (figure 7).

PGR are used to reduce plant height and hence increase lodging resistance (Auskalniene and Auskalnis 2008). The length of the straw is the most crucial factor associated with lodging sensitivity. Shortening the plant height with PGR reduces the risk of lodging (Rajala, 2003).

Several authors have reported the direct influence of nitrogen fertilization on the increase of plant lodging sensitivity (Mykhalska et al., 2020; Leonte, 2011; Berry et al., 2004; Griffin, 1998), but Zhang et al. (2017) state that it is unclear how much nitrogen fertilizer to apply and what doses to use on crop to maintain the plants' lodging resistance.

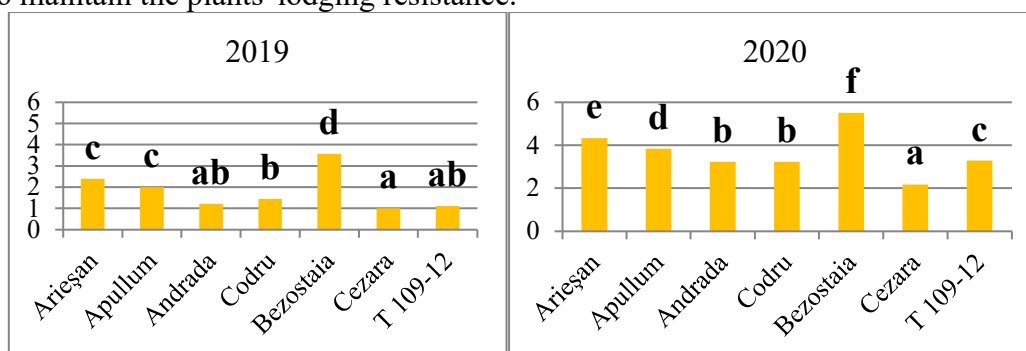


Figure 7. Genotype lodging tendencies classification according to Duncan Test in 2019 and 2020

Regarding the influence of the PGR treatment on yield, there were genotypes that had an increased yield in the Stablan-treated plots compared to the untreated control, especially in 2019 even if the rate of nitrogen applied was the same. Arieșan, Apullum, Andrada, Codru and Bezostaia achieve significantly increased yield compared to the control as shown in figure 8.

The main reason retardants are used is to reduce the risk of lodging, to reduce the yield losses caused by this undesirable phenomenon. Therefore, the effect of retardants is not a direct one on yield, but rather an indirect one by preventing losses that may occur in years with favorable conditions for lodging.

Fertilization had a greater influence on yield than the treatment with the two retardants, so higher yields were obtained in both experimental years in F2 where nitrogen was administered on crop (figure 8 and figure 9). This experience has also demonstrated the impact of nitrogen fertilization on yield. As numerous authors have pointed out, the most significant agronomic factor improving production is nitrogen fertilization (Litke et al., 2018; Harasim et al., 2016; Abedi et al., 2011), so the highest yields were achieved where the highest rate of nitrogen fertilization was applied (F2).

Similar to our experiment Auskalniene and Auskalnis (2008) also observed the ambiguous influence of PGR on winter wheat yield, with the yield being strongly affected by the year-specific conditions and the genotypes used in the experiment, and less by the PGR treatment.

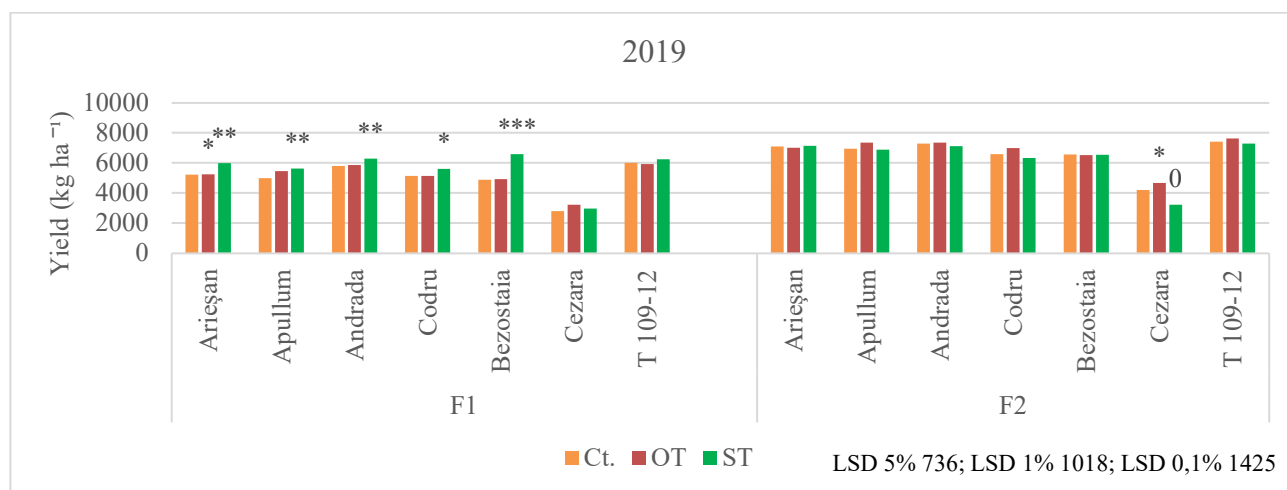


Figure 8. PGR influence on yield in 2019

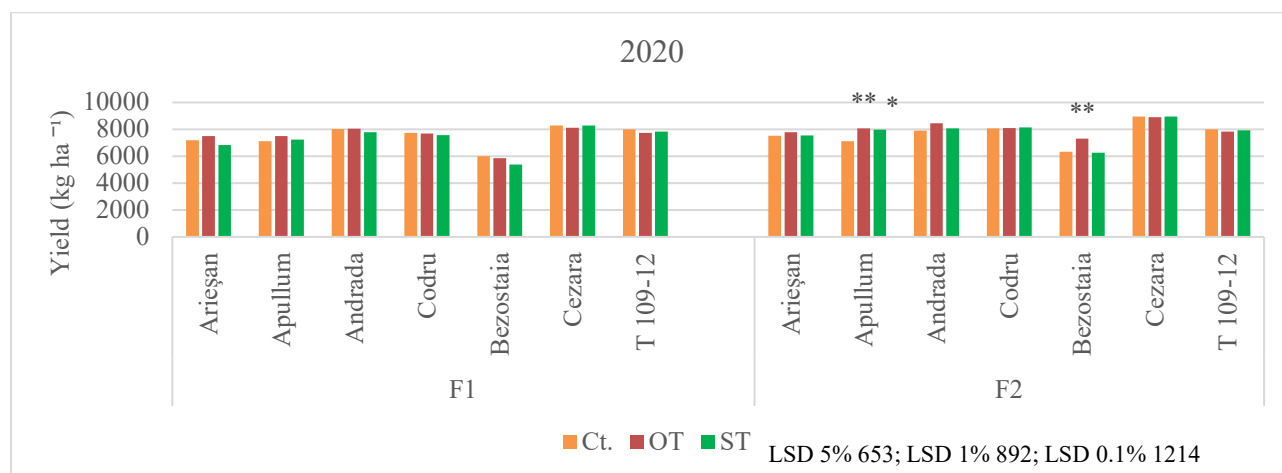


Figure 9. PGR influence on yield in 2020

Plant height is not directly correlated with productivity. The aerial part of the plant, in general, is positively correlated with the root system, taller varieties having a deeper root system, achieving constant yield, under unfavorable conditions (Muntean, 1995).

As shown in figure 10, according to the correlation coefficients, in 2019, the plant height and yield had a significant positive correlation. Typically, the relationship between plant height and yield is a positive one, genetically not a very close one. In 2020, when the genotypes from this experience were smaller due to drought during the stem extension stage, the relationship between plant height and yield was significantly negative correlation for the untreated variants, Stabilan-treated variants, and for the Optimus-treated variants as well.

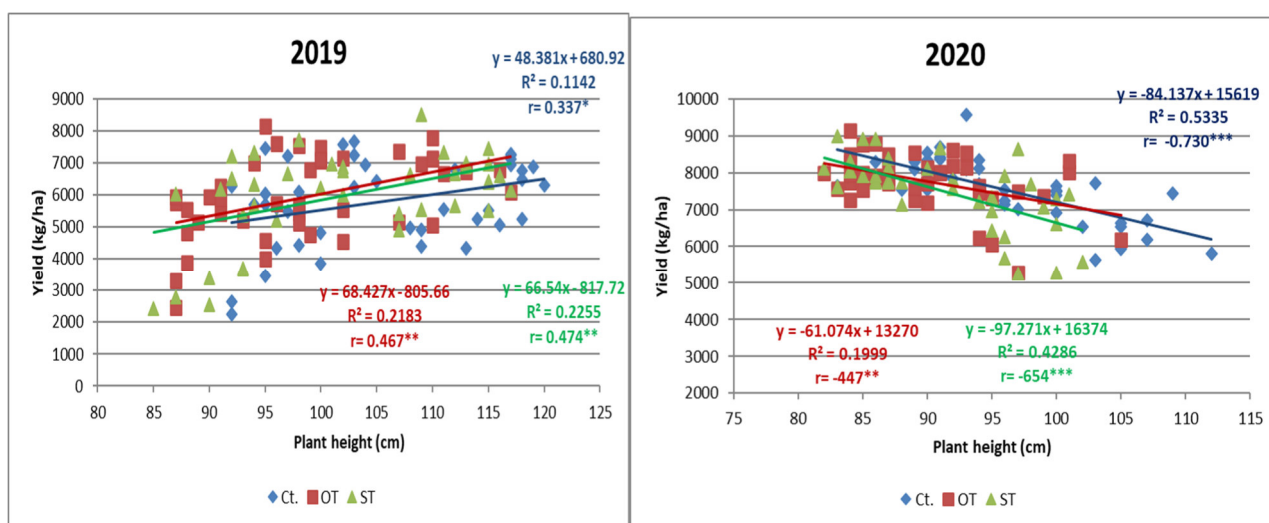


Figure 10. Pearson correlation between plant height and yield in 2019 and 2020

CONCLUSIONS

- The response of the genotypes to the application of the PGR treatment regarding plant height was very different from one genotype to another, the tall genotypes being the ones to which the plant height was reduced the most.
- The plant's height was reduced due to the retardant's effect on internode length.
- Cereal lodging is strongly influenced by climatic conditions, in 2019 when the end of the winter wheat growing period was droughty lodging manifestation was moderate, on the contrary in 2020 when it rained heavily at the end of winter wheat growing period, lodging occurred with a much more intensity.
- Genotypes with a tall plant height had a higher lodging manifestation in the plots where the amount of nitrogen applied on crop was the highest, but PGR treatment decreased the lodging risk of these genotypes; Cezara had the best lodging resistance from all the genotypes.
- The effect of the PGR on winter wheat yield was very different in these two experimental years, the yield being strongly influenced by the genotype, nitrogen fertilisation and the environmental conditions.
- The main reason for using PGR is to reduce lodging risk, and thus the yield losses caused by lodging, so the PGR effect on yield is not a direct one, but rather an indirect one by preventing yield losses that may occur in the years with favorable season conditions for lodging.

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2.3. PROSPECTS FOR USING CYANOBACTERIA OF THE GENUS *NOSTOC* AS BIOFERTILIZERS IN THE CULTIVATION OF *MONARDA FISTULOSA* L.

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Abstract

The article presents quantitative results of the effect of the use of combined cyanobacterial biofertilizers from the genus *Nostoc* (species *Nostoc gelatinosum*, *N. punctiforme* and *N. linckia*) on the cultivation of the medicinal plant *Monarda fistulosa* L. The biomass of cyanobacteria was introduced into the soil in the following doses: 20, 30 and 40 kg/ha (raw biomass). The most significant effects were observed when applying doses of 30-40 kg/ha, where there was an acceleration of plant development by 1-2 days, starting from the stage of stem formation and until fruiting, an increase in plant height by 0.26-3.5 cm, increasing biomass by 15-20% and improving the health of agricultural crops. As a result of the experiments, it can be concluded that cyanobacterial biofertilizers of the genus *Nostoc* had a positive effect on the morphophysiological aspects of *Monarda fistulosa* L. and have the potential for wide use.

Key words: cyanobacteria, bio fertilizers, medicinal plant

INTRODUCTION

Some species of cyanobacteria were, are and will be some of the most beneficial biofertilizers for the soil, the administration of which contributes to the improvement of the state of the soil ecosystem, especially by increasing the quantity of fixed biological nitrogen, increasing the productivity of crop plants and creating the premises for maintaining the ecological balance. Additionally, the application of cyanobacterial fertilizers causes significant changes in microbial communities, increasing microbial biomass and favoring the proliferation of gram-negative, gram-positive bacteria and actinomycetes from the soil surface to greater depths. Cyanobacterial fertilizers have the potential to reduce reliance on traditional fertilizers and minimize manure application (Afkairin et al., 2023).

The positive effects of co-cultivating plants with cyanobacteria are not limited to nitrogen supply. Cyanobacteria produce numerous secondary metabolites that can be useful to plants, having growth-stimulating effects or increasing their resistance to disease. Also, biotic and abiotic stress can be reduced by the action of such metabolites. Some species of cyanobacteria form symbioses with plants and as a result, the improvement of their health status is attested and ensures the survival of the cyanobacteria (Ikeuchi, 2013; Kollmen, 2022).

Cyanobacteria are also used as foliar biofertilizer in the cultivation of many crop plants. Thus, it was demonstrated that triple biofertilization with intact cells of *Microcystis aeruginosa* MKR 0105, *Anabaena* sp. PCC 7120 and the alga *Chlorella* sp. significantly improves physiological performance and growth of fertilized plants, increases cytomembrane stability, chlorophyll content, net photosynthesis intensity, transpiration and stomatal conductance, while reducing intercellular CO₂ concentration. Also, biofertilization with cyanobacteria led to increased plant N, P and K content, enzyme activity (dehydrogenases, RNase, acid/alkaline phosphatase and nitrate-reductase) and improved willow plant growth (Grzesik, & Kalaji, 2017).

Research to date has shown that the use of *Nostoc* cyanobacteria in the cultivation of canola, wheat, cantaloupe, lettuce and beans has the effect of increasing plant growth, increasing seed yield,

increasing leaf pigment content, improving plant tolerance to stress, cold and drought and increasing the relative water content of the leaves (Takács, & Ördög, 2019).

Recently, there has been an increased interest in the use of cyanobacterial biofertilizers in the cultivation of medicinal plants, since many of them are used to prepare teas and obtain extracts, which implies, in most cases, the exclusion of chemical fertilizers. However, for the optimal development of these crops, it is necessary to provide them with nutrients. Thus, due to their properties, cyanobacteria are an important source of biofertilizer for medicinal plant crops, contributing both to their nutrition and to maintaining soil health and improving the quality of the final production.

Research on the use of cyanobacteria as a fertilizer in the cultivation of medicinal plants has been carried out, resulting, in most cases, in beneficial effects on both the plants and the soil. Research has shown that foliar application of cyanobacterial biomass extract to *Mentha piperita* cultivation led to plant growth and improved essential oil content and quality (Shariatmadari, & Ghassempour, 2015). Another study analyzed the biomass management of *Anabaena vaginicola* and *Nostoc spongiaeforme* on soil, when cultivating *M. piperita*. Cyanobacterial application resulted in significant increases in growth indices, including increased root and shoot biomass, number of leaves, leaf area, number of nodes and degree of branching, as well as increased content of photosynthetic pigments. Administration of the cyanobacterium *Nostoc* caused a 25% increase in the essential oil content of *M. piperita* biomass. Plants treated with cyanobacterial biofertilizers showed the highest concentrations of menthone and limonene, with a 2.36- and 1.87-fold increase, respectively, as well as a 98% increase in the transcript level of the limonene synthase gene and 55% of the menthone-reductase gene (Ghotbi-Ravandi, & Nohooji, 2023).

The interest of using cyanobacteria of the genus *Nostoc* in the cultivation of monarda is primarily due to the beneficial properties possessed by the plant. It is well known that *Monarda fistulosa* L. is a biomass medicinal plant that has antimicrobial, anthelmintic, anti-inflammatory, anti-tumor, anti-seborrheic, antioxidant properties (Жилякова, 2013; Кисленко, 2011; Куркин, 2016; Наumenko, 2012). In many countries, monarda is used in food as a spice and aromatic additive, preservative for vegetables and fruits, base for soft drinks. Monarda essential oil has pronounced antimicrobial action, anthelmintic, antibiotic activity, immunomodulatory effect, also used for inhalations for diseases of the respiratory tract (Clintock, 1982; Бакова, 1999; Работягов, 1998).

Taking into account the mentioned, we aimed to evaluate the quantitative impact attested to the administration of cyanobacteria of the genus *Nostoc* on the culture of *Monardei fistulosa*.

MATERIALS AND METHODS

In order to evaluate the impact of the application of biofertilizers based on cyanobacteria of the genus *Nostoc* on the different development phases of *Monarda fistulosa*, field experiments were carried out. The study was carried out on the lands of the "Melnic Cristin Victor" Țărănești Farm in the village of Dobrogea, Republic of Moldova.

As a biofertilizer, the biomass combined, in equal parts, of *Nostoc gelatinosum*, *N. punctiforme* and *N. linckia*, from the cultivation of the stems from the Collection of Algae Cultures of the "Vasile Șalaru" Scientific Research Laboratory of the State University of Moldova, on the nutrient medium Detmer, was used. The cyanobacteria biomass was applied to the soil at the end of March 2024, in the following doses: 20 kg/ha – Variant 1, 30 kg/ha – Variant 2, 40 kg/ha – Variant 3 (wet biomass) and Variant 4 – control (untreated lot). Each experimental variant was replicated on an area of 30 m². During the experiment, phenological indicators, plant morphological parameters, biomass production

and the weight of 100 seeds of the experimental plants were monitored. Phenological parameters were determined according to the specific method (Бейдман, 1974).

RESULTS AND DISCUSSIONS

The analysis of the ontogenetic stages of plant development is an essential indicator of the state of crops and their growth rate. Our research aimed, in particular, to analyze the impact of cyanobacterial fertilizer administration on virginal and reproductive growth periods.

The analysis of the juvenile stage revealed that, in the culture of *Monarda fistulosa* L., the appearance of specific morphophysiological indicators that allowed the differentiation of the cultures was attested. In the vegetative phase of growth, no significant changes were registered in the variants with administration of cyanobacterial biofertilizers, and this phase took place practically in the same period for all experimental variants (up to the 45th day).

The application of cyanobacterial fertilizers had the effect of accelerating the onset of the ontogenetic phases of budding, flowering and fruiting. The most significant results were attested in Variant 3, where the budding and fruiting phases were accelerated by 1-2 days compared to the control batch. Thus, we can conclude that the application of cyanobacterial fertilizers from the genus *Nostoc* contributes to the acceleration of the emergence of the ontogenetic phases of budding-fruiting in the culture of the plant *Monarda fistulosa* L.

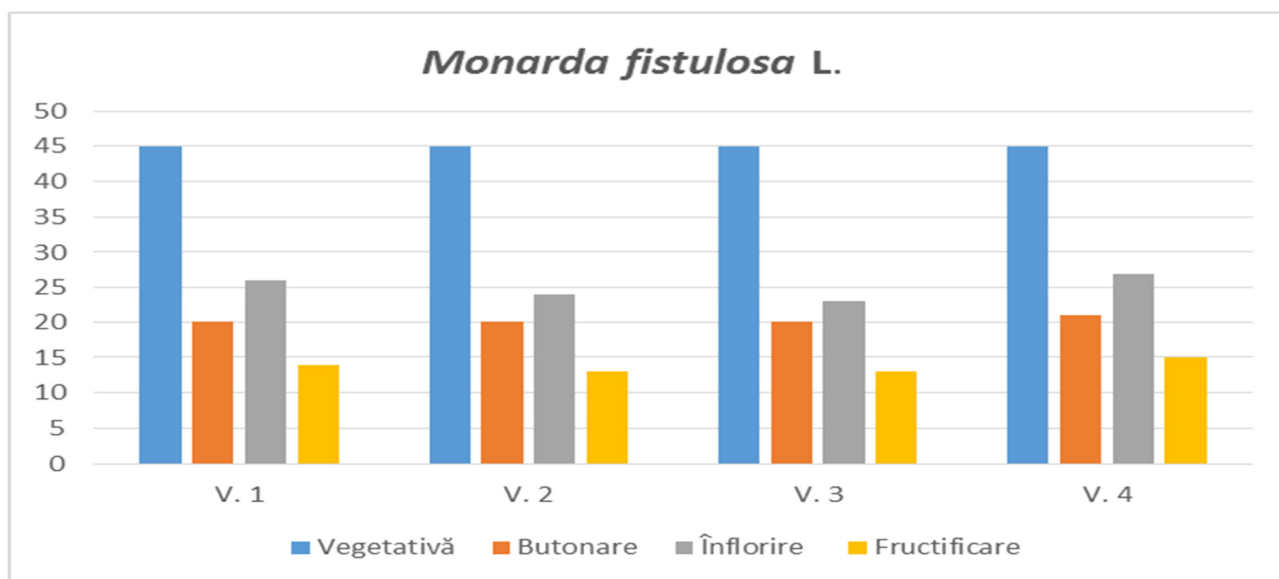


Figure 1. The ontogenetic phenological changes of *Monarda fistulosa* L. parvenite as an effect of the administration of cyanobacterial fertilizers from the genus *Nostoc*

Another essential morphological indicator of the growth of *Monarda fistulosa* L. plants is their height. As an effect of the application of cyanobacterial fertilizers from the genus *Nostoc*, an increase in the height of *Monarda fistulosa* L. bushes was attested.

The largest plant sizes were recorded in the variant with the application of 40 kg/ha, where an increase of 5.77% (by 3.5 cm) in height was observed, compared to the control variant. In the variants with administration of cyanobacterial fertilizers in doses of 20 and 30 kg/ha, an increase in the height of the plants by approximately 2.31-2.64% was observed.

It is well known that the application of organic fertilizers contributes to increasing the height of *Monarda fistulosa* L. According to other researches, the application of organic fertilizers at a dose of

50 t/ha to the cultivation of *Monarda fistulosa* L. caused an increase in plant height by 28.95% (Орёл, 2018, с. 70-76).

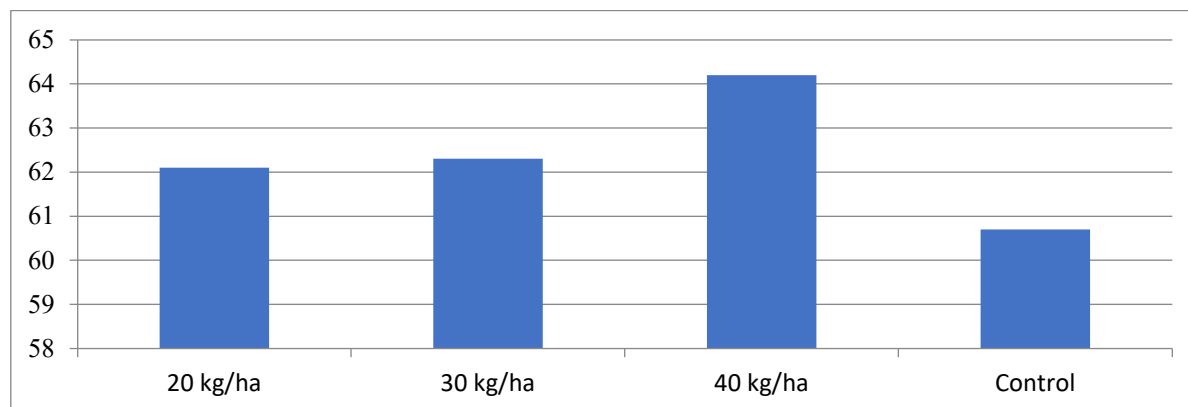


Figure 2. Changes in the height of *M. fistulosa* plants certified as a result of the application of *Nostoc* cyanobacterial fertilizers, cm

These values were recorded during the years 2015-2017 in the region of the city of Yalta, Crimea, a period that had much more favorable climatic conditions than those of the previous year, in which we carried out the research. The results obtained by us did not indicate such high values as in the case of the application of organic fertilizers (compost), considering that the administered dose of organic fertilizers (50 t/ha) provides considerable amounts of nutrients, with a major stimulatory effect on the productivity of the *Monarda fistulosa* L. crop. However, these practices have a low economic efficiency, taking into account the "cost-effectiveness" principle, and generate significant economic difficulties for large growers of this crop, due to high costs administration and operation. From an economic and technical point of view, the application of cyanobacterial fertilizers presents significant advantages compared to organic ones, because cyanobacteria can persist for a long time in the soil, can easily reactivate even in anhydrobiosis conditions, and their administration is much simpler and does not involve major expenses.

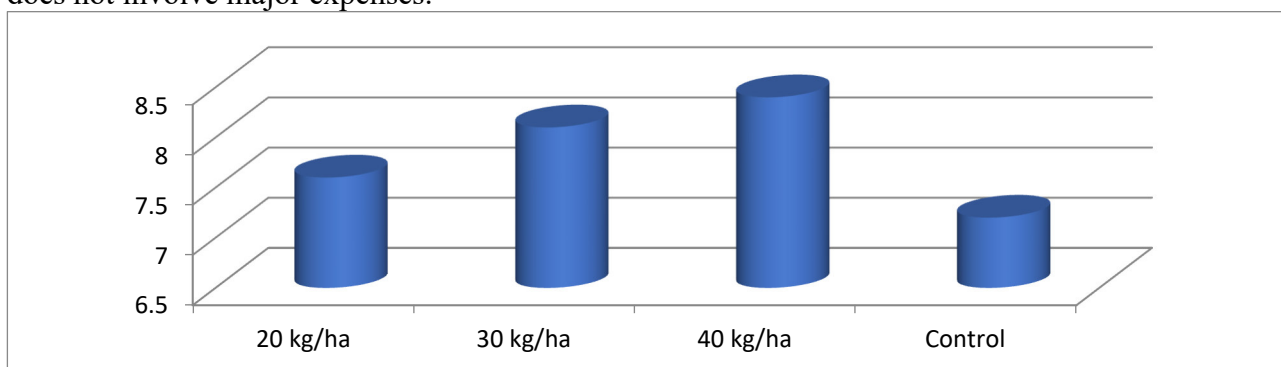


Figure 3. The amount of biomass of *M. fistulosa* L. obtained as a result of the application of cyanobacterial fertilizers of the genus *Nostoc*

The application of cyanobacterial fertilizers has the effect of stimulating the biomass of *Monarda fistulosa* L. In all variants of application of cyanobacterial fertilizers, a quantitative increase in biomass was found. The highest values were recorded in the lot treated with a dose of 40 kg/ha, where

the biomass was 20% higher compared to the control variant. In the other variants, with doses of 20 kg/ha and 30 kg/ha, the biomass increase was 5.55-15.00%.

According to the research carried out, the application of organic fertilizers (compost) in a dose of 50 t/ha to the cultivation of *M. fistulosa* L. determined an increase in productivity of 20.29%, a fact that supports the advantages of using cyanobacterial fertilizers (Opěl, 2018, c. 70-76).

The significant increase in productivity of *M. fistulosa* L. plants is explained, first of all, by the fact that cyanobacteria of the genus *Nostoc*, applied as biofertilizer, stimulate plant health and increase their resistance to water stress. They also have a beneficial effect on soil biodiversity, especially by stimulating bacterial activity, accumulating fixed atmospheric nitrogen and mobilizing other soil nutrients. Last but not least, cyanobacteria contribute to the retention of water in the soil, thus favoring the development of plants.

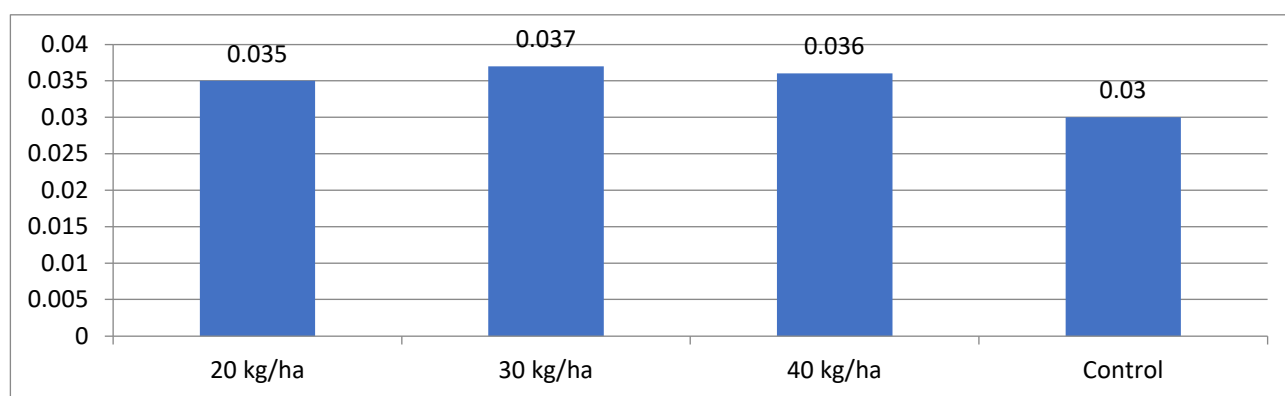


Figure 4. The weight of 100 seeds of *M. fistulosa* L. obtained in the experimental lots, g

An important index that determines the productivity of the crop is the quantitative analysis of the seeds. This was done in the fruiting phase of the *Monarda fistulosa* L. Thus, it was found that, in the variants with administration of cyanobacterial fertilizers, the mass of the seeds was higher by 16.66%-23.33%. The most significant results were recorded in the variant with the administration of cyanobacterial biofertilizer in the dose of 30 kg/ha (0.037 ± 0.001 g), followed by the variants with 40 kg/ha and 20 kg/ha.

Increased seed weight indicates that the reproductive productivity of the crop has increased. The administration of cyanobacterial fertilizers has a positive impact on the quantity and quality of *M. fistulosa* L. seeds, thus contributing to an increase in yield.

CONCLUSIONS

The application of cyanobacterial biofertilizers from the genus *Nostoc* to the cultivation of *Monarda fistulosa* L. in the severe climatic conditions of 2024 had a positive impact, manifested by accelerating the onset of the ontogenetic phases of budding and fruiting by 1-2 days, increasing the height of the plants by 2.31-5.77%, increasing the biomass of the above-ground part by 5.5-20% and increasing the weight seeds by 16.66-23.33%.

The most significant results were recorded in the variants with administration of 30-40 kg/ha of cyanobacterial biofertilizers from the genus *Nostoc*. Based on the results obtained, we find that there

are favorable premises for the use of cyanobacterial fertilizers in the cultivation of *M. fistulosa* L., in order to increase biomass production.

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2.4. THE SPRING CEREALS AND SOIL TILLAGE SYSTEMS

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Abstract

With changes in weather patterns and increased awareness of environmental issues, sustainable development and environmental protection are becoming a priority. The research carried out in the Turda area, aimed to highlight the performance of several spring cereal species under different soil tillage systems (conventional, chisel, disk, and no-tillage). The biological material used in our study consists of varieties developed by SCDA Turda and includes three species of spring cereals: wheat – the Feleacu variety, oats – the Mureșana variety and the Vâlcele line, and barley – the Romanița variety. Yields across the four systems ranged from 3525 to 4879 kg/ha (Feleacu), 3936 to 4880 kg/ha (Mureșana), 4450 to 5260 kg/ha (Vâlcele line), and 5403 to 5484 kg/ha (Romanița), respectively. The obtained results highlighted the suitability of spring cereals developed at A.R.D.S. Turda for cultivation in a no-tillage system.

Key words: spring cereals, climate, soil tillage system, yield

INTRODUCTION

Global agricultural crop production is susceptible to the impacts of climate change (Lobell et al., 2011; Goncharov et al., 2023; Parra-López et al., 2024). In the 21st century, global warming and climate change present a severe environmental threat, potentially causing irreversible damage to ecosystems and reducing production potential (Fischer et al., 2002; Agovino et al., 2019; Chețan et al., 2022). Climate change scenarios suggest that warming will generally lead to a decrease in yields of major staple crops like wheat (Zougmore et al., 2021).

Several studies have shown that cereal production is sensitive to temperature increases (Lobell et al., 2008; Zhao et al., 2017; Asseng et al., 2017) and precipitation deficits (Brisson et al., 2010; Moore and Lobell, 2015). Hence, there is a need to enhance research aimed at improving and expanding tillage systems across different pedo-climatic conditions. The adoption of unconventional agricultural systems (Rusu et al., 2007; Rusu et al., 2015; Chețan, 2020) is justified by the rising temperatures, irregular rainfall patterns (Saleem et al., 2024) and the increasing degradation and deterioration of soil resources (Kraut-Cohen et al., 2020).

Due to shifts in weather patterns and a growing awareness of environmental concerns, sustainable development and environmental protection have emerged as key priorities (Semenov and Halford 2009). Confronted with new challenges, agriculture must integrate technological innovation with sustainable practices (Zheng et al., 2024). The use of spring cereals, such as spring barley, into crop rotation increases the yield of subsequent crops, thereby improving the agronomic efficiency and sustainability of the farming system. This is attributed to the nitrogen accumulation in the soil, facilitated by spring barley's ability to fix atmospheric nitrogen through its symbiosis with specific microorganisms (Lammas and Shitikova, 2024).

Sustainable soil use in the Transylvanian Plateau relies on conservative and regenerative practices that enhance soil quality, while the region's spring temperatures and rainfall can be suitable for growing cereals such as spring wheat, barley and oats (Rusu et al., 2024).

In this context, the study aims to assess the impact of environmental conditions, biological factors, and technological influences on both the quantity and quality of wheat, oats and spring barley production.

MATERIALS AND METHODS

In the autumn of 2023, an experimental field was established at Agricultural Research and Development Station (A.R.D.S) Turda to test the suitability of spring straw cereals for cultivation in different tillage systems. The experiment was established on a Phaeozem soil (S.R.T.S, 2012) with loamy-clay texture, a neutral pH, good supply of nitrogen, phosphorus and potassium and a medium humus content. The experience is organized according to the method of subdivided plots (Săulescu and Săulescu, 1967) and is included in a three-year rotation, spring cereals-maize soybeans. Each experimental plot measures 144 m² (12 m wide × 12 m long).

The experimental factor were represented by:

- **A factor**, soil tillage system with four levels: a₁ conventional system with ploughing (CS); a₂ unconventional system – minimum tillage with chisel (MTC); a₃ unconventional system – minimum tillage with disk (MTD); a₄ unconventional system – no-tillage with direct sowing (NT).

- **B factor**, species: b₁ Feleacu wheat variety; b₂ Mureșana oat variety; b₃ Vâlcele oat line; b₄ Romanița barley variety.

After harvesting the previous crop (soybeans), land preparation was carried out for each experimental variant. Plowing and chisel tillage were performed at a depth of 30 cm, while disk tillage was carried out at a depth of 15 cm. In the direct sowing variant, there was no intervention on the soil, the sowing being carried out in uncultivated land (Figure 1). The seedbed preparation in the spring, before sowing, was carried out using the Kuhn rotary harrow in combination with the John Deere 6630 tractor.

To prevent the attack of diseases, the seed used for sowing was treated with a product containing 150 g/l of prothioconazole and 20 g/l of tebuconazole, at a dosage of 0.5 liters per ton of seed. The sowing of wheat and oat was done at the end of February, the barley sown on the first day of March. The sowing density was 500 germinated grains/m² and the distance between rows 18 cm, using the seeder DIRECTA. Simultaneously with the sowing, the basic fertilization with 300 kg/ha NPK (15:15:15) was also carried out. The additional fertilization comprised 100 kg/ha CAN (calcium ammonium nitrate) applied at the twin-leaf stage and foliar fertilizers administered together with the chemical treatments to control the harmful agents (Table 1).

The harvesting was carried out at the end of July. Experimental data were processed by analyzing the variance (Poly Fact, 2015) and determining the significant differences (LDS, 5%, 1%, 0.1%).

The climatic conditions registered at ARDS Turda, from October 2023 to July 2024, are presented in Table 2 (Source: Turda meteorological Station longitude: 23°47'-latitude 46°35' - altitude 427 m).

Table 1. The chemical treatments applied to control the harmful agents, Turda 2024

Variant	I Treatment	II Treatment
b ₁ Feleacu	Broadway Star 260 g/ha + Flexity Trio 0.25 l/ha + Mizona 0.5 l/ha + Apis 0.2 l/ha + Maxi Grow 0.5 l/ha + adj. Vital 0.25 l/ha	Revicare 1.0 l/ha + Mavrik 0.25 l/ha + Agrok 1.0 kg/ha
b ₂ Mureșana	Amino 600 1.0 l/ha + Falcon Pro 0.6 l/ha	Revicare 1.0 l/ha + Mavrik 0.25 l/ha + Agrok 1.0 kg/ha
b ₃ Vâlcele	Amino 600 1.0 l/ha + Falcon Pro 0.6 l/ha	Revicare 1.0 l/ha + Mavrik 0.25 l/ha + Agrok 1.0 kg/ha
b ₄ Romanița	Sekator Progress OD 0.13 l/ha + Amino 600 0.5 l/ha + Falcon Pro 0.6 l/ha + Apis 0.2 l/ha + Maxi Grow 0.5 l/ha	Revicare 1.0 l/ha + Mavrik 0.25 l/ha + Agrok 1.0 kg/ha



Plow (CS)



Chisel Pinocchio 2.5 (MTC)



Disk Discover xm2 (MTD)



Kuhn rotary harrow



Gaspardo-Directa seeder (NT)

Figure 1. The equipment used in the experiment, specific to each system

The research area, for the period 1957-2024, is characterized by a multiannual average temperature of 9.3°C and a multiannual average rainfall of 532.4 mm. In terms of the thermal regime, it can be seen that the agricultural year 2023/2024 was very warm. The average temperature values (11.1°C) are above the multiannual average (7.6°C), the deviation being +3.5°C. In terms of rainfall the agricultural year is characterized as excessively dry (317.9 mm), with a deficit of 166 mm compared to the multiannual amount (433.9 mm) for the period under study (Table 2).

Table 2. Thermal and precipitation regime registered in the agricultural year 2023/2024 in Turda

Month	Temperature (°C)			Precipitation (mm)		
	Agricultural year 2023/2024	Average 67 years	Difference ± °C	Agricultural year 2023/2024	Sum 67 years	Difference ± mm
October	14.0	9.8	+ 4.2	19.8	35.4	- 15.6
November	5.2	4.0	+ 1.2	43.6	28.2	+ 15.4
December	1.2	- 1.2	+ 2.4	17.8	27.5	- 9.7
January	0.2	- 3.3	+ 3.5	4.8	21.7	- 16.9
February	7.0	- 0.6	+ 7.6	9.2	19.2	-10.0
March	8.8	4.4	+ 4.4	37.7	24.3	+13.4
April	13.3	10.0	+ 3.3	38.8	45.6	- 6.8
May	15.8	15.0	+ 0.8	60.7	69.4	- 8.7
June	21.7	18.0	+ 3.7	36.2	84.6	- 48.4
July	24.0	19.8	+ 4.2	49.3	78.0	- 28.7
Average/sum	11.1	7.6	+ 3.5	317.9	433.9	- 166.0

RESULTS AND DISCUSSIONS

The data in Table 3, reflect that, spring wheat (Feleacu variety) have specific tillage technologies requirements. Of the four variants studied, the conventional tillage system (with plow) it is the most suitable for this crop in the pedo-climatic conditions of Transylvania. In the other unconventional systems (MTC, MTD) compared to the conventional, the yield were reduced, the differences ranging from 261 to 548 kg/ha (showing a significant negative influence). Apparently, under the conditions of a soil with more than 40% clay, spring wheat are less suitable for direct sowing in NT and presented very significance negative influence with a difference of 1354 kg/ha compared to the control (CS). In this variant, the lowest yield is recorded (3525 kg/ha).

Table 3. The influence of tillage system on FELEACU spring wheat yield, 2024

Variant	Yield (kg/ha)	%	Difference	Significance
a ₁ CS	4879	100	0	Control
a ₂ MTC	4618	95	-261	0
a ₃ MTD	4331	89	-548	00
a ₄ -NT	3525	72	- 1354	000
LSD (p 5%) = 108; LSD (p 1%) = 198; LSD (p 0.1%) = 439				

For spring oats, the Mureșana variety, the yield achieved were highest in CS (4881 kg/ha). The MTC, compared to the control variant, had a distinctly significant negative influence on yield (4399 kg/ha). The MTD system (4241 kg/ha) and the NT system (3938 kg/ha) had a very significant negative influence on yield, with differences compared to CS ranging from 641 to 943 kg/ha (Table 4).

Table 4. The influence of tillage system on MUREȘANA spring oat yield, 2024

Variant	Yield (kg/ha)	%	Difference	Significance
a ₁ CS	4881	100	0	Control
a ₂ MTC	4399	90	-484	00
a ₃ MTD	4241	87	-641	000
a ₄ -NT	3938	81	-943	000
LSD (p 5%) = 89; LSD (p 1%) = 163; LSD (p 0, 1%) = 361				

In the MTC (5244 kg/ha) and MTD (5126 kg/ha) systems, for the Vâlcele oat variety, the yields were close to the control variant (5260 kg/ha), with the yield differences being insignificant (ranging from 16 to 134 kg/ha). There were no important quantitative differences between unconventional system (minimum tillage) and the conventional system that affected crop yield. In the case of the NT system, the yield was lower (only 4350 kg/ha), with a difference of 910 kg/ha, which was statistically significant and very negative, as shown in Table 5.

Table 5. The influence of tillage system on VÂLCELE spring oat yield, 2024

Variant	Yield (kg/ha)	%	Difference	Significance
a ₁ CS	5260	100	0	Control
a ₂ MTC	5244	99	-16	-
a ₃ MTD	5126	96	-134	-
a ₄ -NT	4350	83	-910	000
LSD (p 5%) = 33; LSD (p 1%)=61; LSD (p 0,1%)=136				

The yield achieved with spring barley (Romanița variety) exceeded 5000 kg in three tillage systems, except for the direct sowing variant (Table 6). The highest value was recorded in the control variant (5484 kg/ha), followed by the MTD system (5403 kg/ha). In the MTD system, spring barley realized 5134 kg/ha, which was lower than yield obtained in the CS. The difference of 350 kg/ha showed a distinctly significant negative influence. The NT system had a very significant negative influence on yield (4777 kg/ha), with a difference of 707 kg/ha compared to CS.

Table 6. The influence of tillage system on ROMANIȚA spring barley yield, 2024

Variant	Yield (kg/ha)	%	Difference	Significance
a ₁ CS	5484	100	0	Control
a ₂ MTC	5134	94	-350	00
a ₃ MTD	5403	99	-82	-
a ₄ -NT	4777	87	-707	000
LSD (p 5%) = 85; LSD (p 1%) = 157; LSD (p 0,1%) = 347				

The research conducted by Känkänen et al. (2011) regarding the suitability of spring cereals (wheat, oats and barley) for cultivation in the conventional system compared to the no-tillage variant shows that the no-tillage system negatively affects yield. Among the species included in the experiment, oats was the most productive spring cereal species in the no-tillage system. The yield of spring wheat was lower, but barley was the most vulnerable to the drought that occurred towards the end of the vegetative period and as a result the harvest was greatly reduced. Other authors, including Machado et al. (2007), reported reduced spring cereal yields under no-tillage system compared to the plowing variant. Contrary to these results, Carter (1991) obtained close yields on barley and wheat, when the optimal climatic conditions were met.

If the average yield is calculated across all soil tillage systems and the studied variants are ranked, the first place goes to the Romanița barley, followed by the Vâlcele oat line, and finally the Mureșana oats and the Feleacu wheat, as shown in the data presented in Figure 2.

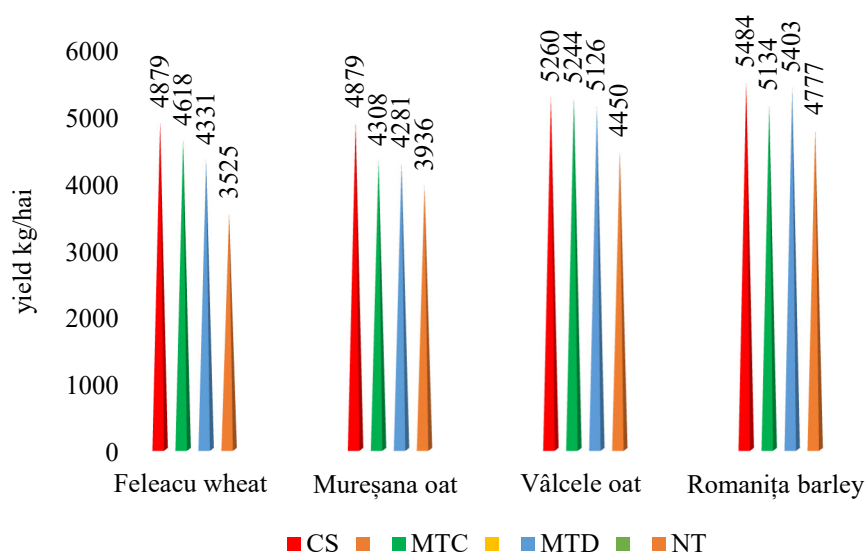


Figure 2. Ranking of the yield made by the species included in the experiment, depending on the tillage system and the climatic conditions

The hectoliter grain weight (TW), the thousand-kernel weight (TKW) and the protein content of the grains (%) are all influenced to some extent by the soil tillage system.

In spring wheat (Feleacu), higher values of TW were obtained in CS (72.8 kg/hl) and MTD (72.7 kg/hl) slightly lower in MTC (71.8 kg/hl), and the minimum value recorded in NT (69.8 kg/hl). Although TW was reduced, the NT system led to an increase in TKW (33.1 g).

For the Mureșana oat variety, both TW and TKW had superior values in the CS system (59.3 kg/hl; 30.7 g) compared to the other systems, the minimum was recorded in the MTC variant (54.0 kg/hl; 30.3 g).

For the Vâlcele oat line, significant TW values were determined in CS and MTC (50.5 kg/hl), followed by NT (50.4 kg/hl) and MTD (49.9 kg/hl). With a TKW value of 34.1 g (equal to the CS variant), the NT system proved to be superior to the minimum tillage systems (MTD 33.4 g; MTC 33.9 g).

TW in Romanița spring barley was not greatly influenced by soil tillage systems, with values being close (66.1-65.8 kg/hl), and differences between 0.1-0.3 kg/hl. The maximum value was attributed to the MTD system. TKW ranged from 44.0 to 43.6 g, with the maximum in MTC and NT, and the minimum in CS, while MTD had a value of 43.9 g.

Tillage system did not significantly influence the content in the protein. Regardless of the species analyzed, the variation amplitude was less than 1% (Table 7).

Table 7. The influence of experimental factors on TW, TKW and grain protein (%)

Species (B)	Indices	Tillage system (A)			
		a ₁ CS	a ₂ MTC	a ₃ MTD	a ₄ NT
b ₁ Feleacu wheat	TW (kg/hl)	72.8	71.8	72.7	69.8
	TKW (g)	31.9	31.7	31.4	33.1
	Protein (%)	10.05	9.83	10.17	9.63
b ₂ Mureșana oat	TW (kg/hl)	59.3	54.0	54.8	54.7
	TKW (g)	30.7	30.3	30.5	30.5
	Protein (%)	9.54	9.13	9.25	9.40
b ₃ Vâlcele oat	TW (kg/hl)	50.5	50.5	49.9	50.4
	TKW (g)	34.1	33.9	33.4	34.1
	Protein (%)	8.76	8.47	8.46	8.32
b ₄ Romanița barley	TW (kg/hl)	66.0	65.9	66.1	65.8
	TKW (g)	43.6	44.0	43.9	44.0
	Protein (%)	9.99	9.29	9.48	9.18

CONCLUSIONS

In unconventional soil tillage systems (minimum tillage) the yields were close to those obtained in the conventional system, which makes minimum tillage systems a viable alternative to the traditional plowing system.

The analyzed elements (hectoliter grain weight, thousand-kernel weight, protein content of the grains) were influenced to some extent by the soil tillage system. In general the higher values were associated to the conventional variant.

Under the conditions of the 2023-2024 agricultural year, the no-tillage variant (directly sown) did not show noticeable results, with the recorded yields being the lowest. Even if the results obtained in the no-tillage variant were not satisfactory, it is important to remember that the transition from conventional agriculture to conservative agriculture takes time, with measurable effects on soil and plants becoming evident after at least 5-6 years.

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2.5. IOT-BASED INTEGRATED AGRICULTURAL MONITORING SYSTEM WITH DISEASE PREDICTION FOR CROP PROTECTION

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Abstract

This research presents an innovative agricultural monitoring solution that integrates IoT technologies with predictive algorithms to improve crop protection and efficient resource management. The proposed system consists of a complex network of IoT sensors deployed in agricultural fields that measure critical environmental parameters such as soil moisture, air temperature, relative humidity, precipitation levels, solar radiation and wind speed. Data is collected in real time via wireless protocols (Wi-Fi/5G) and transmitted to a central processing unit. The developed software platform provides an intuitive interface for data visualization and implements advanced predictive algorithms for crop disease risk assessment. The system includes automatic alerting functionalities that inform users of potential risks, allowing preventive measures to be taken in a timely manner. Hardware and software components are designed to work in synergy, providing a complete solution for crop monitoring and protection. The predictive model uses correlations between environmental conditions and the occurrence of common agricultural diseases, and is constantly optimized through user feedback and data collected during operation. This technical solution allows farmers to optimize resources, improve crop health and reduce costs.

Key words: IoT agriculture, crop monitoring, disease prediction, environmental sensors, smart agriculture

INTRODUCTION

Modern agriculture faces significant challenges, including the effects of climate change, soil degradation, and the growing demand for sustainable resource management. Farmers are increasingly relying on technology to address these concerns in a more efficient manner. The combination of IoT and AI provides practical answers by making agriculture more data-driven. IoT monitoring devices measure critical environmental factors such as temperature, humidity, and soil moisture. This information contributes to better resource utilisation and crop protection (Bălăceanu, Drăgulescu, Bosoc, Orza, Suci, 2021).

Simultaneously, decision support systems enabled by predictive algorithms based on environmental parameters can allow farmers to identify potential plant health issues early (Orza, Bosoc, Bălăceanu, Moraru, Suci, 2023).

This paper presents an integrated agricultural monitoring system based on IoT technologies, designed to protect crops and optimize resource use. The system utilizes a network of IoT sensors to collect critical environmental parameters such as soil humidity, air temperature, relative humidity, precipitation, solar radiation and wind speed in real time. The data is transmitted via wireless protocols to a central processing platform, where predictive algorithms are used to assess the risk of plant diseases. The platform includes automatic alerting capabilities and an intuitive dashboard for visualizing data and processing results, providing farmers with practical tools for quick decision-making.

The development of this innovative system was inspired in part by the results of the **Romanian Earth Observation Collaborative System (ROCS)** project, which provided the basis for advanced infrastructures for storing and processing Earth observation data. ROCS has demonstrated the usefulness of integrating satellite and in-situ data into a unified geospatial framework, providing a model that can be adapted to other domains, including agriculture. In this case, the principles

developed in ROCS have been adapted to small-scale agricultural monitoring, using IoT sensor networks to collect critical environmental parameters and process them through predictive algorithms (Home | ROCS Project, n.d.), (ROCS, 2024).

Therefore, what this paper presents is an integrated agricultural monitoring system that combines hardware and software into a comprehensive solution for effective crop management and agricultural disease risk reduction. By providing farmers precise and user-friendly tools for well-informed decision-making, this approach assists in the shift to a more intelligent and resilient agricultural sector.

The following paragraphs of this section provide an overview of the **state-of-the-art** in this domain. The integration of AI in agriculture has facilitated the development of predictive algorithms that assess the risk of crop diseases. The AI models used in the agriculture sector analyze sensor-collected data to identify anomalies and forecast potential disease outbreaks. For instance, anomaly detection techniques have been used to develop models that predict crop disease risks based on historical weather conditions associated with previous outbreaks (Skelsey, 2021).

Deep learning algorithms have also been applied to predict risks associated with crop pests and diseases, demonstrating the relationship between environmental conditions and disease occurrence (Lee & Yun, 2023).

IoT sensors have become essential in precision agriculture because of their ability to continuously monitor various environmental parameters. Nanosensors, a subset of these technologies, have been developed in order to obtain more information related to soil health, pathogens, and optimize irrigation by monitoring factors such as nutrient levels, pH, and soil contaminants. For instance, graphene-based nanosensors can monitor nitrate and phosphate concentrations, while zinc oxide sensors track nitrogen deficiency in soil. Furthermore, real-time soil moisture level analysis via silicon-based nanosensors is used to provide effective water use and minimise waste (Yadav, Yadav, Ahmad & Abd-Elsalam, 2023).

In modern agricultural monitoring systems, IoT sensors are integrated within advanced software platforms to provide comprehensive solutions for crop management. These systems provide the possibility of real-time data visualization, implementation of predictive algorithms, and the issuing of automated alerts in order to inform farmers about potential risks. An example of such a platform is the EOSDA Crop Monitoring which uses predictive analytics for assessing crop disease risks in order to offer preventive measures that can enhance agricultural management (Mohtasim et al., 2023). Precision agriculture relies heavily on real-time soil health monitoring, which has been greatly improved by recent advancements in smart sensing technologies. The continuous measurement of soil characteristics including moisture, nutrient levels, and pH is made possible by these technologies, which include a range of sensing techniques such as soil probes, remote sensing, and IoT-enabled sensor networks. Precision agriculture systems that incorporate these intelligent sensors allow farmers to make well-informed decisions about pest control, fertilisation, and irrigation, so they can more efficiently use their resources (Sondhiya & Singh, 2024).

To extract useful insights from the vast amounts of data generated by IoT devices, advanced data processing techniques are required. Machine Learning algorithms are essential for analysing large and complex datasets, facilitating the prediction of crop health issues and the recommendation of appropriate interventions. Decision support systems (DSS) that integrate these algorithms assist farmers in making data-driven decisions, enhancing crop yields and reducing environmental impact. The development of user-friendly interfaces for these DSS ensures accessibility and practical utility for end-users in the agricultural sector (Akhter & Sofi, 2022).

The subsequent chapters of this paper are structured as follows: The Materials and Methods section provides a description of the technologies and methodologies used, including the system architecture, data flow, integration with the visualization tool, and details about the prediction algorithm

development. This is followed by the Results and Discussion chapter, where the findings are presented and analyzed in relation to the research objectives. The Conclusions chapter summarizes the key insights derived from the study, while the Acknowledgements section recognizes the support that enabled this work. Finally, the References section lists all sources cited throughout the paper.

MATERIALS AND METHODS

The proposed agricultural monitoring system integrates advanced IoT technologies, software components for data processing and analysis, and an intuitive visualization platform to facilitate real-time decision-making. The system's architecture has been designed to enable accurate environmental data collection, processing it without delays and generating relevant predictions for crop protection. At the heart of the system is a network of IoT sensors, strategically placed in the field, which monitor critical parameters such as soil moisture, air temperature, solar radiation and rainfall levels. These sensors are designed to operate autonomously, powered by solar panels that charge internal batteries, ensuring continuous and sustainable operation. The data collected is transmitted via wireless communication protocols such as Wi-Fi and 5G to the central infrastructure, ensuring stable and efficient connectivity.

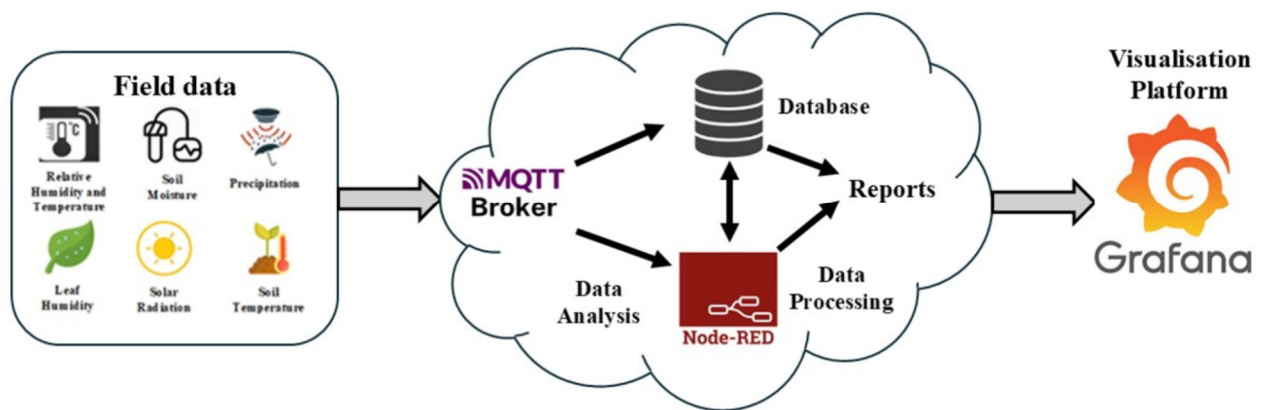


Figure 1. System architecture

The data flow is managed through an MQTT broker, which acts as a central communication node, ensuring an optimized distribution of information. From this point, data is routed in two main ways. On the one hand, it is stored in a centralized database, providing the possibility to perform long-term analysis and correlate historical trends. On the other, the data is processed in real time through the Node-Red platform, where it undergoes rigorous validation, filtering and transformation.

Data processing is an essential element of the system, ensuring both the accuracy of the information and the ability to generate relevant predictions. Within Node-Red, data are analyzed by a set of algorithms that identify correlations between environmental parameters and conditions conducive to the occurrence of agricultural diseases. The algorithms are continuously adapted based on newly collected data, improving their accuracy through iterative learning. In this way, the system can detect patterns in the evolution of environmental factors and predict crop risks.

Processing results are integrated into the Grafana platform, which provides an advanced visualization interface. The Grafana dashboards allow users to monitor environmental parameters and generated predictions in real time, facilitating rapid identification of potential risks. In addition, the system

features an automatic alert mechanism that notifies users when critical conditions are detected, enabling them to intervene in a timely manner to prevent disease and optimize production.

Through this integrated architecture, which combines autonomous IoT devices, advanced data processing technologies and efficient visualization tools, the agricultural monitoring system ensures a continuous flow of relevant information. Thanks to its flexibility and scalability, the solution can be adapted for different crop types and climatic conditions, thus contributing to more efficient management of agricultural resources, reducing costs and improving crop safety.

For the continuous monitoring of environmental factors influencing the risk of vine diseases, the system has been equipped with a network of IoT sensors able to measure in real time parameters such as air temperature and humidity, soil moisture and solar radiation. This data is transmitted via the MQTT protocol to the central platform, where it is processed and analyzed to determine a crop-specific risk index.

To develop the prediction algorithm, the Node-RED platform was used, which allowed the implementation of a modular and adaptable logic flow. Initially, the data are subjected to a filtering process, removing outliers and compensating for possible missing measurements. Subsequently, each parameter is transformed and scaled according to its impact on disease occurrence. Particular attention was paid to the relationship between temperature, humidity and solar radiation, as these factors play a crucial role in pathogen development.

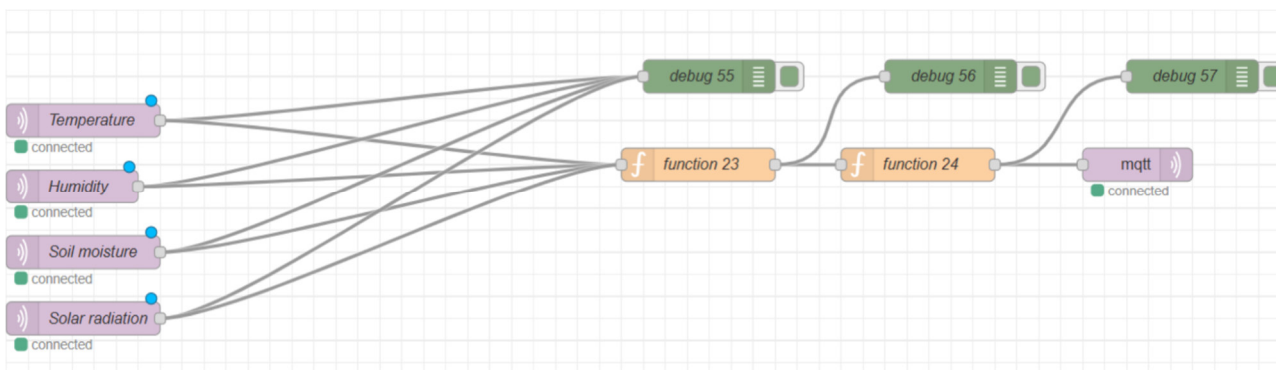


Figure 2. Node-RED flow

The risk index is calculated using a weighting method, which takes into account the influence of each parameter on the likelihood of disease occurrence. It has been observed that high temperatures and high humidity favor the development of pathogens, while low solar radiation and soil moisture can contribute to an environment conducive to their spread. Data is processed in real time through streams defined in Node-RED, and the results are transmitted to the visualization and analysis platform, where users can quickly interpret the situation and make informed decisions to protect crops.

RESULTS AND DISCUSSIONS

Monitoring and predicting environmental conditions plays a key role in the management of diseases affecting agricultural crops, where climatic and soil factors directly influence the development and spread of pathogens. In this context, IoT-based systems and predictive algorithms are an innovative and efficient solution, providing farmers with access to a continuous flow of essential information needed to make rapid and informed decisions. By integrating data from sensors distributed in the field and applying advanced analysis algorithms, the proposed system allows not only real-time monitoring of key environmental parameters, but also the identification of conditions that favor the emergence and evolution of diseases, thus facilitating the adoption of appropriate preventive measures and reducing the negative impact on crops. This chapter presents the results obtained from the testing of

the proposed system, with particular emphasis on the accuracy of the predictions generated by the developed algorithms, the reliability of data transmission over the network and the overall impact on the agricultural resource management process.

A concrete example of the applicability of the system is the prediction of the risk of occurrence of powdery mildew (*Phytophthora infestans*), an extremely aggressive disease that frequently affects crops and whose evolution is strongly influenced by environmental parameters such as air temperature, relative humidity and rainfall. The predictive algorithms developed in this project were trained to automatically analyze the correlations between these factors, identifying the climatic patterns that precede the onset of infection and determining the critical moments when the risk of infection becomes significant.

During the testing period, data collected from sensors distributed in the field were processed in real time and displayed on the Grafana platform, where users had access to an intuitive interface that presents both the monitored values for each environmental parameter and the estimates generated by the algorithm in the form of detailed risk predictions. Figure 3 and Figure 4 provide an example of a Grafana dashboard that integrates this information, illustrating how the collected data are visualized and used to generate the necessary alerts.



Figure 3. Grafana dashboard (a)



Figure 4. Grafana dashboard (b)

The test results have demonstrated that the system is capable of notifying farmers of favorable conditions for disease development in an optimal timeframe, thus allowing prompt protective measures to be taken, such as the application of appropriate phytosanitary treatments before the infection spreads significantly. By analyzing feedback from the field and using historical datasets to calibrate the predictive models, the algorithms have been progressively improved, leading to a considerable reduction in false alarms and a significant increase in the accuracy of the predictions. At the same time, the implementation of this system has contributed to a more efficient management of agricultural resources, as the optimized use of water and chemicals has reduced operational costs while reducing the negative impact on the environment.

To validate the efficiency of the proposed system, the prediction algorithm, implemented in Node-RED, was extensively tested on a significant amount of data collected during the 2024 growing season, between July and October, the period when the crop is most vulnerable to fungal and bacterial diseases. The main objective of the testing was to evaluate the model's ability to correctly predict the occurrence of conditions favorable for disease development and to generate accurate alerts based on real-time analysis of monitored parameters.

The preliminary results showed a high correlation between the predictions generated by the model and the actual observations made in the field, thus confirming the efficiency of the adopted methodology. In addition to analyzing the accuracy of the algorithm, the tests also included the evaluation of the reliability of the communication infrastructure, the stability of the software platform and the response time of the alert system, which are essential aspects for the efficient integration of the solution in agricultural practice. One of the defining aspects of the proposed system is its energy autonomy, achieved through the use of sensors powered exclusively by solar panels, allowing them to operate continuously without requiring frequent external intervention to change or recharge batteries. In addition, data transmission over 5G networks ensured rapid updates and efficient

integration of the collected information into the analytics platform, without significant delays or interruptions in the communication process.

Detailed analysis of the data collected during the test period revealed significant variations in the main environmental factors depending on the specific climatic conditions of each month. In order to facilitate the interpretation of these results and to extract relevant information with a high degree of accuracy, various statistical filtering methods were applied, including the determination of minimum, maximum and mean values for each monitored parameter, as well as the calculation of monthly rainfall totals, thus providing a clear picture of the impact of humidity on the potential for disease development.

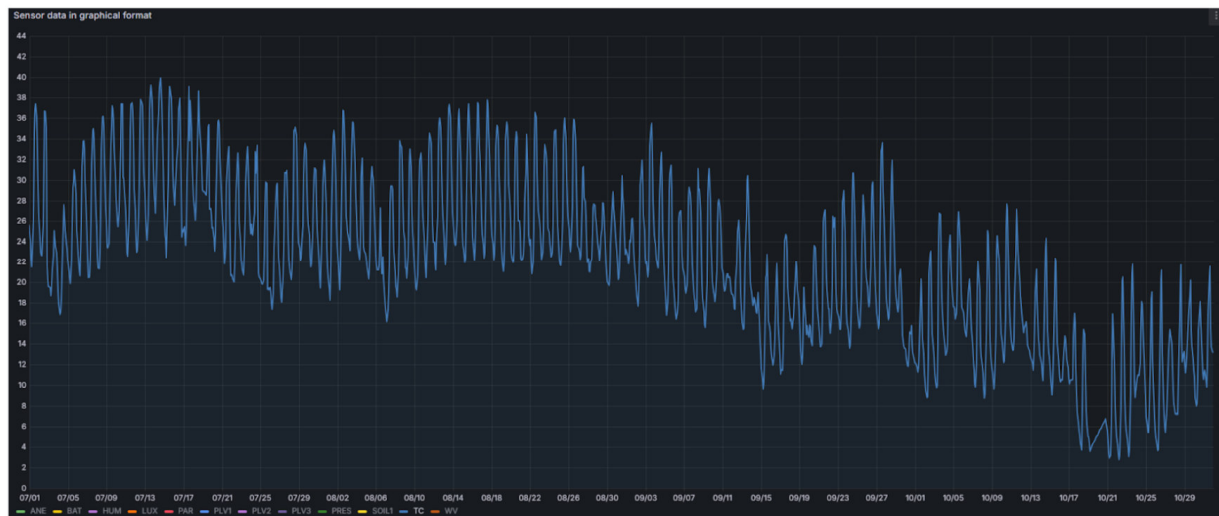


Figure 5. Air temperature

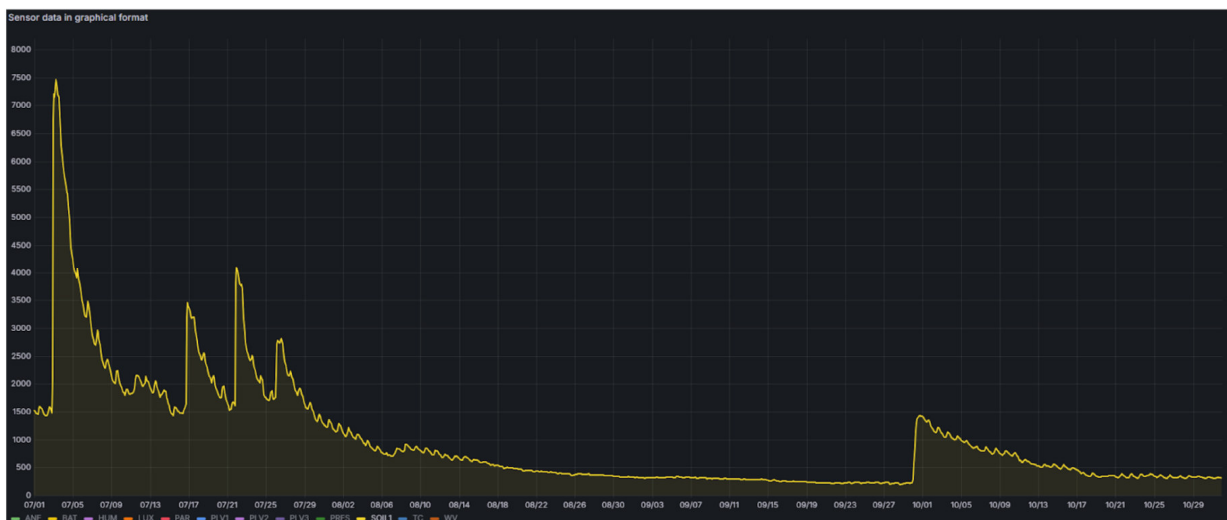


Figure 6. Soil humidity

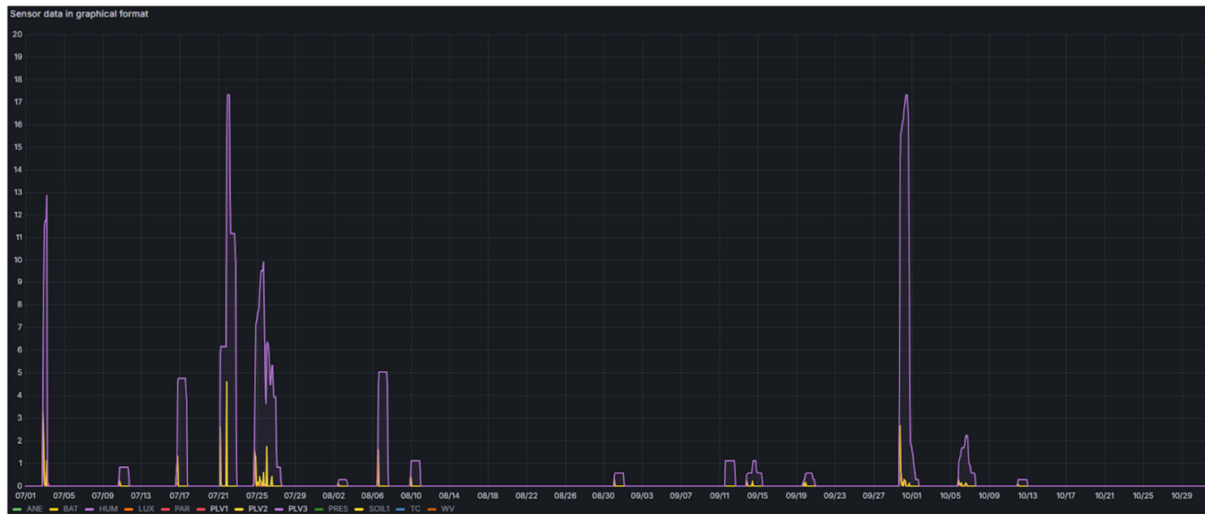


Figure 7. Precipitations

Tests have demonstrated that the proposed system is capable of providing accurate information and precise predictions, allowing farmers to take a proactive approach to crop health management. The integration of feedback received from end-users contributed to the optimization of system parameters, leading to the adjustment of alert thresholds and improved visualization of data displayed on the platform.

The results showed that the system's predictions were highly accurate, providing farmers with the tools to make informed and effective decisions, thus reducing the risk of disease occurrence and spread. The use of this system also allowed for more rigorous resource planning, leading to a significant reduction in losses caused by crop-specific diseases.

CONCLUSIONS

The implementation of an advanced monitoring and prediction system based on IoT and machine learning algorithms represents an innovative solution for optimizing crop management. It enables early detection of conditions favorable to disease development and reduces their impact on yields. The conducted study demonstrated that integrating environmental sensors for measuring essential parameters such as temperature, humidity, and precipitation, combined with intelligent processing of the collected data through predictive algorithms, can generate accurate and reliable alerts that allow for rapid and efficient interventions.

The results obtained during system testing confirmed its ability to provide real-time information with a high degree of accuracy, enabling farmers to take preventive measures based on concrete data. The use of the Grafana platform for data visualization and interpretation offered an intuitive interface, facilitating informed decision-making and resource optimization. The tests highlighted that the system can significantly reduce losses caused by diseases, minimize unnecessary use of chemical treatments, and thus contribute to more sustainable agriculture.

Moreover, the system's technological infrastructure was optimized for energy efficiency and operational reliability by using solar-powered sensors and transmitting data through 5G networks, ensuring continuous monitoring and rapid updates of predictions. The tests showed that the predictive

model integrated into Node-RED had a high correlation with real-world data collected from the field, thereby confirming the performance of the applied method.

Through detailed data analysis and dynamic adjustment of alert thresholds, the system succeeded in improving prediction accuracy, significantly reducing the number of false alarms. This optimization allowed farmers to manage available resources more efficiently, lower operational costs, and adopt a proactive strategy in combating crop diseases.

In conclusion, the developed solution demonstrates the feasibility of using IoT technologies and predictive models in precision agriculture, offering an effective tool for monitoring and protecting agricultural crops. The proposed system can be extended and adapted to other types of crops, contributing to the digitalization of agriculture and enhancing the sustainability of the agricultural sector.

ACKNOWLEDGEMENTS

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2.6. ASSESSMENT OF 25 TRITICALE GENOTYPES UNDER TRANSYLVANIA'S PEDOCLIMATIC CONDITIONS

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Abstract

The purpose of the study is to assess and find new winter triticale genotypes that are adequate for the Transylvania area. Field trials occurred at ARDS Turda in six replications during the growing season 2023–2024 using the balanced square grid method. The first three replications experienced higher fertilisation (N_{100} kg ha⁻¹). No phytosanitary procedures were carried out. According to the Duncan test classification, genotypes 18061T (9835 kg ha⁻¹), 18031T (9680 kg ha⁻¹), Zaraza (9670 kg ha⁻¹), 18013T (9498 kg ha⁻¹), and 17241T1 (9275 kg ha⁻¹) achieved the best productions, while the Tulnic variety ranked last with 5422 kg ha⁻¹. The hectolitre mass (TW) ranged from 59.35 (Haiduc) to 76.2 kg hl⁻¹ (18017T), and the average thousand kernel weight (TKW) value spanned from 30.24 (FDL Ascendent) to 52.01 g (18017T). The 18061T genotype had the greatest harvest index (HI) value of 0.43, while the Haiduc variety recorded the lowest score of 0.27. The range of the average protein content was 8.6% (07320T1) to 10.45% (Zori). Nitrogen use efficiency (NUE) fluctuated from -1.73 (07320T1) to 39.73% (18061T) based on the genotype.

Key words: winter triticale, yield, protein, HI, NUE.

INTRODUCTION

Wheat and rye were crossed in order to develop Triticale species (*Triticosecale* Wittm.). Like wheat, triticale can be classified into three main types: facultative, spring, and winter (Abdelaal et al., 2019). It has a great degree of adaptation to different pedological and agro-ecological environments (Đekić et al., 2014). Because of the quick development of a deep root system, it is valued for its ability to withstand drought during the growing season (Ittu et al., 2008; <https://grdc.com.au/>).

Triticale has a higher protein content than other cereals and is distinguished by a well-balanced structure of essential amino acids. Because of its nutritional value, triticale has become a significant and technologically valuable crop for both providing nourishment for all domestic animal species, especially poultry and dairy cattle (Đekić et al., 2014, Pintilie et al., 2023) and for rational and nutrient-rich human diets (Paiu, 2023). In various goods, like cakes, muffins, tortillas, and pancakes, triticale flour effectively substitutes wheat flour and is frequently used in multigrain breads (Burešová et al., 2010). This flour contains 17 g of protein per serving, 76% of the daily necessary amount of dietary fibre, and is low in cholesterol, salt, and saturated fat. It is also a good source of iron and magnesium (www.organicstyle.com/).

The National Institute of Statistics indicates that the triticale crop is grown on an average of approximately 60,000 hectares in our nation (Brodeală et al., 2024). Located in the middle and northwest of the nation, Transylvania is part of the first macro-region of development. According to Brodeală et al. (2024), the area planted to triticale in this macro-region has averaged between 25000 and 28500 ha over the past three years, with yields ranging from 3400 to 3800 kg ha⁻¹ (Figure 1).

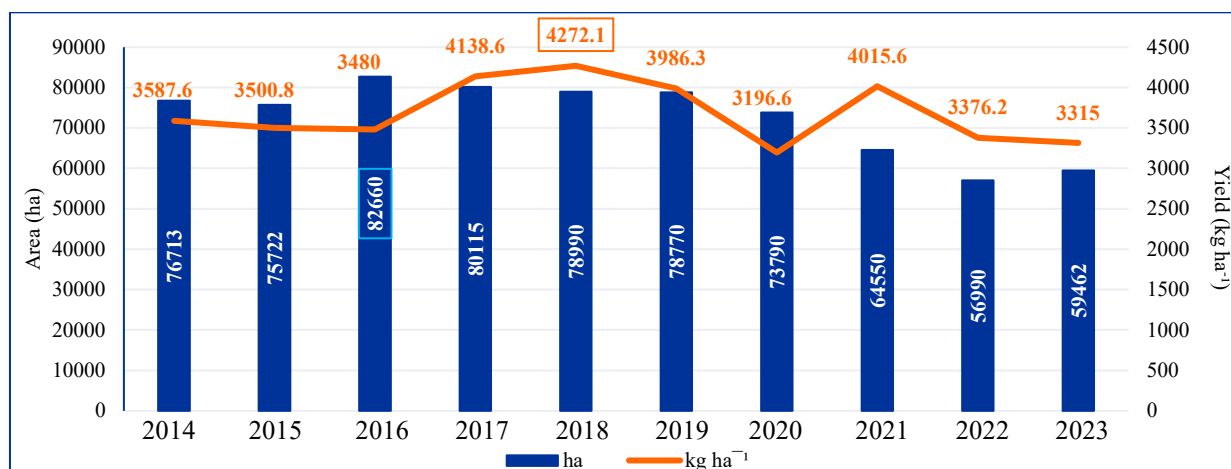


Figure 1. Romania's triticale area (ha) and average yield (kg ha⁻¹) fluctuations since 2014 (FAOSTAT, 2024)

In addition to the environment, mineral nutrition is one of the most significant agro-technical factors affecting grain yield and enabling farmers to take advantage of cereal production potential (Dumbravă et al., 2016). Nitrogen consumption has a major effect on grain output and its quality. High yields can only be stated in intensive agricultural production if a suitable amount of nitrogen is applied during vegetation seasons when plants need it most (Janušauskaite, 2013). In order for triticale plants to grow vigorously and establish roots, stems, and leaves, it is important to maintain an adequate nitrogen content (Ma et al., 2023). Triticale harvests' quantity and quality are directly impacted by nitrogen, which is essential for spike formation as well as grain size and quality (Rajičić et al., 2020). The primary component of protein, nitrogen (N), is a necessary mineral element for plants (Wang et al., 2024). According to Rea et al. (2022), plants that receive adequate nutrition and nitrogen are more resilient to stressors like drought and disease attacks. Additionally, triticale can be made more resilient to frost and other harsh environmental factors through the addition of nitrogen (Sulek et al., 2024).

MATERIALS AND METHODS

Research materials and methods

During the 2023–2024 growing season, ARDS Turda conducted field testing employing the balanced square grid method in six replications. Twenty-five winter triticale genotypes were examined using biological material: ten cultivars (registered before 2020, with the exception of Zaraza, which was approved in 2021) and fifteen advanced breeding lines (under testing).

The soil type was Phaeozem soil, which had a loamy-clay texture, a neutral pH of 6.8–7.2, a clay content of 51.8%–55.5%, a humus content of 2.20–3.12%, a total nitrogen content of 0.162–0.124%, a phosphorus content of 0.9–5 ppm, and potassium levels that were well-supplied at 126–140 ppm. At OSPA Cluj, agrochemical examinations of soil samples from the arable layer (0–20 cm) were performed.

Fertilisation was done in two stages: 250 kg ha⁻¹ NPKS (20:20:0:13) indicated N₅₀ in the fall (before sowing) and N₅₀ kg ha⁻¹ a.s. more (N₁₀₀) in the spring (before heading). Additional fertilisation was applied only on the first 3 repetitions.

A seeding rate of 600 germinating grains m⁻² was used and, the harvestable plot covered an area of 6.25m⁻². The previous crop was unfertilized peas.

No phytosanitary procedures were carried out.

Plots were harvested individually by using a Wintersteiger Plot Combine and the grain yield was reported at uniform moisture content (14%).

Before harvesting, 30 winter triticale plants were taken to the laboratory in order to determine the number of grains per spike, the weight of grains per spike, thousand kernel weight (TKW), test weight (TW), harvest index (HI) and nitrogen use efficiency (NUE).

Individual spikes were beaten using Wintersteiger microbator. Each spike's resulting grains were carefully counted before being weighed using a high-precision scale. The weight of the thousand grains was calculated by dividing the weight of the grains by the number of grains and then multiplying the result by 1000.

The formula for calculating the harvest index of winter triticale genotypes was: grain yield/biological yield $\times$ 100.

Nitrogen use efficiency and/or fertiliser recovery in crop production systems was calculated using the difference method (Varvel and Peterson, 1990).

The Perten Inframatic 9500 analyser was used to determine the protein content.

Climatic conditions

From a thermal perspective, monthly average temperatures were between 0.8 and 7.6°C higher than the multiannual normal, with February showing the largest divergence. January was the only month with negative decadal average temperatures. Wintertime temperatures caused the inactive period to be significantly shortened. Triticale plants' growth and development stages were accelerated by the high temperatures in February, March, and April, resulting in an earlier heading period than in normal years.

There was insufficient rainfall from sowing to harvest, except for November and March, which were considered to be extremely rainy months. Combined with the associated temperatures, the May and June rainfall made it easier for infections like *Blumeria graminis*, *Septoria tritici*, *Puccinia striiformis*, and *Fusarium* sp. to spread.

Table 1. Weather conditions of the experimental area

T	2023			2024							R	2023			2024						
(°C)	X	XI	XII	I	II	III	IV	V	VI	VII	(mm)	X	XI	XII	I	II	III	IV	V	VI	VII
I	13.2	8.0	2.2	2.8	6.5	8.1	14.8	15.5	20.2	22.7	I	0.0	6.0	4.4	2.1	0.6	14.3	0.6	36.4	15.4	35.0
II	14.2	5.1	0.2	-1.2	6	7.1	13.2	14.6	20.8	27.3	II	10.3	35.7	4.4	1.5	8.6	22.1	14.8	5.5	9.9	1.9
III	14.5	1.4	1.3	-0.8	8.6	10.9	12.0	17.1	24.2	22.4	III	9.5	1.9	9.0	1.2	0.0	1.3	23.4	18.8	10.9	12.0
m.a.	14.0	5.2	1.2	0.2	7.0	8.8	13.3	15.8	21.7	24.0	m.a.	19.8	43.6	17.8	4.8	9.2	37.7	38.8	60.7	36.2	49.0
m.a.a.	9.8	4.0	-1.2	-3.3	-0.6	4.4	10.0	15.0	18.0	19.8	m.a.a.	35.4	28.2	27.5	21.7	19.2	24.3	45.6	69.4	84.6	78.0
dev.	4.2	1.2	2.4	3.5	7.6	4.4	3.3	0.8	3.7	4.2	dev.	-15.6	15.4	-9.7	-16.9	-10.0	13.4	-6.8	-8.7	-48.4	-29.0

m.a. = monthly average; m.a.a. = multiannual average;

m.a. = monthly amount; m.a.a. = multiannual average;

Statistical data analysis

The gathered data was statistically analysed using the conventional analysis of variance (ANOVA) in Microsoft Excel 2012 and Poly Fact Software Version 2020.

Least Significant Difference (LSD) tests were conducted using the Poly Fact program at significance levels of 5%, 1%, and 0.1%.

A graphic representation of the genotype-fertilisation interaction was created using Past 4.03.

The Pearson correlation coefficient was used to assess the connection between two variables.

RESULTS AND DISCUSSIONS

Grain yield

Advanced triticale breeding lines are employed in this sort of experiment if they provided at least 10% more than the average yield of the varieties that compose the comparative competition crop the year before (Soare, 2022) or 15% more than the control cultivar (Potlog and Velican, 1971).

The Duncan test was used to classify the genotypes under research (Figure 2). The genotypes 18061T, 18031T, Zaraza, 18013T, 17241T, and 18017T had yield increases that were greater than the mean by 19.5–26.7%. The older genotypes were ranked last because their harvest rates were below average. Yields ranged from 5200 kg ha⁻¹ (Tulnic) to 10200 kg ha⁻¹ (18061T) depending on fertilisation (Table 2). Since the additional fertilisation was carried out at advanced phenophases (before heading), the average yield values of the two fertilisation levels were quite comparable (Table 2).

Thousand kernel weight

Grain size is indicated by TKW, a genetically determined characteristic. Figure 3 reveals that the weight of the 1000 kernels ranged from 30.24 g (FDL Ascendent) to 52.01 g (18017T), with an average of 40.32 g. For this quality criteria, the genotype 18061T (50.99 g) also performed well.

Based on the genotype-fertilisation interaction, genotypes 18061T and 18017T had the highest 1000-kernel weight of 53.4 g and 52.87 g, respectively, whereas Haiduc and FDL Ascendent obtained the lowest value of 27 g. On both fertilisation levels, the genotype 07320T1 exhibited near values, with negligible variations from N₅₀ fertilisation of just 0.16 g (Figure 4).

When fertilised with N₁₀₀ as opposed to N₅₀, the average TKW value was 1.54 g lower. The prolonged growing season and the drought that occurred during this phenophase may have contributed to the grains' insufficient filling. Genotypes Pisc and 17272T1 responded positively to fertilisation, their TKW increasing by 9.72g and 9.39g, respectively. Additionally, fertilised genotypes Utrifun and Haiduc showed a sharp decline in TKW, with a difference of more than 11 g.

Test weight

A key metric for evaluating the physical properties of grains, figuring out flour yield, and estimating how much seed can be stored is the test weight. This quality indicator is affected by several factors, including changes in grain moisture at harvest, the presence or absence of impurities, grain size, shape, density, and surface attributes, rainfall and dryness throughout the grain-filling period, disease attacks, and pests. This quality parameter had a mean value of 69.3 kg hl⁻¹. As depicted in Figure 5, the extreme mean values of test weight were 59.4 kg hl⁻¹ (Haiduc) and 76.2 kg hl⁻¹ (18017T). A high average value of the TW was also noted for the Zaraza cultivar, 75.9 kg hl⁻¹.

The test weight values of the triticale genotypes under evaluation ranged from 55 kg hl⁻¹ (Haiduc) to 77 kg hl⁻¹ (18031T), depending on the interaction of factors, as shown in Figure 6.

On the whole, compared to the older varieties, an improvement in this quality parameter can be observed in the advanced breeding lines and in the latest varieties created, such as Zaraza and Zvelt.

Harvest index

The harvest index defines the weight of a harvested product as a percentage of the total weight of a crop's plants and is determined by interactions between genotypes, environment, and crop management. Usually, the harvest index is one of the most important parameters in the plant breeding programme and is used to screen for the best genotype. In order to interpret how a crop responds to various environments and climatic variations, the harvest index concept is required. According to Hay (2008), the values for contemporary varieties of the majority of grain crops that are grown extensively fall between 0.4 and 0.6. The majority of the time, steady individual grain weight and higher grain population density have resulted in improvements in the harvest index.

The average harvest index in our tests was 0.35. As can be seen in Figure 7, Haiduc and OdăFD had the lowest harvest index, of 0.27 and 0.28, respectively. Significantly above average were the genotypes 18061T with 0.43, 18031T with 0.42, Zaraza and 17241T1 with 0.41, and 18056T with 0.40.

Protein content

The protein content of grains is one of the most important factors influencing cereal nutritional value. The process by which protein is extracted from grains is linked to nitrogen translocation following anthesis. Grain nitrogen sources are divided into two categories: retranslocation from aboveground organs (70-80%) and reabsorption from the soil following anthesis (20-30%) (Li et al., 2024). Additional fertilisation towards the end of April (boot stage) and rainfall in the immediate following period (3rd decade of April – 23.4 mm, 1st decade of May – 36.4 mm) made nutrients available to plants for grain formation and filling, as well as grain quality improvement.

The average protein content of the winter triticale under investigation was 9.7%, as depicted in Figure 9. With an average protein content of less than 9%, the 07320T1 genotype had the lowest quality. Significantly superior to the experiment's average were the genotypes Zori and Tulnic, which had 10.5% protein, followed by 18339T with 10.2% protein, and by 17241T1 and 18017T, each containing 10.1% protein.

Additional nitrogen fertilisation is necessary for increasing the quantity and quality of winter triticale protein, as illustrated in Figure 10. Winter triticale grains exhibited a 1.31% increase in protein content when N₁₀₀ was applied. On N₅₀ fertilisation, the protein content varied between 7.8% (07320T1) and 9.7% (Zori), with limits of variation ranging from 9.4% (07320T1) to 11.3% (Haiduc, Tulnic) on N₁₀₀. Regardless of the amount of fertiliser used, genotype 07320T1 was found to have the lowest quality. This may indicate a deficiency of genes that improve this attribute.

Nitrogen use efficiency

Increasing crop production and quality while lowering fertiliser inputs and limiting environmental harm requires efficient nutrient usage. One method to increase crop productivity and quality is nutrition management. Nonetheless, maximising fertiliser use efficiency (NUE) is essential to achieving the desired yield with a minimal amount of fertiliser. Using the right fertiliser in proper quantities is one of the most crucial management techniques for boosting crop output and fertiliser efficiency. It was found that the global N usage efficiency in cereal crops is 33%. As crop yield rises, NUE decreases as the N dose increases (Rawal et al., 2022).

In the experiments undertaken, nitrogen use efficiency averaged 18.1% (Figure 11). The lowest NUE value was reported for genotype 07320T1 (-1.73%). Genotype 18061T, ranked as the most productive genotype, also had the highest NUE value (39.73%). Genotypes Zori and 18056T also showed NUE values higher than the average of the experiment, 31.13% and 31.97%, respectively.

Correlations

Direct, noticeably positive correlations between yield and yield components are indicated by the values of the correlation coefficients calculated for these interactions in Table 3.

The significantly positive connection between protein content and NUE ($r = 0.368^*$) indicates that further fertilisation during advanced phenophases (before heading) supports protein accumulation in the grain and enhances its quality.

Figure 12 depicts a graphical relationship between production and protein content. The decreasing slope of the regression line, as well as the wider spread of data surrounding it, suggests a negative but insignificant association between yield and protein. Quadrant IV genotypes with excellent yields and quality are of great interest. In this example, three genotypes exist: 18031T, 17241T1, and 18017T. Their average yield exceeds 9000 kg ha⁻¹ and has a protein content of 10%.

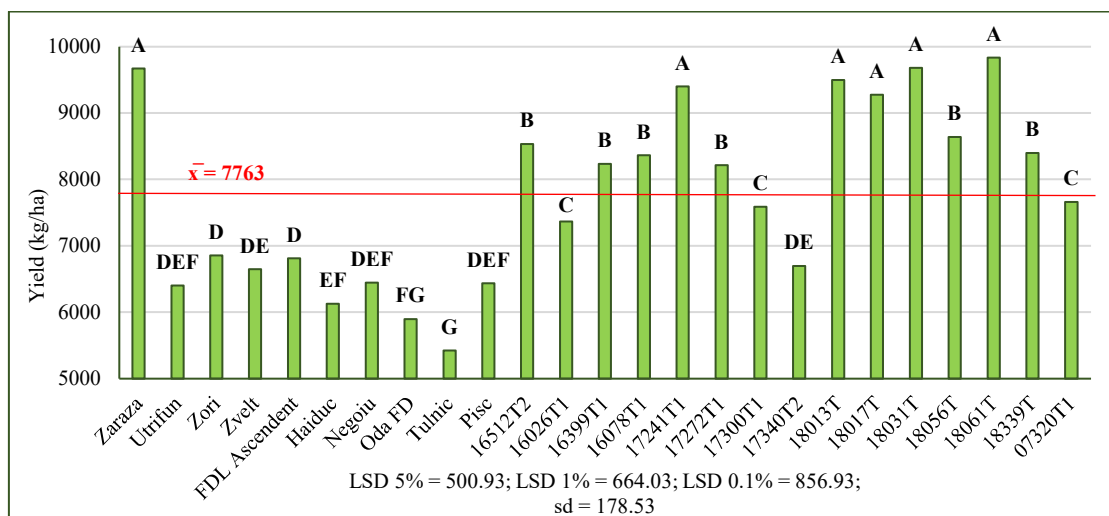
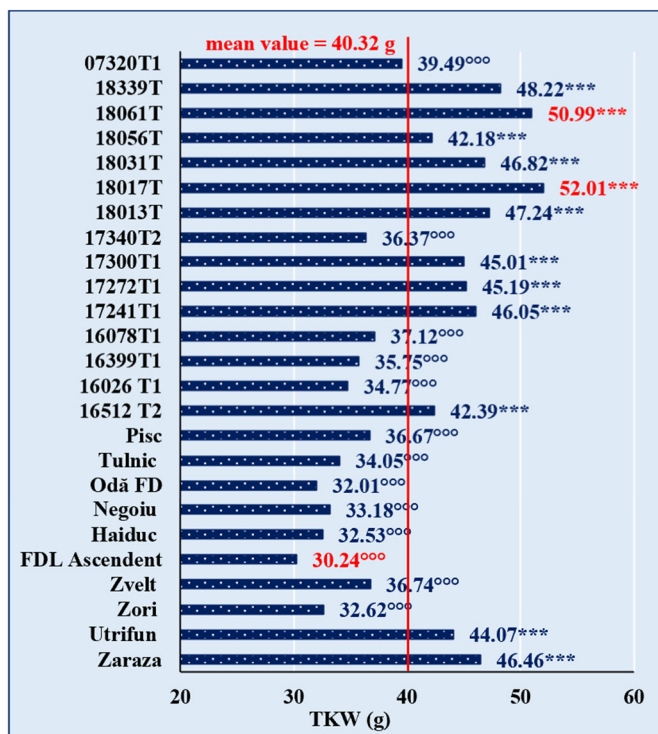


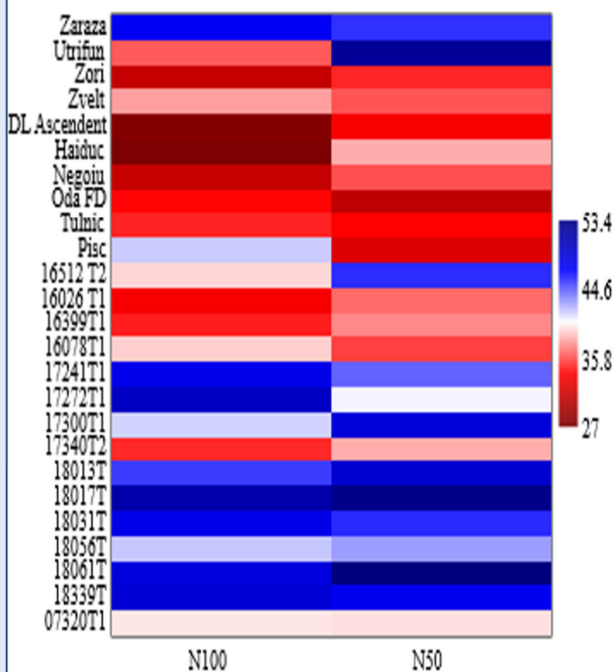
Figure 2. Classification of cultivars based on the average yield achieved using the Duncan test

Table 2. Effect of nitrogen on yield (kg ha⁻¹)

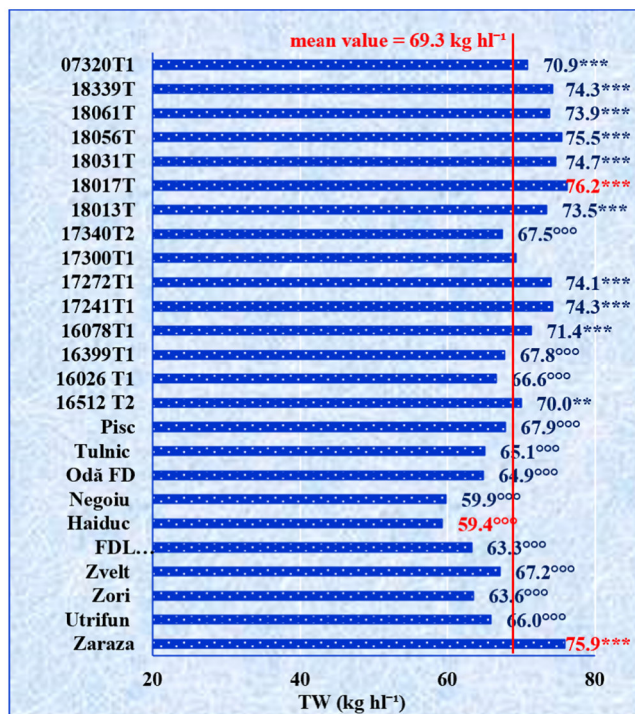
Crt. no.	Genotypes	N ₁₀₀	N ₅₀
1	Zaraza	9773 ^{***}	9567 ^{***}
2	Utrifun	6567 ^{oo}	6236 ^{ooo}
3	Zori	7211	6497 ^{ooo}
4	Zvelt	6825 ^{oo}	6470 ^{ooo}
5	FDL Ascendent	6967 ^o	6655 ^{oo}
6	Haiduc	5787 ^{ooo}	6470 ^{ooo}
7	Negoiu	6623 ^{oo}	6269 ^{ooo}
8	Odă FD	5900 ^{ooo}	5890 ^{ooo}
9	Tulnic	5625 ^{ooo}	5219 ^{ooo}
10	Pisc	6802 ^{oo}	6068 ^{ooo}
11	16512T2	8582 [*]	8480 [*]
12	16026T1	7109	7626
13	16399T1	8074	8392
14	16078T1	8088	8635 [*]
15	17241T1	9196 ^{***}	9603 ^{***}
16	17272T1	8261	8163
17	17300T1	7442	7736
18	17340T2	6567 ^{oo}	6822 ^o
19	18013T	9452 ^{***}	9544 ^{***}
20	18017T	9146 ^{***}	9404 ^{***}
21	18031T	9940 ^{***}	9421 ^{***}
22	18056T	8729 ^{**}	8547 [*]
23	18061T	10158 ^{***}	9511 ^{***}
24	18339T	8703 [*]	8087
25	07320T1	6890 ^o	8430
	mean	7777	7750
	LSD 5%	708.42	
	LSD 1%	939.08	
	LSD 0.1%	1211.88	



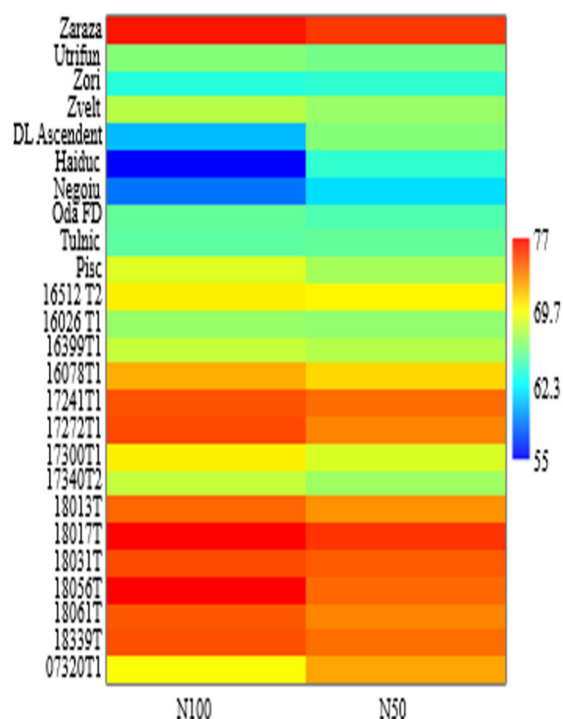
LSD 5% = 0.52; LSD 1% = 0.69; LSD 0.1% = 0.89;
Figure 3. Mean values of thousand kernel weight



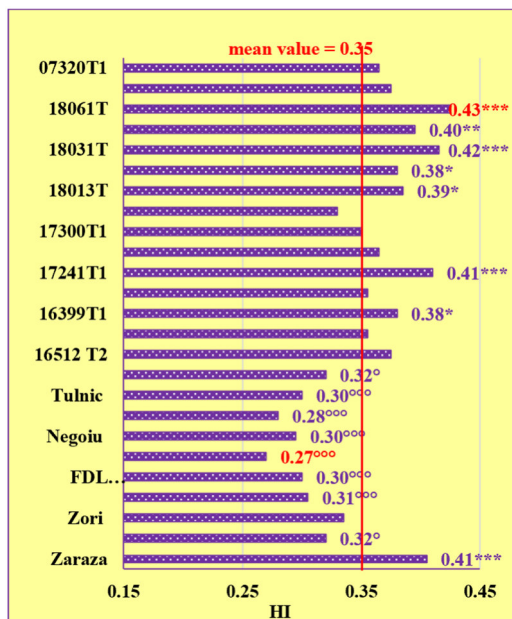
LSD 5% = 0.73; LSD 1% = 0.97; LSD 0.1% = 1.26;
Figure 4. Effect of nitrogen on TKW



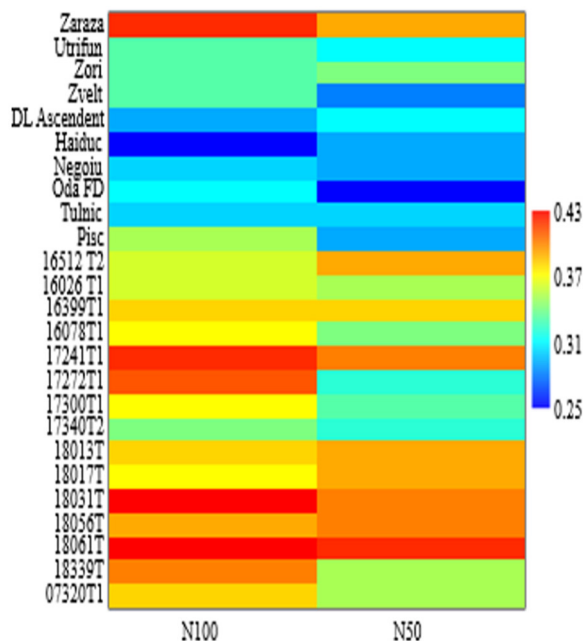
LSD 5% = 0.46; LSD 1% = 0.61; LSD 0.1% = 0.79;
Figure 5. Mean values of test weight



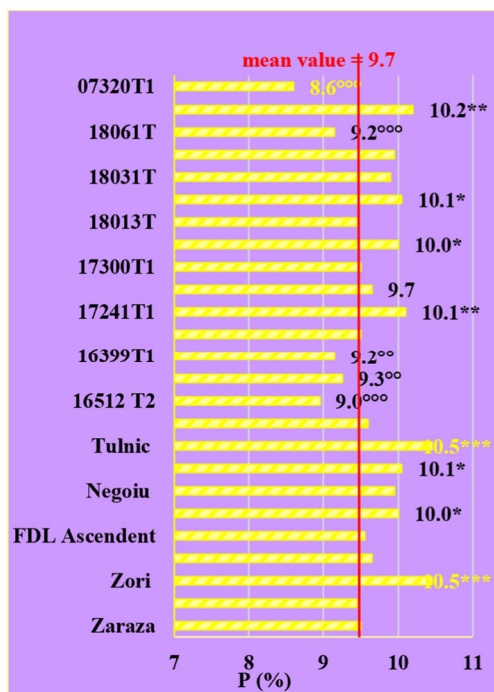
LSD 5% = 0.65; LSD 1% = 0.86; LSD 0.1% = 1.11;
Figure 6. Effect of nitrogen on TW



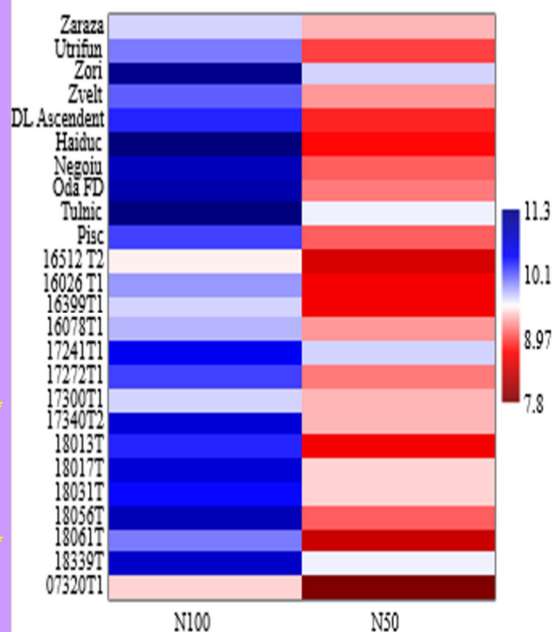
LSD 5% = 0.03; LSD 1% = 0.03; LSD 0.1% = 0.04;
Figure 7. Mean values of harvest index (HI)



LSD 5% = 0.04; LSD 1% = 0.05; LSD 0.1% = 0.06;
Figure 8. Effect of nitrogen on HI



LSD 5% = 0.31; LSD 1% = 0.41; LSD 0.1% = 0.53;
Figure 9. Mean values of protein content



LSD 5% = 0.44; LSD 1% = 0.58; LSD 0.1% = 0.75;
Figure 10. Effect of nitrogen on protein content

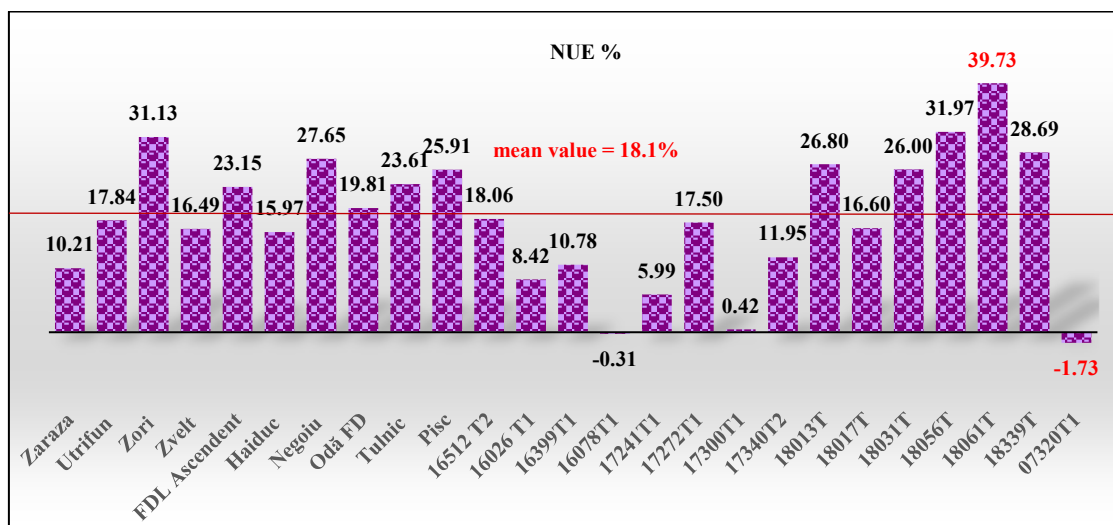


Figure 11. Mean values of nitrogen use efficiency

Table 3. The correlations between yield, yield components, quality and nitrogen use efficiency

	Yield kg ha ⁻¹	(kg No.s/m ²	No.g./s .	W.g./s. (g)	TKW (g)	TW (kg/hl)	HI	P (%)	NUE (%)
Yield kg ha ⁻¹	1								
No.s./m ²	0.368	1							
No.g./s.	0.484	0.005	1						
W.g./s. (g)	0.819	0.173	0.698	1					
TKW (g)	0.805	0.224	0.378	0.925	1				
TW (kg/hl)	0.862	0.333	0.408	0.818	0.855	1			
HI	0.944	0.412	0.535	0.818	0.789	0.878	1		
P (%)	-0.276	-0.478	-0.226	-0.208	-0.146	-0.168	0.293	1	
NUE (%)	0.022	-0.135	-0.304	-0.055	0.085	-0.034	0.020	0.368	1

α 5% = 0.337; α 1% = 0.396; α 0.1% = 0.505;

No.s./m² = number of spikes/m²; No.g./s. = number of grains/spike; W.g./s. = weight of grains/spike; TKW = thousand kernel weight;

TW = test weight; HI = harvest index; P = protein content; NUE = nitrogen use efficiency;

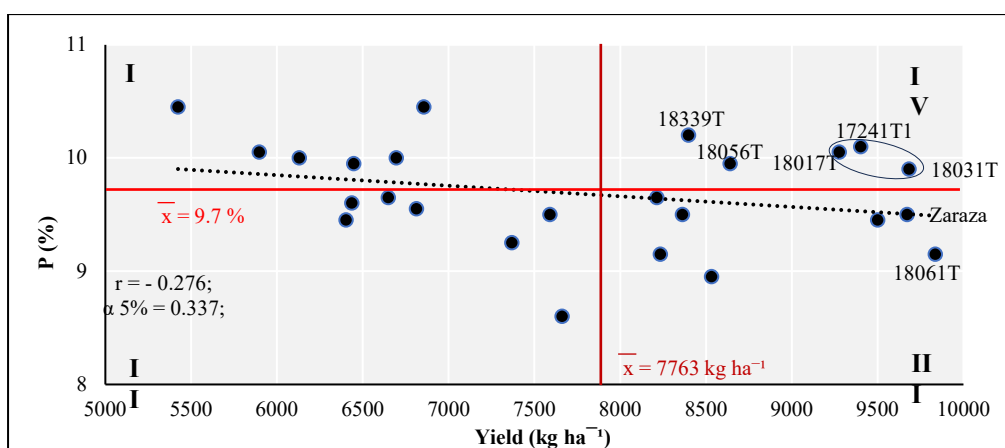


Figure 12. The relationship between yield and grain protein content at winter triticale

CONCLUSIONS

Despite the fact that no phytosanitary procedures were carried and the weather conditions were favourable for diseases (*Blumeria* sp., *Puccinia* sp., *Fusarium* sp.), winter triticale behaves well in Transylvanian circumstances, according to the results.

Due to their excellent average yields, the genotypes 18061T (9835 kg ha⁻¹), 18031T (9680 kg ha⁻¹), Zaraza (9670 kg ha⁻¹), 18013T (9498 kg ha⁻¹), 17241T (9400 kg ha⁻¹) and 18017T (9275 kg ha⁻¹) are the most suitable for the Transylvania region.

The most productive genotypes (18061T, 17241T, Zaraza, and 18031T) had the greatest average harvest index value (>0.4).

Higher N rates resulted in enhanced grain protein content; therefore Zori and Tulnic genotypes had the highest average protein content (10.5%), and 17241T and 18017T (10.1%) followed.

Additional fertilisation during advanced phenophases (prior to heading) favours protein accumulation in the grain and improves its quality, as evidenced by the considerably positive correlation between protein content and NUE ($r = 0.368^*$).

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